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The black art of rubber

Non-linear, non-isotropic, heat and load sensitive, no wonder engineers do not like tyres

Ixion was expelled from Olympus and blasted with a thunderbolt. Zeus ordered Hermes to bind Ixion to a winged, fiery wheel that was always spinning. This is either traction control failure, or too hard a compound…

'The time has come,' the Walrus said,
To talk of many things:
Of shoes – and ships – and sealing wax
Of cabbages and kings
And why the sea is boiling hot
And whether pigs have wings.'

The subject this month is the most effective racing product of all – rubber. Getting a car to go two seconds a lap faster is a difficult and expensive proposition, whereas you can bolt three seconds a lap very easily with a different set of tyres.

The quote 'I don't care what it is as long as round and black' alludes to the fact that the black is only there because of the carbon black added to avoid ultraviolet light degradation of the latex and the elastomer used in racing tyres, which can contain little natural rubber as tapped from a tree.

Of all the ingredients on a car, this is the most elusive one, and one engineers do not like much. It is non-linear, non-isotropic, heat and load sensitive.

The base components used to be a natural very green element, the sap from the Hevea brasiliensis tree, cured and vulcanised and applied over a woven canvas bag.

Natural rubber is still a component of tyres but synthetic rubber is made by the polymerisation of petroleum-based precursors called monomers. The most prevalent synthetic rubbers are styrene-butadiene rubbers (SBR) derived from the copolymerisation of styrene and 1.3-butadiene.

Other synthetic rubbers are prepared from isoprene (2-methyl-1,3-butadiene), chloroprene (2-chloro-1,3-butadiene), and isobutylene (methylpropene) with a small percentage of isoprene for cross-linking. These can be copolymerised to produce products with a range of physical, mechanical, and chemical properties. Did one mention chemistry is one's weak point?

This is where the black magic of compounders comes in, and gives you the grip levels you are looking for. As usual, there is no free lunch, and balancing grip, rapid warm-up and durability is a tricky act. Synthetic cis-polyisoprene and natural cis-polyisoprene are derived from different precursors by different chemical pathways. The monomers can be produced pure and the addition of impurities or additives can be controlled by design to give optimal properties. Polymerisation of pure monomers can be controlled to give a desired proportion of cis and trans double bonds.

Natural rubber consists of polymers of the organic compound isoprene. Forms of polyisoprene used as natural rubbers are classified as elastomers. Rubber is harvested mainly in the form of the latex from trees (collecting the sap by tapping).

Natural rubber is used extensively in many applications and products. In most of its useful forms, it has a large stretch ratio and high resilience, and is extremely waterproof. This comes in useful to make the contact patch 'cog' into small asperities in the track, and enable a more than unity coefficient of friction.

The stretch, resilience and waterproofing is also essential in another application for latex, the humble condom, which is used in quite stressful conditions (well, at least if you are doing it right).

The natural shape a canvas bag wants to assume is a circular shape (as old tyres used to be) the racing tyre is a fat cylinder, albeit not to the dimensions we have seen in the past, but only because of regulations.

To keep this shape, and to deflect laterally and vertically at the right amount for maximum contact patch, is an art in itself, that depends on weft and weave of cloth (in this case composed of Kevlar, rayon, aramids or steel), the way sidewalls are built, the stiffeners and bead construction, and the effect of the belt in radial tyres, crossplies being rare nowadays.

The use of different compounds on each corner of the car is not unknown…

Tyres are difficult enough to engineer as it is. Sometimes, a sit down and think approach is best

The whole shebang being a pneumatic device, the stiffness or deflection value of the carcass will depend on the pressure of the air, or more commonly nitrogen that fills it, which in turn depends on the temperature of the gas. The input of energy going into the tyre also varies whether it is braking, accelerating or cornering.

Some championships forbid the use of tyre heaters. There is a fine art of choosing the right initial pressure, so the right pressures are in tyres at the right lap for qualifying, or the pressure does not increase too much during the race, which can lead to a runaway build up (increased pressure reduces footprint, which then increases unit load, which then generates more temperature which increases pressure in a self reinforcing loop.)

The other difficult characteristic of tyres is that given all these variables, and the fact that it is damped only by the hysteresis of the rubber, trying to spring and damp the car is made very difficult as the loads from the chassis will obligatorily go through the tyre...unless you have got your springing and ride height very wrong. Skating on the bottom of the chassis reduces your grip level considerably.

Tyres nowadays are not so much on the edge as in the days of "gumball" qualifiers, that lasted just one lap if the compounding was right. The driver had to do the out lap slowly so as not to overheat the compound right up to the last corner, before getting on it.

Knowing how to use your qualifying tyre given those conditions is not easy, as having the opportunity to test one lap tyres came few and far between. With Pier Luigi Martini at Minardi we capitalised on that, as having tested over 200 sets of qualifiers for Pirelli gave us the opportunity to put Minardi on the front row at Phoenix, alongside Senna in the McLaren. Pier Luigi was simply able to use 100% of the tyres' capabilities.

The softness of the tyre rubber is varied by changes in the proportions of ingredients added to the rubber – carbon, sulphur and oil. They also are compounded to have distinct operating temperature windows.

Chosing your carcass and compound, when several are available, can be an intricate process, depending on the track temperature, your drivers' driving style, car setup, how "green" or rubbered up is the track, and atmospheric conditions.

On one memorable test in Malaysia running for a week with 20 Formula Nippon cars and testing 600 sets of tyres produced a track so rubbered up we were running four seconds faster than ever before and the cars had no vices – rubber on rubber brought levels of grip hitherto unknown. Oh happy days.

This above all: to thine own contact patch be true.

The flaws in F1 funding

Sponsorship in the tens of millions raises eyebrows but some teams face bankruptcy

The matter of F1 being too expensive rumbles on, supported by the number of teams in financial difficulty and may be about to disappear.

Certainly F1 teams could operate and race well at half the current costs; Ross Brawn among others has openly stated this and sometimes the wastage of money by top teams that is not directly connected to improving performance beggars belief. However, it seems that an 'I'm all right Jack' attitude among these same teams combined with a surprising lack of authority being exercised by Jean Todt, President of the FIA, is preventing this from happening. Therefore the real issue is perhaps not that F1 is too expensive per se, it's that the show as it currently stands simply does not justify to sponsors the amounts that F1 teams need to ask of them. The reasons for this are many and impossible to cover in 1,000 words, but I can try to make some relevant observations.

Aspirations

Let's say that a middle-grid team with aspirations needs $80m from a primary sponsor, in addition to the TV money it has earned and the various smaller backers it has attracted, together with a contribution from one of its drivers. Given that an equivalent amount probably needs to be spent on exploiting the partnership via marketing and PR campaigns, that's an awful lot of money for the sponsor to commit. But, in context, a $100m spend each by a number of major corporates on sponsoring events such as the Olympics and the football World Cup is an accepted fact. Britain's latest Americas Cup sailing challenge appears confident of obtaining backing in excess of this amount; in the UK's Premiership transfer market $1.3bn changed hands this summer.

So the money exists, and to an international business corporation dealing in tens or even hundreds of billions of dollars an annual expenditure of $160m, although undoubtedly high, is not necessarily an unrealistic part of its overall marketing portfolio. Break it down a bit, and it comes to less than $8m per event in the F1 calendar. Given the acknowledged global coverage and following of F1, that doesn't seem unsupportable in judging the critical Return-On-Investment, if the commensurate benefits are seen to exist. It is a big 'if' of course, and therein lies the nub of the issue, confirmed by experienced F1 marketing professionals to whom I've been speaking.

It's easy to be deflected on the question of why F1 is seemingly becoming less popular – with consequent negative effect on the potential revenues coming in – by peripheral criticisms concerning engine noise (lack of); the impression of sleaze that surrounds some aspects of its administration; the constant emphasis on money, money, money; often obscure over-regulation, both technical and sporting; bland circuits that don't challenge drivers sufficiently and criticism that there are no characters in F1 anymore.

Certainly these aspects of F1 don't help, and admittedly I would like to hear less PR-speak from the drivers and the team spokespeople, but I don't think these are the major issues. After all, we do have a wonderfully-developing grudge match between the pair of Mercedes drivers, the fair dinkum Aussie boy grabbing unexpected wins, the best driver stirring the transfer pot to get a race-winning car for next season, the popular English former champ struggling to hang on to his career and the lantern-jawed South American waiting in the wings to (literally) overturn his rivals or throw it into the fence seemingly just for the sheer hell of it. Plenty of material for the media to work on, surely? TV figures are down I suspect because it is no longer the only accessible medium, especially among young people, who rely on the multitude of internet sources for downloading their entertainment when they want it, where they want it, how they want it. If they cannot get F1 on this basis, then they will follow something else.

TV figures are down because it is no longer the only accessible medium, especially among young people

Sponsorship of F1 can present an uneven playing field so along with big bucks some teams struggle

I see no evidence to suggest that F1 teams are doing anything significantly different and innovative from what they have done before, despite this multi-media age, in order to raise the funding required. They need to look to the entertainment industry as one example of how a brand (and sometimes this can be simply a celebrity) can be developed, faithful fans attracted, new markets exploited via a multitude of instant-access and interactive channels.

Is it not an irony that with F1 drivers becoming ever younger, they and their teams and sponsors are apparently not connecting with the youth market that F1 needs to take it forward?

The Mr E factor

The same point is even more true of F1's promoter. Bernie Ecclestone is rightly acknowledged as having performed wonders in terms of F1's survival and past prosperity. Now his extraordinary antipathy to the reality of an already-changed world demanding multiple means of viewing sport appears to be the stopper in the potential sponsorship Genie bottle. I guess the basic reason is that he can control the TV income, but social media is quite another thing!

Similarly I think that he needs to relax the iron grip he has on media images of F1 racing, and the lockdown on any associated activities that are not authorised and paid for. The teams and sponsors need this freedom in order to take beneficial advantage of relating directly to their target audiences. Fans need to have more access to the show, better opportunities to see their heroes and to be treated with more respect. One can understand Bernie's reluctance to loosen the reins – after all, the whole F1 edifice has been built on TV revenues and exposure, along with race promoters' fees. Nonetheless, the business model has to radically change to safeguard the future of the sport, and who better to have the drive, balls and vision to do this than Bernie himself, possibly the greatest entrepreneur in sport?

Linear star-to-be?

Coming from a sound pedigree, Red Bull's latest RB10 car represents evolution from a position of strength

By SAM COLLINS and KATE WALKER

"We did have problems with it setting itself on fire, but that was not because it was not cooling, that was because it was burning

As the 2013 season drew to a close they were unbeatable. The Red Bull RB9 was simply the best car on the grid and the team cruised to its fourth straight world championship. But 2014 was going to be different, the dominant family line of evolutionary designs that started with the RB5 of 2009 was to be broken by a new rulebook. The RB10 would, on the face of it, be the first of a new breed of Red Bull, and the last car that Adrian Newey saw through its life.

At first glance, however, there are some clear family traits that suggest that in reality the family line has continued, albeit with some new features, it is something that its chief designer, Rob Marshall confirms. 'The RB10 is to an extent an evolution of the RB9 but the cooling layout of the car is very different,' he admits. 'But, in other areas of the car, things are very generic, RB9 to RB10. Despite the big regulation change it is still an evolution in those areas.'

As *Racecar Engineering* closed for press, Red Bull still had a mathematical chance of winning the World Championship. It is not a realistic one, although it does sit in a comfortable second position in the standings. The reason for this, according to the team's rivals, is the car's aerodynamic performance, generally felt to give the highest downforce level and the best efficiency, something the team itself believes too, another example of family resemblance perhaps.

'It is difficult to say if we do things differently in terms of aero development,' says Marshall. 'If we have a way of iterating concepts faster as we do not know what our rivals do. In aerodynamic terms, basically the aim with RB10 was to recover as much of the loss imposed on us by regulation changes as possible. There were some features that were radically different, notably the introduction of a narrow front wing and losing exhaust blowing. They were the focus of much of the work, and I guess it went better for us than the others.'

But the aerodynamic advantages of the RB10 were not evident when the car first

The narrow and long PWR heat exchanger sits above the intercooler, contrary to popular belief the RB10 does not suffer from cooling issues.

appeared in an incomplete state just ahead of the start of pre-season testing. When it did take to the track its runs were slow and very short. Whenever it returned to the pits it was accompanied by the acrid smell of burning car, indeed sometimes it did not even manage to get out of the garage before smoke billowed from its rear end. It was clear that the RB10 had serious issues, and many of them were blamed on the Renault power unit, which certainly had its own issues (see p16), but not all of the RB10's problems were down to that.

'It was, you could argue, a result of aggressive packaging, but we felt that we needed to take a few risks to try to get a good package that would minimise the aerodynamic damage of this very large cooling requirement,' Adrian Newey explained after the testing issues were discovered. 'The Renault seems to have a particularly large cooling requirement. Everybody of the three engine manufacturers will have a different target for how hot their charge air is going back into the plenum and Renault have given us a fairly challenging target. It has all sorts of advantages if we can get there, but it is not easy to achieve.'

These comments, allied to additional cooling slots being added to the bodywork of the RB10 in testing, suggested that the car was getting too hot but Marshall explains that this was not the case. 'That is something of a misconception about our car. We have never really had cooling problems. We did have some problems with it setting itself on fire, but that was not because it was not cooling, that was because it was

Vocal critic Newey set to bow out

While the Red Bull RB10 is billed as Adrian Newey's final grand prix car, in fact he will remain with the team until the end of the calendar year, and is therefore involved in the development of the new RB11, although he won't see that through to the start of the season. But he has been a vocal critic of the 2014 regulations, and is stepping back from his role at Red Bull Racing to work on other projects (thought to be the Americas Cup) as a result. His thoughts on the current regulations are certainly thought-provoking.

'If you make the cars of an increasingly fixed aerodynamic specification then it becomes GP1 as far as the chassis is concerned. And we're already, in my opinion, in grave danger of getting close to that; that the regulations define a lot of the car. So, increasingly the cars will look more and more similar. I would actually be arguing for an opening of the aerodynamic regulations. As far as the cost is concerned then I think the Resource Restriction Agreement, in terms of restriction in wind tunnel testing and CFD, goes a long way to reducing the aerodynamic cost because aerodynamic cost is two things: it's the research – wind tunnel, CFD – which is hugely expensive, then the manufacture of the parts that comes out of that. This year I think we've seen a slowing of the number of parts that people are introducing because, as I say, the regulations are quite restrictive by one point, and by another point we are now heavily into a set of regulations that had their roots in the 2009 change.

So, everybody's becoming quite evolved in where they are. But I think, certainly from what I hear and people I've spoken to, including journalists, insist that the public does have a lot of interest in the changes to the cars and what happens, and that's what differentiates it from other sports.

In F1 you have got this combination of different factors. You've got the driver, the chassis which is obviously not just aerodynamics but it's heavily aerodynamic-driven, and the powertrain. And it's that blend of features that makes it exciting and interesting. If you look at IndyCar, for instance, which went to one-make chassis some years ago, ever since it's been one-make it's viewing has fallen and fallen.

Budgets

Obviously, as engineers, I guess we would ideally like the sort of CanAm-type regulation of maximum length and width or whatever it was and do what you like within that, But, realistically, that's not practical nowadays, so I think it's a very difficult one to strike that balance between something which allows the maximum amount of freedom whilst not having the budgets going completely out of control, where it becomes a complete spending war and without having a huge difference in the performance of the vehicles, because if we had too much freedom, the chances are that one team would strike it right each year and everybody would complain that the racing's a bit dull.

Unfortunately, that has happened a bit this year but that's another matter. I think as far as the power train is concerned, the only slight concern that I would voice is that I think it is absolutely correct that these power units are an incredible piece of technology and something of which we should be very proud of as an industry.

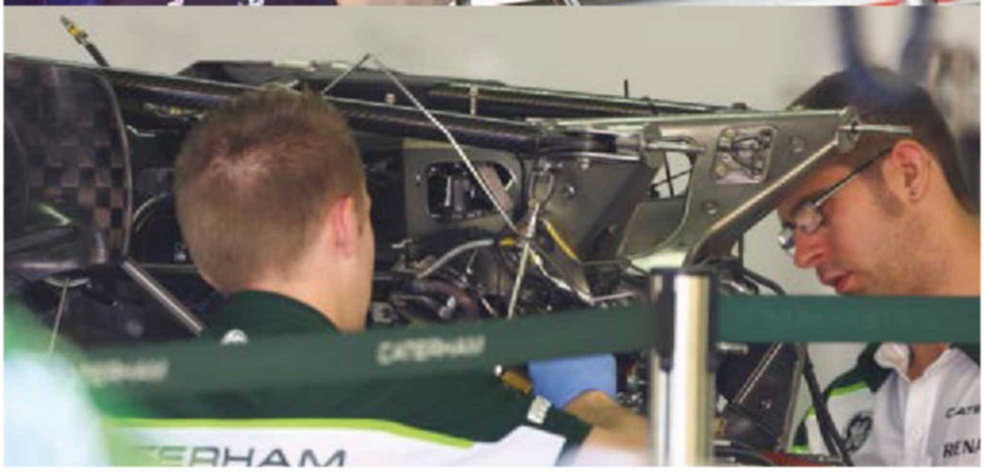
What's not clear is that as the freeze becomes more and more solid, if one power unit then has an advantage over another, or one is clearly behind, how that is addressed. If you are in that position, you have no way of upgrading your power unit because you're frozen, and you're doomed to forever be behind, but I think that's something which hopefully can be discussed and should be resolvable, particularly because the engines do all now carry – or all cars carry - torque sensors. Those torque sensors do seem burning, and that was a different problem. In fact, the cooling has always been good on the car. Cooling has been a significant area of development over the years, but the years where you have to do a lot are the years where the car doesn't cool well. This year it does, so we have not done perhaps as much as others.'

The Red Bull cooling system does differ to that of the other Renault engined cars. Indeed, each has a distinct and different solution. On the RB10, the PWR heat exchangers are narrow and fairly flat and run right along the flank of the car, with an intercooler at the base. It is a solution that has drawn admiring glances from rival teams.

Tight at the rear

Much of pre-season trouble has since been put down to the Red Bull design trend of very tight packaging of its cars, especially around the rear, and Marshall accepts that the team pushed this area a bit too hard on the RB10.

'We took some big bold steps on how small we could make everything and it took us longer than it should have done to get to the point where we had stopped those things burning. It was a side effect of pushing the envelope and seeing how far we can take things, we pushed too far and didn't give ourselves enough time as we were fighting for the 2013 championship,' he admits candidly. 'The truth is if we had a month longer pre-season testing would have been a lot less trouble but as it was, the first time the car had run was the first test, and the first time a lot of systems on the car had run was also the first



Red Bull developed two transmissions for the 2014 season, one for the RB10 (top) and the other for the Caterham CT05 (above). The forward section of the first iteration of the latter is believed to have had to be reworked due to its tendency to catch fire, while the former features a metal forward section which did not suffer from similar issues.

to be a little bit noisy but basically very reliable and give a good signal. So, it's entirely possible for the FIA to look at the outputs from those torque sensors and see where everybody is, not only across engine-matched factories, but also of course the variable of fuel. So, if a particular engine and petroleum company has the benefit over another, then it's able to do so and within that, it has the means, if it wishes to, to allow some equalisation for anybody that finds themselves behind in a frozen area.

My opinion of it is that, from a technical aspect first of all, you have to question the whole thing behind the new power units. When you get into things like batteries, then an electric car is only green if it gets its power from a green source. If it gets its power from a coal-fired power station then clearly it's not green at all.

A hybrid car, which is effectively what the Formula One cars are, then a lot of energy goes into manufacturing those batteries and into the cars, which is why they're so expensive. And whether that then gives a negative or a positive carbon footprint depends on the duty cycle of the car – how many miles does it do? Is it cruising on the motorway at constant speed or stop-starting in a city?

So this concept that a hybrid car is automatically green is a gross simplification. On top of that there are other ways to make it fuel efficient. You can make it lighter, you can make it more aerodynamic, both of which are things that Formula 1 is good at. For instance the cars are 10 per cent heavier this year, a result, directly, of the hybrid content. So I think technically, to be perfectly honest, it's slightly questionable.

From a sporting point of view, to me, efficiency, strategy etc, economy of driving, this concept is very well placed for sportscars, which is a slightly different way of going racing. Formula 1 should be about excitement. It should be about man and machine performing at its maximum every single lap.

Compromises

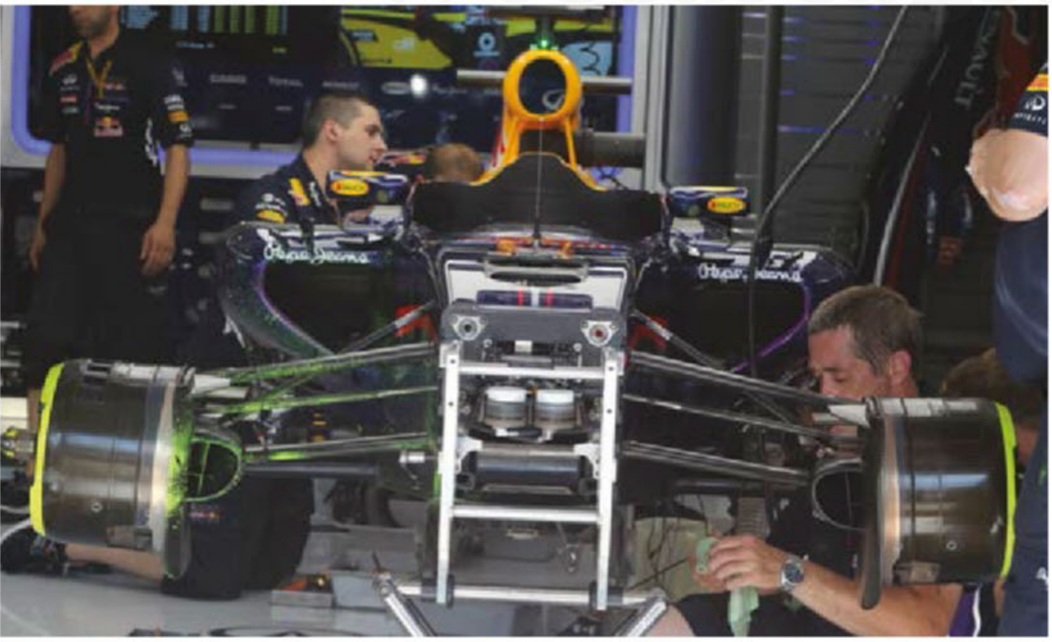
Don't get me wrong, I'm not suggesting we should go back to gas-guzzlers, although actually the V8s were extraordinarily efficient. But it seems to me that what we have done is create a set of regulations which are technically interesting, but I still question whether they get all the compromises right.

On the aero side, yes of course we have lost some downforce, but the aerodynamic efficiency of the cars hasn't dropped a lot. What has dropped is the load they can give at maximum downforce, maximum wing level and of course the cars are going a lot slower and that should be factored in when we talk about the whole fuel efficiency thing. OK, they're using 50 kilos less fuel but they're going a lot slower to achieve that.

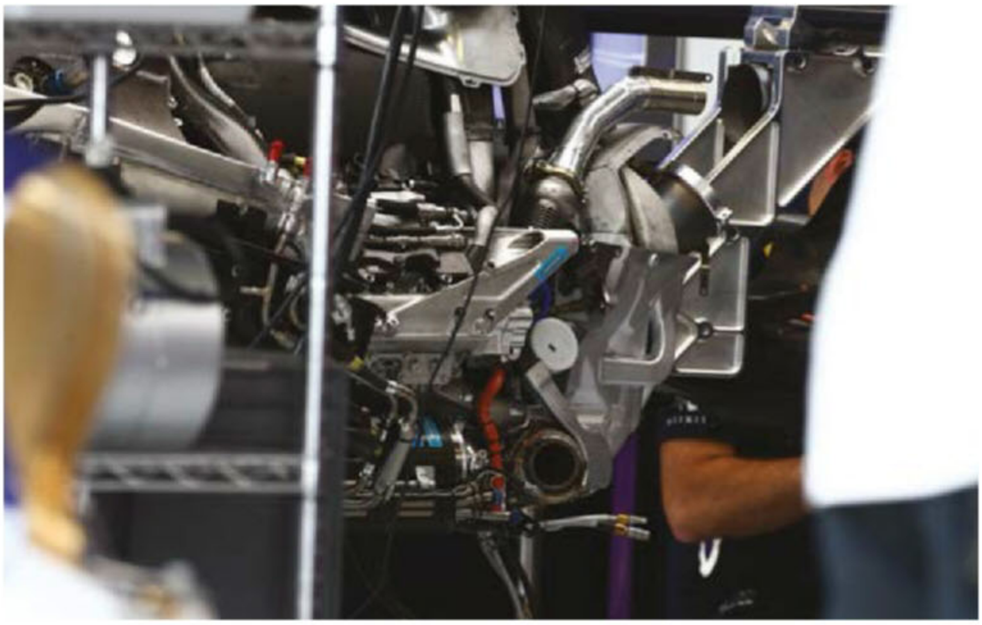
Ultimately, then there is a relationship between cost, weight, aerodynamics…all sorts of factors if you're going to go into road relevance. How you weigh that, how you proportion it is impossible for an open-wheeled single-seater. It's a very different beast. So, no easy answer.

The cost of the power unit has at least doubled compared to last year, which is difficult for some of the smaller teams, so it's a very complicated balance I think is the honest truth.

"Don't get me wrong, I am not suggesting we should go back to gas-guzzlers, although actually the v8s were extraordinarily efficient"



The RB10 retains the long established Red Bull suspension layout of pull rod-actuated dampers and torsion bars at the rear and pushrod at the front. At the start of the season it featured a front-to-rear interconnection but this was dropped when the legality of such systems was questioned mid-season



A look at the left-hand side of the RB10's engine bay with the exhaust system and transmission removed reveals the location of the MGU-K (black cylinder at the engine block base) plus the sheer complexity of a 2014 power unit

The roll hoop of the RB10 bears a strong resemblance to the designs used on all Red Bull cars since 2009

test. If we had been able to rig-test some of the systems ahead of that, we would probably have had fixes in place ahead of the first test.'

It has been suggested that had Red Bull used one of its allowed pre season 'filming' days to shake down the car then it would have been able to solve the problems earlier, but Marshall dismisses this.

'If we had a filming day before the first test we would have still set the car on fire and wouldn't have fixed the issue before the first test or the second. We needed to fix long lead time items, but there was not time to do so. Every time we sent the car out we knew it would come back on fire. The alternative was not send it out, and not learn about the rest of the car. We accepted that there would be a lot of work to do between runs but still learn about the rest of the car.'

Marshall would not be drawn on what exactly the problem was, only stating that it was a long lead time item. 'We knew what we needed to do to fix it. We had made something too weak and had to make it bigger. It was not one of those things that was a quick fix, it took multiple weeks, and the new spec did not arrive until the Australian Grand Prix, and we have used it ever since.'

Bell housing

This suggests that the issue related to the transmission casing, specifically the bell housing. The Renault RS34 has its turbocharger and wastegate located at the rear of the V6 engine, essentially in the bell housing. Red Bull uses a full composite structure in this area and its is clear to see that it essentially has holes in it to accommodate the turbo and associated pipework. As the casing is a fully stressed member holding all of the inboard suspension pick-ups it could be assumed that having large holes the bell housing would reduce rigidity but, according to Marshall, that is not the case. 'Dealing with the heat in the bell housing area on our transmission was a challenge, but stiffness wise it just means a bit more weight on it and we don't think the car is compromised by cutting a hole in the gearbox,' he adds.

Red Bull Technology, the organisation which is basically responsible for the design of the car also supplies the complete transmission to the Caterham CT05, and the internals to the Toro Rosso STR9. However, in the case of the Caterham the gearbox is notably different to that of the RB10, possibly explaining why the green cars did not burn quite as often as the RB10 during its early running.

'The case used by Caterham is half carbon half metallic,' Marshall explains. 'The front half is the metallic bit, the regulations do not allow us to hand over suspension components to another team, so they have to design their own suspension to design their car. Many of the suspension pickups are on the bell housing, so doing a metal case for them meant that it

helped them in terms of lead time. The rear of the gearbox is the same as ours, but the front bit, the bell housing which is not really gearbox but a spacer, is different. The lead times gives them a bit more freedom as a carbon case like ours takes much longer. We also have different exhaust systems so you could not fit the Caterham gearbox on our car.'

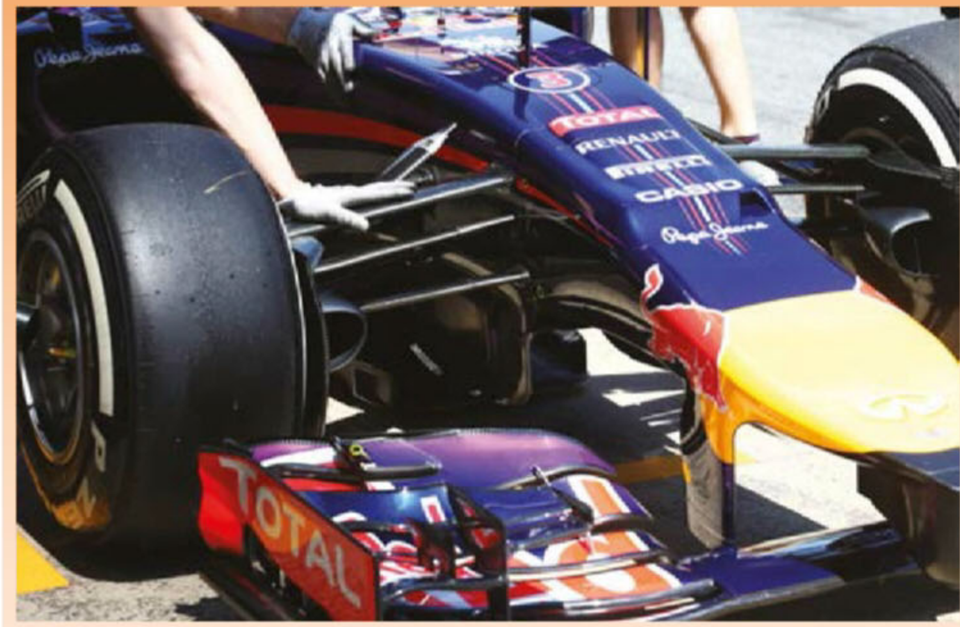
Having to add weight to get the troublesome component to be able to withstand the demands of 2014 Formula 1 would have been an added headache for the engineers at Milton Keynes, who like all of the others developing cars for this season struggled to get the design under 691kg and maintaing the mandatory 314kg/370kg weight distribution.

'Getting the car to a reasonable weight was very challenging, it was one of the things we were most concerned about as we designed the car,' Marshall continues. 'You don't have to get it very wrong to be a long way out. If you are 1 per cent out, it is big. Estimating the weight of components is very difficult, especially carbon work. If you are working with metal components, its reasonably easy to calculate the weight of them as long as you do not forget all the washers nuts and bolts. In carbon you can't do that so easily. That was our biggest target from a mechanical point of view, making sure the car was not overweight – we achieved that and we have got some freedom within the weight distribution window.'

It has been suggested that the weight limit in 2014 was too tough for the teams to meet, and not every team was able to do it. According to Newey, that not only puts a pressure on drivers to lose weight but also on the financial resources of the teams 'we're certainly right on the edge of the weight limit with both drivers and our drivers are on the lighter end,' he reveals. 'I think the power units have come out heavier than expected and that's putting a lot of pressure on the teams. It's another hidden factor that drives the cost up because saving weight tends to be a very expensive business.'

From the first race the Red Bull RB10 showed strong pace. As it crossed the finish line in second place at the Australian Grand Prix it was the first time the car had been able to complete a race distance, and the result was something of a relief to the team. Even though it was later disqualified, the cars performance level was clear to see, but so were its reliability issues, something that dogged the RB10 for the entire season and cost it many points. But if the family line continues into 2015 and the problems that troubled Red Bull and Renault in 2014 can be resolved, then the RB11 should be a title contender.

Nose job



At the start of the season, the RB10 featured a cunning solution to get around the rules relating to the placement of cameras on the nose of the cars. The technical regulations state that the cars must run two TV cameras on the nose, but Red Bull noticed a loophole and mounted the cameras deep underneath the cars 'vanity panel' on top of the nose. With a small opening for the lens, as one might expect, this did not produce especially good images for television and according to Marshall 'the FIA were not particularly impressed'. After initially trying a larger opening the team was forced to change the layout to a more conventional design with cameras mounted on 'horns' like those on the Ferrari and Mercedes noses.

TECH SPEC

Chassis construction
Composite monocoque structural designed and built in-house

Front suspension
Aluminium alloy uprights, carbon-composite double wishbone with springs and anti-roll bar

Rear suspension
Aluminium alloy uprights, carbon-composite double wishbone with springs and anti-roll bar

Transmission
Eight speed longitudinal gearbox mounted with hydraulic system for power shift and clutch operation

Dampers
Multimatic

Wheels
OZ Racing

Tyres
Pirelli
Fronts: 245/660-13
Rears: 325/660-13

Brake system
Brembo calipers, frictional material; carbon/carbon composite discs and pads

Fuel system
ATL Kevlar-reinforced rubber bladder

Electronic systems
MESL Standard Electronic Control Unit

Engine
Renault Energy F1-2014, 1.6 litre 90 degree 6-cylinder. Max rpm 15,000, 24 valves. Cylinder block in aluminium

Fuel
Total

Late-night solutions

After a shaky start to the F1 season Renault made the most of a regulatory mini-thaw – and hasn't looked back

By SAM COLLINS

When Red Bull racing won the Belgian Grand Prix, many, not least those at Red Bull, were surprised. The team had not expected to be competitive and admittedly while the Belgian result was something of a fluke (the two Mercedes had rendered each other uncompetitive on the second lap) it was the team's third win of the year. At the start of the season there had been question marks over the ability of any of the Renault-powered cars to even finish a race let alone win one. But the turnaround in form is the result of a breathless development programme from the Renault Sport F1 engineers, still ongoing.

The Renault RS34 'Energy F1 2014' was the first 2014 Formula 1 power unit to be shown off in public, initially in the pages of this magazine in late-2012, then later at a high-profile launch in Paris in the summer of 2013. Everything seemed to be fine, the French manufacturer seemed to be ahead of the game while rumours of problems at Ferrari and unreliability at Mercedes were everywhere. But then came the inaugural pre-season test of 2014 held at the Jerez circuit in southern Spain.

It was not the first time that the RS34 had been run on track. That first test had come a little earlier at a sodden circuit in Italy, mounted to the back of a Toro Rosso, but it was the first time that the cars had been pushed, and it was the first run for Renault's top team, Red Bull. It was a disaster. The Renault powered cars barely completed any laps and those that did were far off the pace.

'The underlying causes were not straightforward,' said Rob White, deputy managing director, Renault Sport F1. 'There wasn't a single component or system that caused particular trouble. A number of related things were troublesome, principally concerning the control and operation of the various sub-systems of the power unit within the car. For example on the first run day, we had problems with a sub-system within the energy store that did not directly concern either the battery or the operation of the battery – it is an electronic part that was in the same housing as the energy store.

'We subsequently had problems with turbocharger and boost control systems with knock-on effects on the associated engine management systems, which went on to provoke mechanical failures.'

Those failures meant that the Renault Sport specialists had to rebuild the battery packs overnight in an attempt to get the cars to run properly the next day, but as White admits, other problems arose. 'Sometimes you make one thing right and three other things pop up that you did not expect, so you can end up chasing a problem.' At Jerez the chase went on through the nights in the Renault trucks and in the garages, while in Paris the chase continued on the dynos at the firm's HQ. 'In parallel to running in Jerez, the team at Viry ran dyno test programmes to investigate the trackside problems and to propose solutions. We identified the probable root cause of our main turbo control issues, implemented some workarounds that were first seen at the end of day three and deployed in the three cars for day four of the test. This established a very minimalist baseline from which we could build,' says White. But chasing the problem was a game that continued right through the pre-season testing period.

For the second pre-season test, held in Bahrain, Renault brought an updated version of the RS34 in an attempt to solve the issues seen in Spain.

White says; 'We made a number of specification changes to the energy store, involving modified hardware, requiring some gymnastics in engineering, procurement, assembly and logistics. We also introduced two levels of power unit control system software updates, the first being effectively what would have been a decent starting point for Jerez.

'It eliminated some bugs that allowed us to make mapping and calibration corrections, which subsequently allowed us to operate the cars in a more robust way to gather mileage. The second layer of software changes had more functionality to allow a greater authority to the control systems, giving better performance and driveability, and a larger degree of power unit systems integration. All the cars started on the first route and all cars migrated to the second solution as we gathered mileage.'

The issues were, at least in part, seemingly blamed on an issue with the dyno at Renault Sport F1. 'We now know that the differences between dyno and car are bigger than we expected, with the consequence that our initial impressions were incomplete and imperfect,' White told the press after the first test. 'We are frustrated to face this litany of issues that we should have ironed out on the dyno.'

But White clarified those remarks later in the season; 'It was not a problem with the dyno – instead it was a case of the only way you can really test the environment of putting something in the back of a car on a track and running it on a track is by actually doing it. There are things that you just cannot simulate on a dyno.'

Renault Sport uses a number of dynos for its F1 programme, with identical test cells not only at its base in the outskirts of Paris, but also at its subcontractor Mecachrome. The French aviation specialist has a very long relationship with Renault and in 2014 is responsible for building all of the engines used in Renault-powered cars racing in Formula 1, while the technical support and operation of those engines is conducted directly by Renault Sport engineers, led by head of track operations Remi Taffin.

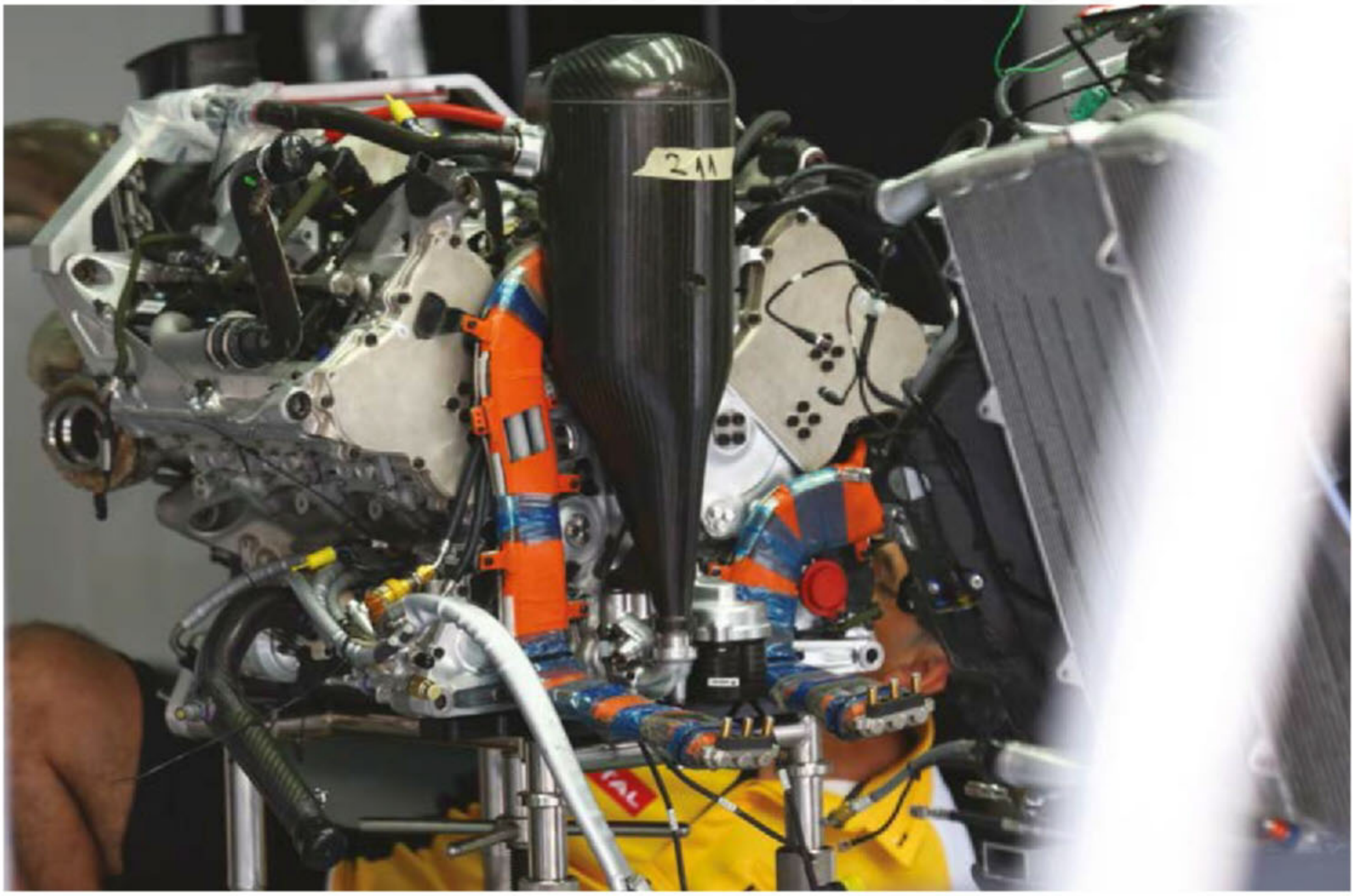
But the reliability problems continued right through both tests in Bahrain, and the deadline for freezing the specification of the whole power unit for the duration of the 2014 season came and went without Red Bull able to complete a race distance. That engine homologation, or 'freeze' as it is more commonly known, would originally have meant that the Renault power unit would have been more or less as it was as the teams left Bahrain for Melbourne and the opening race of the season, but a subtle change in the regulations threw Renault Sport a lifeline.

Appendix 4 of the 2014 F1 sporting regulations was amended to include the wording: 'A power unit delivered to the FIA after 28 February 2014, or modified and re-delivered to the FIA after that date, with which the FIA is satisfied, in its absolute discretion and after consultation with all other suppliers of power units for the Championship, could fairly and equitably be allowed to compete with other homologated power units.

'Such changes will normally only be accepted if they are being proposed for reliability, safety or cost-saving reasons.'

There was no disputing the lack of reliability of the Renault power unit, at the first race of the year only three of the eight Renault powered cars finished the race, but

A subtle change in the regulations before the first race of the season threw Renault Sport a lifeline



From bad to good – Renault's 2014 updated version of the RS34: 'People think that it is just a dumb old engine because we have these advanced machines attached to it, but there is nothing simple about developing an engine like this – it is a highly complex thing and there will be issues', was the opinion of Renault's Rob White

tantalisingly all three were in the points (until one was disqualified due to fuel flow meter irregularities).

In the early races of the season many problems were found with the hybrid elements of the power units. Failures of batteries and MGU's were common on some cars, but many of these issues were fixed without having to resort to using the 'reliability, safety or cost' route.

Software, lubricants and fuel are not 'frozen' like the rest of the power unit and it was the first major area of in-season development according to Remi Taffin. 'At the test in Bahrain in April we tested several new software modes that moved us closer to the limits of the Power Unit than before,' he admits. 'In the opening three races we were some way from the edge of the performance envelope but the new modes allowed us to run more to the extreme. The power unit had improved driveability and greater life from each part. Likewise we worked on the energy management per lap, particularly in the slow corners. We knew we were missing out on the straights but the new software gave us greater traction in the turns.'

The second part of that update came in Monaco where more software changes were made to improve drivability and reliability. Total also introduced a new fuel at the race which again helped improve traction and responsiveness, according to Renault.

But as the electrical gremlins started to be worked out of the system, other issues had started to show their head, mostly based around the internal combustion engine, which surprised many to the mild annoyance of Rob White: 'People think that it is just a dumb old engine because we have these advanced machines attached to it, but there is nothing simple about developing an engine like this – it is a highly complex thing and there will be issues.'

Indeed ahead of the Canadian Grand Prix some hardware changes were introduced under the 'reliability, safety or cost rule.' The new specification parts were introduced as the teams cycled through their allocations of power unit parts, but Renault has been very cagey about exactly what was changed mechanically, despite the fact that for them to have made the changes in the first place both Ferrari and Mercedes would have had to approve. The reason for this caginess may be that Honda, coming in 2015 would not be entitled to see the paperwork.

Renault has been cagey about exactly what was changed mechanically, despite the fact that both Ferrari and Mercedes would have had to approve

Listening to the rumour mill in the paddock suggests that the RS34 received a new specification turbocharger, MGU-K and MGU-H shafts as well as a revised lubrication system, though this is not confirmed.

Regardless of what the changes were, they worked – and the performance of the Renault-powered cars, especially the Red Bull, bore this out – but there were still reliability issues, and the world champions started heaping pressure on to its power unit supplier. 'The reliability is unacceptable. The performance is unacceptable. There needs to be change at Renault,' Red Bull Team Boss Christian Horner complained following the Austrian Grand Prix where one of his cars had again broken down. 'It can't continue like this. It's not good for Renault and it's not good for Red Bull.' Renault's other customer teams were hurting, too, including Toro Rosso, Caterham and Lotus.

Eventually changes did come, and new management was put in place at Renault Sport F1. Focus was placed on the Red Bull team and although not likely as a direct result, the performance of the cars improved, leading to that win at Spa. 'A victory at an engine circuit where we were expected to struggle shows the never-give-up, never surrender mentality we

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"A victory at the circuit we were expected to struggle on shows our never-give-up attitude and how the knocks make us work harder"

'We are looking at all of the pieces that we are allowed to change and we are working through a process of what parts we want to change. That is not complete yet but it will be a change,' says White of Renault's engine plans going forward to the 2015 Formula 1 season

have at Renault Sport F1 and how the knocks just make us work harder and smarter,' Taffin enthused following the win. 'In the past few months we have been working even closer with Red Bull, and the race on Sunday was an example of optimising a chassis and engine package. This clear direction and streamlining is paying dividends.'

Although driver Daniel Ricciardo is still in contention for the drivers' title, much of Renault's work is now focused on the 2015 power unit, which could have very little in common with the RS34. By regulation the only things that must be carried over are a few dimensions. Everything else can be updated within a set budget of changes (see RE V23N11). 'We are looking at all of the pieces that we are allowed to change and we are working through a process of what parts we want to change. That is not complete yet but it will be a change,' White says cryptically.

Perhaps the troubles of the 2014 season, turning the RS34 into a race-winning engine will have taught the Renault Sport engineers some crucial lessons that perhaps their rivals have yet to encounter. When the RS35-powered Red Bull RB11 is rolled out at Jerez next year it could again be a title contender.

Backdrop to a world beater

At the end of 2013 the FIA Formula 1 World Championship bade farewell to its normally aspirated V8s and embraced brand new power units that combined a hybrid V6 turbo engine with two energy recovery systems – the MGU-K that works under braking, and MGU-H which harvests energy at the exhaust. Monza's 2014 race offered an ideal opportunity to compare and analyse the performance of modern low downforce-spec F1 cars with their previous counterparts.

The recent grand prix emphasised an important point; the 2014 regulations have greatly enhanced the cars' efficiency while maintaining – and even increasing – their level of performance.

1. A two-second gain in a single year

The 2013 season saw F1 cars fitted with normally aspirated V8s delivering around 800bhp (that's 590kW without the extra 60kW provided by the KERS). Monza's speed traps recorded single-seaters clock around 340km/h, with pole-sitter Sebastian Vettel posting a lap of 1:23.755 in qualifying aboard his Infiniti Red Bull Racing-Renault. A year later the fastest Q3 time was 1:24.109, achieved with a car weighing 50kg heavier – a 1.8secs deficit – and using harder tyres. Once these differences have been accounted for and the times corrected, this year's lap represents a two-second gain over the course of 12 months.

2. Fuel consumption down to 1.9kg per lap

The 2014 regulations also brought another revolution, with a 35 per cent reduction in the amount of fuel permitted for each race (100kg against 150kg last year). It's been made possible thanks to the V6 engine's high degree of hybridisation: 20% of the power is now electric and comes from the energy recovered under braking and harvested at the exhaust. The average Monza consumption rate therefore went from 2.5kg per lap in 2013 to under 1.9kg a lap this year. With the same mass, the corrected 2014 time is faster.

3. An F1 car's energy source distribution

In 2013, the vast majority of energy available came from the 160kg of fuel used by the car. Power generated by fossil energy and transferred to the wheels reached 30 per cent, while the remainder escaped in the air. A single KERS unit also ensured the share of electric power remained quite limited. In 2014, with a 100kg restriction in fuel mass, the share of electric power has grown significantly. A greater percentage is now transferred to the wheels, which vastly improves the overall energy efficiency. Electric energy is much more important (4MJ) than it was last year. It comes from two different sources: braking and the exhaust.

4. Better energy efficiency

In 2013 an F1 car's efficiency was rated at 30 per cent, which has increased to 40 per cent in 2014. This has been made possible by reducing the internal combustion engine's displacement (and amount of friction), the introduction of a turbocompressor, and cutting the number of revs from 18,000 to 13,000. The efficiency of a car fitted with an internal combustion engine cannot exceed 50 per cent. Only a fully electric engine can achieve a much higher efficiency.

Additional stats and facts

- 30% fuel mass reduction between 2013 and 2014.
- 0 points: the aerodynamic efficiency improvement of an F1 car between 2013 and 2014.
- In qualifying, the 25kg battery delivers an extra 10 per cent of energy, which amounts to 200g of fuel per lap.
- While overtaking during the race, Daniel Ricciardo's Infiniti Red Bull Racing-Renault reached 362.1kph, smashing the 2013 top speed by an impressive 20kph.

Information supplied by Renault Sport F1


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Originally a design exercise, the car was then developed for track use and will support the World Series by Renault tour

Balanced attitude

A winning entry in a Renault Sport concept competition, the R.S. 01 project pitched design against aerodynamics to break new ground

Renault has built what may be the fastest single-make GT racer in the world. Its new R.S. 01 was shown off in the form of renderings ahead of its track debut in France.

Designed partly as a styling exercise, the R.S. 01 could hint at the look of the overdue new Renault-Alpine production car, but that does not mean that the new car misses real aerodynamic performance.

The car has (according to Renault) better aero performance that that seen in GT3 and GTE and is closer in fact to DTM. Cl (lift coefficient) and CdA (drag coefficient) are similar to those of a Formula Renault 3.5. At the top speed of 300km/h, the downforce of 1.7 metric tons is equivalent to that of a Formula Renault 3.5.

The design process, though, started with a competition to find the best initial concept according to Éric Diemert, design director Renault Sport Technologies. 'All our projects begin with an in-house competition. At the end of three weeks, we chose the work of Akio Shimizu, a young Japanese designer,' he says. 'We then made a digital mock-up of his drawings. This took us into the technical phase, based on constant small-loop exchanges with Renault Sport Technologies and Dallara. The aim was to establish the best possible balance between our requirements in terms of design and aerodynamics. With each iteration, performance was verified by means of CFD calculations. We then milled a full-size mock-up. This stage was crucial to validating the vehicle's proportions and attitude. The result showed our decisions to be sound, so subsequent changes primarily concerned fine-tuning of the body lines, air intakes and extractors.'

Under the skin the R.S. 01 is closer to a Le Mans prototype than a GT car, despite its looks. The car's technical design was headed by former Oak Racing and Mygale designer Christophe Chapelain (who came up with the new LMP1 rear wing used on the Pescarolo 01 in 2011, see RE V21N7). The Frenchman opted to use a Dallara carbon-fibre monocoque built to meet LMP1 safety (though not dimensional) standards. The tub, which includes a 150-litre fuel tank, features a steel roll cage at the top similar to that used in GT500 and DTM. At the front, a crash box absorbs energy in the event of frontal impact. Another crash box attached to the gearbox plays the same role at the rear of the car. Completing the list of safety features are a collapsible steering column, and a Sabelt bucket seat with a six-point harness.

The semi-stressed engine is bolted to the rear of the monocoque. Prepared by Nismo, the 3.8-litre V6 twin-turbo engine is derived from the Nissan GT-R VR38DETT. The main change in relation to the production model is the dry sump system intended to prevent oil surges during long corners. The Cosworth electronic unit features a traction control function. Turbo pressure is set to deliver over 500hp with maximum torque of more than 600Nm. This positions the R.S. 01 between a GT3 and a DTM car in terms of outright performance.

The engine is mated to a longitudinal seven-speed gearbox supplied by Sadev. With an eye to cost control, identical ratios will be used for all tracks. However, it will be possible to adjust the preload setting of the self-locking differential. Activated by steering-wheel paddles, the sequential gearshift system is managed by

"After three weeks we chose the work of Akio Shimizu, a young Japanese designer. We made a digital mock-up of his drawings"

The high level of aerodynamic downforce is reflected in the suspension design

an XAP electromagnetic actuator. Developed specially by ZF Race Engineering, the clutch system features an anti-stall function and is designed for an extended service life.

The high level of aerodynamic downforce is reflected in the suspension design. In the same way as on sports prototypes, a conventional double wishbone layout has been adopted with pushrods and Öhlins dampers.

Adjustable for compression and rebound, the systems are positioned on either side of the body at the front, and longitudinally above the gearbox at the rear.

The braking system combines 380mm carbon discs from PFC Brakes with six-piston calipers. This choice is an excellent compromise between efficiency and endurance.

Renault Sport R.S. 01 is also fitted with Bosch Motorsport ABS. The partner of Renault Sport Technologies for all its motorsport products, Michelin has developed special 18-inch tyres, mounted on wheels of original design with a central nut.

The cars will be used in a new series called the Renault Sport Trophy which will follow the well-established World Series by Renault tour. The 2015 season will be open to 20 'Pro-Am' teams, classified according to the rules of the FIA World Endurance Championship (WEC). Track time is currently estimated at more than four hours per car and per driver, over a three-day weekend.

Renault's return to sportscar racing has long been expected, and was originally meant to be based around a still-unseen new Alpine design. A partnership with Caterham cars was announced but the alliance collapsed in June this year having little to show for itself. 'Renault will now continue to develop its own Alpine sports car to be launched in 2016, as initially planned,' read the formal press release at the time. 'Caterham Group also plans to continue with its own sports car.'

How the R.S. 01 fits in with the Alpine brand, and whether it does even relate to that brand, is not yet clear.

Michelin has developed special 18-inch tyres mounted on original wheels with a central nut

TECH SPEC

Chassis:
Dallara carbon monocoque chassis and steel roll cage

Safety:
Monocoque chassis, roll cage and crashboxes compliant with FIA LMP1 2014 standards, collapsible steering column, Sabelt seat FIA 8862/2009 standard

Bodywork Composites:
Aerodynamic features front blade and splitter, stepped flat bottom, rear diffuser and rear wing

Engine:
Type: Nismo V6 – 24 valves – 3799cc
Layout: Longitudinal central rear
Feed Injection: 2 turbochargers
Max power: > 500bhp
Max torque: 600N.m
Max engine speed: 6800rpm
Electronic management: Pectel SQ6M with traction control
Data acquisition: Cosworth ICD Pro

Transmission:
Type: Rear-wheel-drive
Gearbox: Sadev sequential, 7 speed + reverse
Control: XAP semi-automatic with steering-wheel paddles
Differential: Limited slip
Clutch: ZF Race Engineering, long service life with anti-stall function

Running gear and suspension:
Suspension Double wishbone + pushrods
Dampers: Öhlins 2-way adjustable
Brakes: PFC Brakes 380mm carbon discs, 6-piston calipers, Bosch ABS system
Steering: Hydraulic power steering

Wheels: Braid wheels, central mounting
Tires: Michelin 30/68 R18 (front) and 31/71 R18 (rear)

Dimensions, weight and capacities
Length: 4,710 mm
Width: 2,000 mm
Height: 1,116 mm
Wheelbase: 2,744 mm
Front/rear track: 1,675 / 1,624 mm
Fuel tank: 150 liters

Weight: < 1,100 kg

Porsche promise

That rare breed, the rear-wheel-drive rally car, has a new potential champion in the shape of Tuthill Porsche's 997 R-GT

By MARTIN SHARP

Last month we detailed the Toyota GT86 CS-R3, a rare new rear-wheel-drive rally car, eligible for rallying up to world level from next year. But another new rwd car is already eligible. Tuthill Porsche's 997 R-GT demonstrated promising potential while contesting and finishing its first rally, the Rally Germany in August, round nine of the 2014 WRC. It is 28 years since Saeed Al Hajri drove his 911 SC RS to fourth overall on the Acropolis Rally, the last contemporary Porsche to finish a WRC event before this year.

The R-GT regulations were announced in 2011, enabling Grand Touring cars to contest rallies to World Championship level. That year the FIA received just one R-GT homologation request; from Lotus for its Exige R-GT. The homologation process became prolonged and FIA technical department has seen fit to revise the eligibility criteria for R-GT cars from this year. Homologation by manufacturer into the specific category is no longer required and each individual R-GT car must have an FIA Technical Passport, a quasi-homologation document issued by the FIA against each individual car's VIN.

The car's owner or preparation team must have the proposed R-GT car inspected – and with luck certified – by the relevant national ASN and undergo the time-consuming process of readying the individual Technical Passport for submission to the FIA for approval, at an admin cost just shy of £6,400 (€8,000).

During his former career at Prodrive, engineer Graham Moore became well-versed in liaison between manufacturers and the different direction, but we thought at the time that the Cup car gave us the best option for performance and good components.'

With their competition spec conrods and pistons, Carrera Cup engines are renowned as reliable units, in particular the 3.8-litre option chosen by Tuthill in its purchase of a 2012 Generation Two ex-Cup 997 racer as the basis for the rally car.

However, circumstances just before Rally Germany have caused the Tuthill engineer to reflect that 'obviously we weren't expecting such a drastic restrictor size, so we need to review that and it may be that a standard engine with that restrictor might be reliable.'

On the Friday before rally week the Tuthill R-GT was on its trailer being towed to rally HQ town Trier. The technical passport issue

> **"Cars derived from a production model which are built specifically for a Manufacturer's Cup are allowed, so long as 30 have been produced"**

homologation was granted in July 2012. That month the Lotus contested only the first two special stages of the Rally Vinho de Madeira before crashing out of the event on the third. The car has not been seen on a competitive stage since... so far.

R-GT rules specify road-legal series production GT cars with two doors, two, or two-plus-two seats, one or more luggage compartments available for sale through a manufacturer dealer network, and of which at least 200 identical examples must have been produced in 12 consecutive months. Four-wheel-drive GT cars can be used as the basis but a kit must be available to make them two-wheel-drive. But crucially, cars derived from a production model which are built specifically for a Manufacturer's Cup are allowed, so long as at least 30 such cars have been produced.

There are rumours of an R-GT Cup beginning next year, encompassing six tarmac rounds, three in the WRC and three in the ERC. However, GT car manufacturers are evidently loath to homologate cars for the sport of rallying. It is therefore encouraging that the FIA on homologation issues. Moore is now in charge of the Tuthill 997 R-GT project and says: 'The hardest bit was the technical passport with all the photographs. They say it is a simplified homologation document – I would say it isn't that simplified, it's a good start – it will evolve; we are already on version two.'

The R-GT rule allowing Manufacturer's Cup cars results from a direct Tuthill enquiry to the FIA about the eligibility of Porsche Carrera Cup cars for this rallying category. It is an idea that the FIA GT Championship introduced in 1999 with the Ferrari 550 Millennio.

Moore: 'I started the homologation process, all the discussions, once we got the all-clear for homologating or using a Cup car as a base. Obviously, Porsche made more than 30 of them so that's the criteria, a minimum of 30 cars. That was accepted and we used that as our base because you get a lot of really good bits with it – engine, gearbox, brakes, carbon doors, all the lightweight stuff, all the air intake system for the engine, so it's a good base for the [rally] car. You could do one from a standard road car and come at it from a was to all intents and purposes a matter of getting the approval sticker and applying it to the roll cage before scrutiny. To equalise the performances of the widely varying types of GT cars eligible for R-GT the rules stipulate a minimum weight-to-power ratio of 3.4kg/bhp. The MSA inspectors' calculations showed that a 65mm diameter inlet restrictor plate would exceed the minimum ratio comfortably yet provide competitive performance.

No conformation of this diameter had arrived before the car was trundling its way towards Trier. Until that Friday, when an email announced that the restrictor size was to be 36mm. Surprised, Moore 'lathed' one up in a Trier machine shop, fitted it to the engine, whose Bosch engine ecu crunched car weight and acceleration figures through its maths channel after the car was tested and came up with a fairly accurate estimate of 325bhp. That figure was some 100bhp and 1500 fewer maximum rpm than with a 65mm restrictor and would severely hurt performance.

The minimum R-GT car weight limit in the 997's capacity category is 1200kg, yet

The Tuthill 997 R-GT project is being run by former Prodrive man Graham Moore, who is well used to the sometimes precarious liaison between manufacturers and the FIA on homologation issues

Standard Porsche calipers are used for the rally car

With the flat-six power train rearwards of the rear axle line, the R-GT's weight remains rear-biased

With a front-mounted spare and a fuel tank up-front the static weight balance has been brought forward

because the rules call for what is essentially an equivalent to Group N specification it is not allowed to remove areas of metal and it is therefore impossible to build a 997 to that limit. Post-Germany, Tuthill Porsche did the sums, as its boss, Richard, recalls: 'It weighed 1307kg on M-Sport's scales before the rally, without driver and co-driver. So, a WRC regulation is the true weight of the car, they allow 160kg for crew and equipment – and, apart from Google, no-one's got a car that drives itself yet! So if we're talking about 3.4kg/bhp weight/power; shouldn't it be as the car's driving down the stage?'

The best weight/power ratio the team calculates it can achieve is 4.1kg/bhp. It ran in the Rally Deutschland at 4.6kg/bhp, 'and that's massive,' Richard Tuthill says, adding: 'it does depend on what they think the weight is – and wouldn't it be helpful if they told us what they think?'

"It was more about a passion for decent cars and proper driving. These projects are driven by passion not business"

But the rally was a success for the team. Despite the performance deficit, Tuthill and co-driver Stephane Prevot finished the rally 27th overall after 326 stage kilometres after one front-right puncture and a driving mistake when Tuthill followed a left arrow after a crest when clearly Prevot had called a right.

After the puncture Tuthill knew there was no chance of a top 20 finish. 'That just reinforced even more that I was there to get a finish,' he said. The car had no mechanical problems and Graham Moore achieved his aim of building data as a building block for further developments.

Wet surfaces

Tuthill is very comfortable driving on wet surfaces and relishes the challenge. It rained on the Monday before the rally at a test stage set up for 15 cars by event organisers ADAC. Rated Estonian, Ott Tanak, came 10th overall on the rally in his Drive Dmack Fiesta R5... yet was slower in the wet on that Monday test stage than Tuthill in the Porsche 997 R-GT.

The Briton was convinced that 'in the right hands it will be a top 20 car without a doubt, and I think that on the right stages it will definitely beat the R5s. The car can be quick. The problem in Germany was a rusty driver and a need just to deliver a finish.'

This R-GT project has severely dented Tuthill's piggy bank, but he has gone about it for all the correct reasons. 'The principal reason was that I just think that to drive these cars is great fun, and something that I believe the spectators will enjoy and that the drivers will enjoy, so it was more about passion for decent cars and proper driving. These projects are driven by passion, not business, and then the business follows.'

As deliberations over weight/power ratios continued at press time, Tuthill had already entered the car for the Rallye de France at the beginning of October. If budget can be secured the French WRC event holds great R-GT promise. Tuhill's intention is for the ideal driver to take the wheel; François Delecour, a man with experience of rallying Porsches who is most definitely not short of driving talent and a natural application of enthusiasm. The Frenchman is 'in the loop' for the rally and assisting in the budget search.

The other part of the R-GT promise for Rally France is that works Porsche sportscar racer Romain Dumas intends entering his new 997 R-GT, developed by his own firm RD Limited. An interesting part of this challenge is that Dumas' car is based on the special edition 4-litre RS 997, to which the FIA have applied a 34mm diameter restrictor. This was never a Carrera Cup car so the RD Limited project is based on a road car, unlike Tuthill's Cup-based R-GT.

Richard also has his eyes fixed on November's Wales Rally GB for the gravel specification Tuthill 997 R-GT. As it will be the car's first event over dirt surfaces he wants to drive in GB; thereby gaining data and experience, as in Germany.

'I keep a record of what we've done to the car [during the rally]; it's actually not much really. Nothing broke; nothing wore out. We had a bit of a scare in a road section – he thought he could feel something loose in the steering and we got some stuff out – as it turned out it was just a bolt on the subframe so we tightened that up and it was all right – so really it's been pretty good,' said Tuthill Porsche's R-GT project chief engineer Graham Moore after Rally Germany.

Moore opted to site the engine air intake restrictor between the air box and the throttle body, similarly to the Cup race cars. There is no position regulation such as that for turbocharged engines; dimension from the turbo blades, just that the normally aspirated Porsche engine has to have a restrictor. The single throttle feeds six inlets which have

The car contested Rally Germany using Carrera Cup gear ratios and final drive. Graham Moore says: 'We didn't use sixth gear but the engine did have a reasonale amount of torque and we would look at the ratios in conjunction with the restrictor'

variable lengths to improve torque. 'This is something we'll have to look at, certainly with the [36mm] restrictor,' says Moore. 'Maybe you could spend a lot of time and money trying to find the optimum place for the restrictor... hopefully it will be better if we can get a bigger one. That's the issue really – that's pretty much crippled the engine. This is its first event so we can obviously now go back to the FIA if they want some data from the car so that they can have some data to compare to the top cars.'

The car contested Rally Germany using Carrera Cup gear ratios and final drive, which turned out to be 'not too bad. Obviously we didn't use sixth gear but the engine did have a reasonable amount of torque and we would look at the ratios in conjunction with the restrictor. We looked at ratios but we didn't bother to make new ones because we thought that if the restrictor's going to change we'll end up having a load of ratios that don't match the engine power. There are other ratios – I know the guys over here [Germany] run shorter gearboxes in the national rallies, so we'll see.'

Not that the team was expecting the restrictor size to change, particularly after the MSA inspection, certification and recommendations. Moore is both sanguine and hopeful over the issue: 'It was a surprise really – we didn't expect it to change. So there we are, that's it; we have to comply and... we did reasonably well with what we had, and the ratios were OK, it wasn't a hindrance anyway. I think there's some leeway there; we can have a go, but it won't happen overnight. So they [the FIA] have got some indication anyway.'

"The ride's important; the tyres are different and you are running on bumpy roads so the damper has to suit that"

Rally Germany also provided a good base set of data on tyres of the correct size to assist in selecting optimum gear ratios. The Michelins used on the event were 650mm diameter.

The standard – big – Cup racing rear spoiler is approved for the rally car and although it is fully adjustable, Tuthill ran it in Germany on the base setting. An aero aid that size must contribute to the racecars' performances considering the speeds achieved in circuits.

Because the 997 racecars carry just the driver the Cup roll cage is asymmetric; the rally car needs to accommodate a co-driver so the asymmetric cage is ineligible.

As a non-road-legal racer, the Cup car does not have provision for a spare wheel, yet the R-GT car must be homologated with one spare wheel. Front-mounted spare wheel accommodation must be detailed in the R-GT Technical Passport, with photographs which must show that no extra clearance or strengthening is derived.

The rules allow a removable rear window, so for gravel rallies, when two spares may be sensible Tuthill is investigating the option of throwing a rear wheel/tyre assembly in the back in the case of a puncture. The team has already tested a nine-inch wheel at the rear and found it will run, but 'for gravel you would want to run two spares, just because of tyre wear because we've seen that it does have an appetite for rear tyres – funnily enough!' smiles Moore.

With the flat-six power train rearwards of the rear axle line the R-GT's weight remains rear-biased. With a front-mounted spare and a fuel tank up-front the static weight balance has been brought forward a few percent.

The 997 has MacPherson struts at the front with an, effectively twin-wishbone, rear multi-link arrangement. Exe-Tc dampers have been for many years the mainstay of Tuthill's Historic 911s, and also Moore's particular favourites. Of course, these are used on the first, tarmac spec, 997 R-GT, which has an available 180mm of wheel travel front and rear. 'That's about the limit you can get with the suspension links and stuff on it. We don't actually use all the 180mm, but you can see when it goes over a jump that it's got quite a bit of droop travel.'

Toe-and-bump steer characteristics over suspension travel are evidently very different between racing and rallying and Moore has worked hard to get the R-GT's suspension to work with the travel. It was certainly not a case of bolting-on dampers and crossing the fingers.

Moore describes the dampers as 'quite a trick' and each is supported by a triple-rate progressive coil-over spring 'to give you the protection at the end for the landings, which you don't have in a race car. And we try to control the ride. The ride's important; the tyres are totally different [to race tyres], and you're running on bumpy roads so the damper has to suit that. We've developed; a tarmac-specific damper for bumpy surfaces.' Spring rates are roughly half those used on the Cup cars, but the characteristics are quite different.

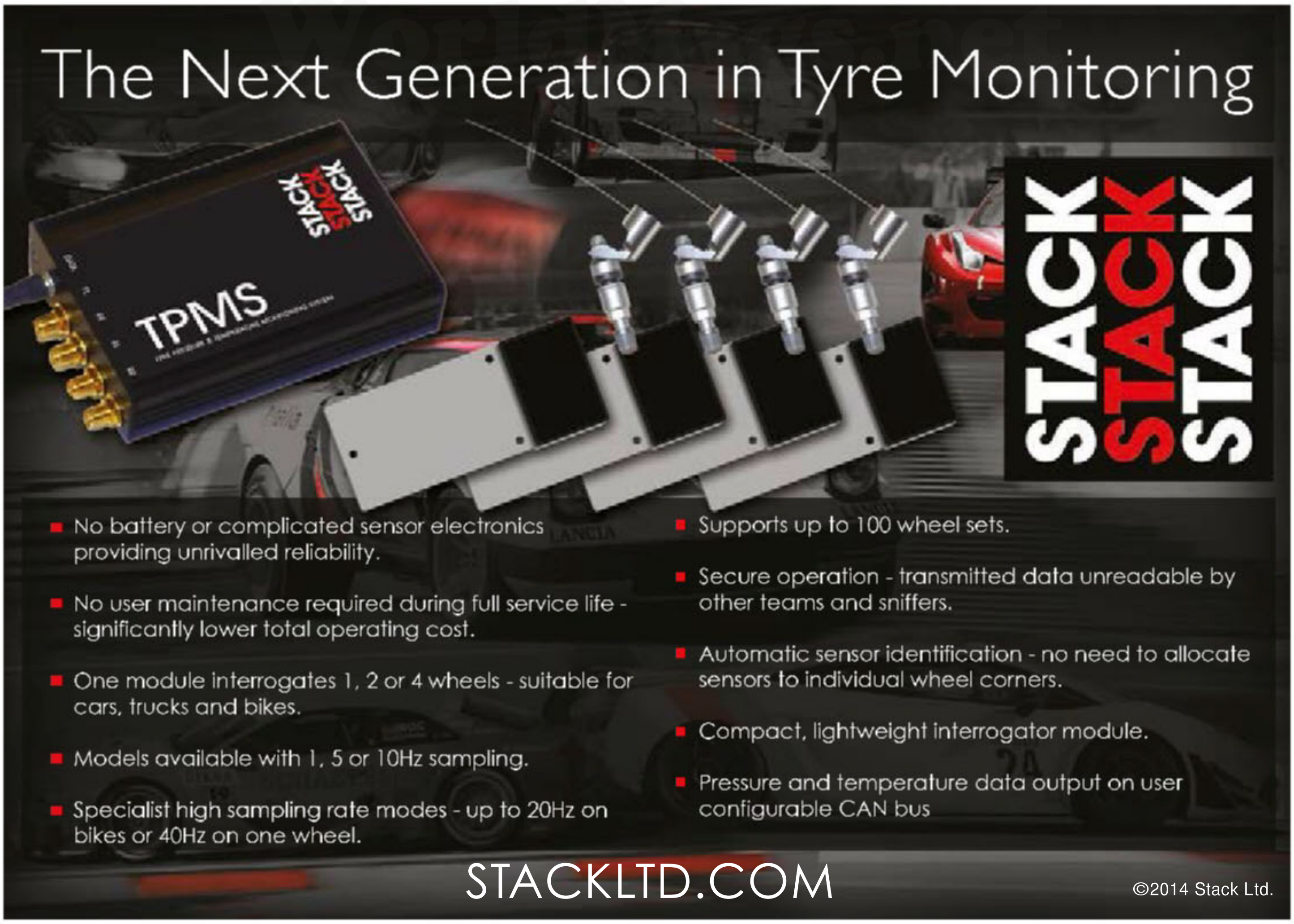
Dossier request

However, as the plans for contesting Wales Rally GB with the car indicate, the Tuthill team's suspension planning does not stop here. A full dossier requesting some further 50mm of suspension travel was submitted to the FIA on May 1. Tuthill explains: 'You can't expect a GT car to have the suspension travel to cope with gravel. And we're only doing it in a very simple way; no bodyshell modifications, nothing.'

Despite the inclusion of gravel specification brakes in the R-GT regulations, the FIA 'didn't expect people to want to run on gravel.' Tuthill asked why gravel brakes are in the regulations?

Moore is confident. The team has an Exe-Tc damper specification already ideally suited to gravel circumstances and immediately suitable for the R-GT, yet stresses that on gravel stages wheel displacement is the issue which is inherently not available in a current GT car. And so, with the regulations standing effectively at Group N currently, there is no allowance to move anything to gain extra travel.

At Rally Germany Moore was positive. 'Speaking to some of Richard's existing customers they're all very keen to see how it's gone this weekend but with a Porsche you do get the reliability. You've got an extremely good car as a base, and there's a very good parts system – it's all standard bits, they're all available. We may offer a kit to people to do their own, because I think there are some people who would like to do their own; we can do the assistance.'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Live axle rears and Mumford linkages

Racers and engineers put their questions to Mark Ortiz

Last month I responded to a question from a reader who was considering using a Mumford linkage in a Cobra kit car. I mentioned in passing that the car best known for using this type of linkage was a design by Arthur Mallock and that one reason he'd used the concept was to get a smooth undertray leading smoothly into a diffuser, along with a low rear roll centre. This prompted a related question from a different reader:

Question

After being out of the seat of a SCCA and other road circuit car, or building one for 34 years, and spending the intervening years involved with aircraft, I am helping my son build a SCCA SPO silhouette sedan. As you can imagine, I am struggling mightily to get back into the 'modern' era.

In this regard, I just read your October *Racecar* column and reference to the Mumford linkage of Arthur Mallock. A long time ago, I built Panhard and Watts-link systems but I don't ever recall the Mumford setup.

Could you send me a copy of your previous review of the Mumford linkage? Hopefully it has some illustrations or photos to help me visualise how it is configured.

Some background: I am 68 years old now and been out of the seat of a racecar for 34 years and have not built a racecar in 35 years. During the years in between I was involved mostly with R&D of aircraft engines and related engine/airframe integration.

Now I am helping my son build a racecar from scratch and man, is that humbling after all these years. I have so much catching up to do, perhaps I should just walk away. While I learned with aircraft possibly a few applicable/transferrable aspects to race cars, such as how to configure low-drag cooling systems, I am long since removed from building a ground vehicle that goes fast.

The car will be an SCCA SPO silhouette 1960s vintage British hatchback and may possibly run in an occasional NASA race, rules permitting. The SCCA interpretation of the SPO and rules appear to me pretty generous except it has to have the open driver's window. The whole project is a homage to old-school but I am applying as much aero as possible while trying to keep some external visual cues so people know what in the hell model/make car this thing is to represent. I am carving the body plug, from which moulds will be made for the body.

A tight budget dictates a simple old-school steel tube space frame chassis with coil over suspension front and rear – with double long arms in front and a three-link, live axle Winters quick change in the rear.

The car on which this one is patterned is relatively small, has a good power-to-weight (approx 700hp) and target weight of 2100lbs, but the overall wheelbase/track and wheel/tyre combination ratio and layout is that of a BMW Tudor GTLM Z4 but looks more like one of those excessive DTM cars. So the frontal area is inherently large and draggy given the overall small size of the car. It is so wide due to packaging the V8 then long front A-arms followed by very big wheels and tyres.

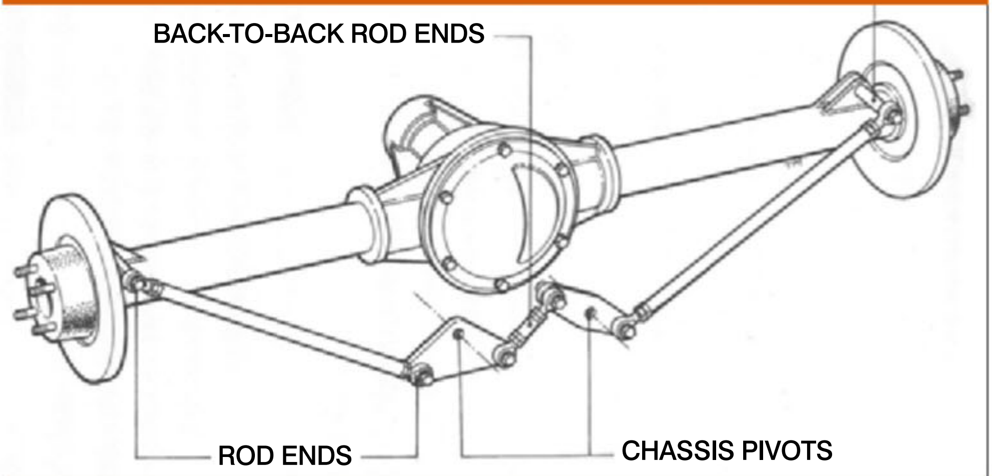
I am working the front body aero shape to get some front downforce, along with double front diffusers, and flat bottom.

This long-winded background leads to the problem at hand: due to the live axle, I am struggling to integrate some degree of a useful rear diffuser while locating the housing.

But of course that damned rear axle housing, and most of the related stuff, runs all the way across – smack dab in the way of where a clean diffuser should be.

And of course a low mount Panhard or Watts-link makes this area even more of a turbulent mess. So that is why I would like to see the layout of the Mumford linkage at the

A *Racecar* solution from the archives



We have tried nine different systems of sideways axle location. The requirement is to provide a rollcentre which stays constant relative to the chassis with suspension travel.

In this respect, the popular, axle-mounted Watts linkage is the worst. By mounting the Watt pivot on the chassis, the rollcentre cannot move, because it has a bolt through it, and the rods do not move in roll. For clearance reasons, it is often convenient to mount the pivot left-of-centre. It the rod lengths and pivot ratios are changed in proportion, Watts' geometry is still maintained. This is an excellent system when super-low rollcentres and ground clearance are not considerations. For a lower rollcentre, the system can be mounted horizontally.

For best compromise with 'stagecoach effect', however, the rollcentre height should be about 3in – and for the optimum ground-effect, the whole mechanism must be above the venturi.

This is where the Mumford axle location system comes into its own. By carefully calculating the pivot lengths, the rollcentre movement can be kept to less than 0.1in. As it is invisible, it can be set to any desired height (even below ground).

Michael Mumford's system, illustrated by the diagram, offers the advantages of nil spurious vertical loads, and excellent rollcentre control. Very low rollcentres are practical, well below ground clearance, and thus the system offers excellent bump scrub. On bump, the ground clearance actually increases.

In the Mallock layout, the rockers and connecting link are small and short

rear. My guess is it probably does not help substantively over the Panhard bar or Watts-link but here's hoping.

The consultant says

My earlier newsletter didn't have any illustrations, but I sent it to the questioner anyway, and did a search for images of a Mumford linkage. I replied:

Here's a link to a picture of one version of the concept: http://www.not2fast.com/chassis/mumford.shtml. Newsletter is attached.

The link actually is to not just a picture but an article from none other than *Racecar*, about five years before my first article in the magazine, authored by Arthur Mallock himself.

It shows the version of the system with the rockers inboard and mounted to the frame. Mallock mentions the issue of how the rear roll centre moves when the suspension moves in ride, which I have also discussed. If the front suspension is independent, it is desirable to have the rear roll centre move up and down with the sprung mass in ride, rather than with the axle. That way the rear roll centre moves similarly to the front one, and the slope of the roll axis doesn't change a lot as the car negotiates crests and dips. Cars race without this characteristic, but it is desirable.

In the Mallock layout, the rockers and connecting link are small and short. The rocker-to-axle links attach to the rockers down as close to the floor pan as possible. The links extend out and up from there to attach to the axle tubes near axle height. Those links then have an instant centre slightly below the floor pan, and that's the roll centre. The whole affair sits just behind the axle.

Many cars run Panhard bars that pass behind the quick change – but it might make more sense to put the Mumford linkage ahead of the axle instead

The Mallock doesn't have a quick-change axle. The Mumford linkage sits where the quick change gears would be with the Winters. It wouldn't be impossible to move the linkage back far enough to clear the quick change. Many cars run Panhard bars that pass behind the quick change. However, it might make more sense to put the Mumford linkage ahead of the axle instead, with the rockers longer than in the Mallock and straddling the rear U-joint or the front of the rear end housing. The connecting link would then pass above the U-joint or housing. Or, if the rockers are made long enough, they could also straddle the quick change gears.

Another possibility would be to have the rockers outboard, mounted to the axle, a long central connecting link, and right and left links running down to frame anchorage points about where the lower ends of the Mallock's rockers are. This makes more of the linkage unsprung mass, but it can simplify frame build and package better in some layouts.

Winters also makes a version of their quick change that has the quick change gears in front. It's a bit harder to change gearing with those, and in some cases the driveshaft can get really short, but that configuration does get the quick change gears out of the area behind the axle. Other considerations permitting, from the standpoint of diffuser design we'd want both gears and lateral locating linkage in front.

According to the Winters catalogue (http://www.wintersperformance.com/catalogs.htm), the large (10in ring gear) quick change hangs just over 6in below the axle centreline. The front cover on the front gear unit hangs a little lower – almost 7in below axle centre. Depending on tyre radius, that gives something like half a foot to the ground. If we have a continuous panel under the diff, we have room for 3in of droop travel and about 3in of ground clearance. This means that for a road car, we cannot run a panel under the diff, but for a pavement race car, we can – just barely, if nothing else is in the way.

We need to keep in mind that the rear axle needs to be cooled. If we isolate it from undercar air flow, it will need a cooler.

We can use almost any kind of lateral locating linkage, provided that any part that moves with the axle is at least six or seven inches above the ground at static condition. Even a Panhard bar seven inches above the ground will work. That gives a fairly low roll centre. Lateral tyre scrub on one wheel bumps won't be huge. The roll centre rises and falls about half as much as the sprung mass in heave. That doesn't really match the front end, but it's not too bad. And the whole linkage is just one simple lateral member.

The only really compelling reason why road racers strive to get extremely low roll centres on live axle rears is suppression of torque roll and torque wedge: the roll movement and change in diagonal percentage due to driveshaft torque acting through the suspension. The amount of diagonal percentage change depends on the relative elastic roll resistance at the front and rear. The greater the elastic roll resistance at the rear relative to the front, the less torque wedge results. To maximize rear elastic roll resistance without getting oversteer, rear geometric roll resistance has to be minimized. That is, the rear roll centre has to be lowered.

But all of this goes out the window if we understand how to cancel torque roll and torque wedge using the longitudinal locating linkage. This is not as difficult as many suppose. It does require that we react brake torque differently than engine torque. Otherwise we get roll and wedge in braking. The simplest way is to have two trailing links at each end of the axle, with the right side ones on a clamped or welded bracket and the left ones on a rotating birdcage that also carries the left brake caliper. For minimal bump steer, the instant centres of both link pairs need to be at or near axle height. The longitudinal location of both instant centres needs to be the same. The longitudinal location of those instant centres – the side view swing arm length – needs to be approximately consistent with this rule: the side view swing arm length, divided by the lateral distance of the link pair from centre of the vehicle, needs to equal the overall axle gear ratio. An alternative is to use a torque arm and put both calipers on birdcages or brake floaters. A similar relationship governs the lateral offset of the torque arm and its length: the length of the torque arm divided by its lateral offset should equal final drive ratio.

The ideal geometry will vary as we adjust gearing to suit different courses. However, we don't need perfection on this. Just getting close will put us ahead of competitors who do not use anything but springs and anti-roll bars to deal with driveshaft torque.

CONTACT

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Running well after a trade-off too far

A power unit is a complex thing, so learn to read the pressure signs

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

Engine failure is the last thing anyone wants when running a racecar or any other car for that matter. Therefore there is a great emphasis on preventing engine failures and if they do occur to understand why and what happened. A power unit can be a very complex thing with many auxiliary components attached that can potentially stop the car. The engine itself, though, is a fairly well understood entity and if we take care of the basics it should run reliably.

Looking at three key elements of an engine gives us a good platform for both investigating and preventing failures – temperatures, pressures and electrical health. Temperatures are critical for the performance of the engine, but the cooling efficiency of the engine is quite often compromised by aerodynamics. The engine is often asked to run hotter than is optimal as there is performance gained by closing off cooling ducts to improve the aerodynamics. As with everything, it is a trade-off and the engine guy has to deal with the consequences.

In most cases the temperature increases fairly slowly, so it is important to take note of trends, rather than focusing on the exact value, unless of course we are running so close to the limit that failure is likely. Noting trends can help show whether the temperature is actually under control or not. In the case of a pressurised water cooling system, the pressure value of the water can also provide important clues. The pressure should rise along with temperature, but if the pressure starts to go down and temperature up, it could mean that the system is losing water and trouble is on the horizon, see **Figures 1 and 2.**

Pressures also tell us a wealth about the health of the engine. Steady oil pressure and, as stated above, good water pressure, mean the engine is going strong. Pressures tend to change more rapidly so it is important to log them faster and monitor them more closely. The pressures are also related to a pump of some description so there are values that can tell us whether the pump is healthy or not. A good example is a mechanical engine oil pump. This means that the pressure is related to engine rpm, it is therefore possible to look at the oil pressure as a function of the engine rpm to see whether the pump's efficiency is reduced. Looking at these values on an X-Y plot shows a very clear picture of the pressure values, **Figure 3.**

Electronics touch more or less every part of the car and the engine, especially, needs a fair bit of current to service its basic functions, inject fuel and ignite the spark. If there is a problem somewhere in the engine electronics, it is possible that the spark is not strong enough, causing rough running or the injectors don't get enough juice which can potentially mean the engine's fuelling becomes lean. As things generally happen very fast when it comes to combustion, it can be difficult to measure directly what goes on in the

It's a trade-off; the engine guy has to deal with the consequences

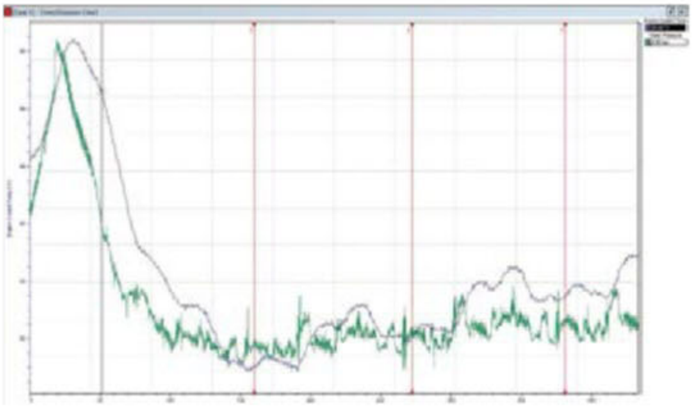

Figure 1: Water temperature and pressure change hand-in-hand to show a healthy water circulation

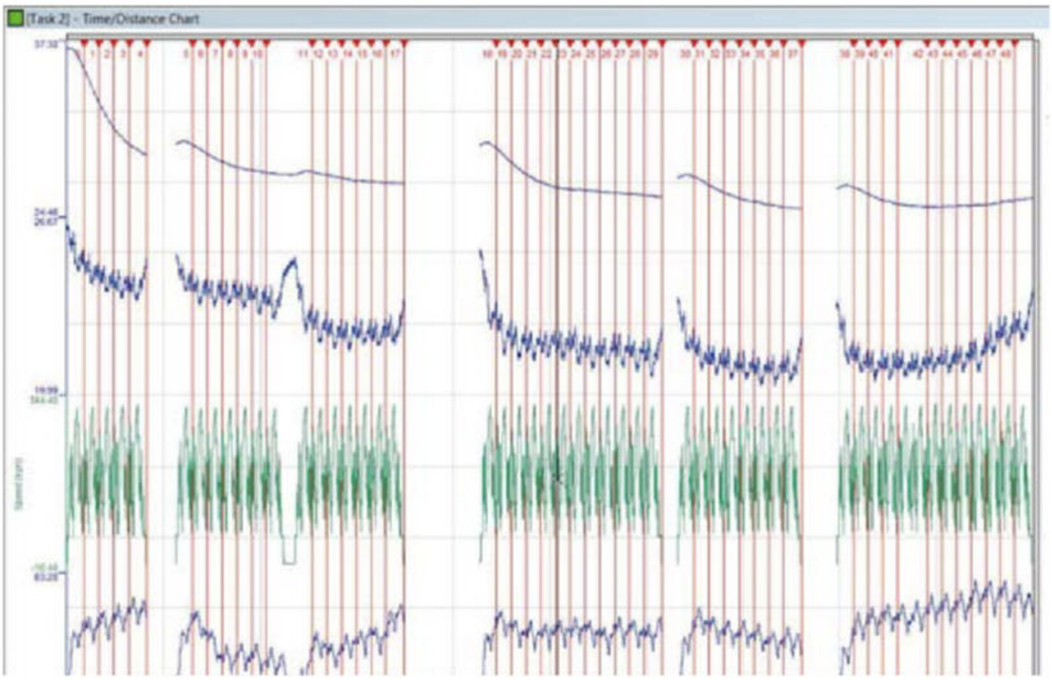

Figure 2: Three different temperature trends. Note the difference between heat soak and cool down when the car stops (speed in green)

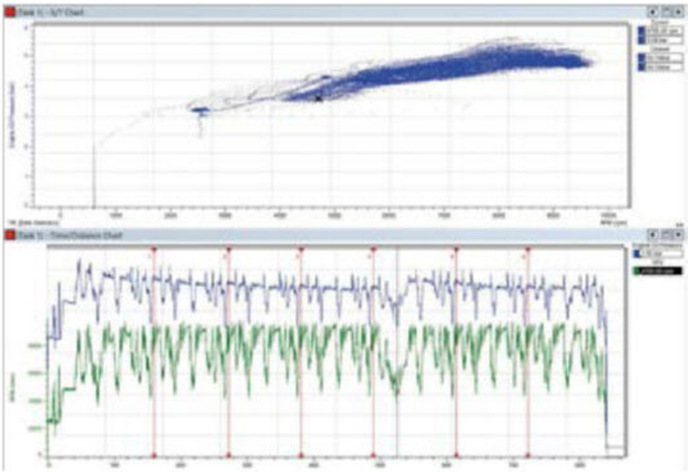

Figure 3: Two examples of how oil pressure and rpm can be viewed to show the relationship

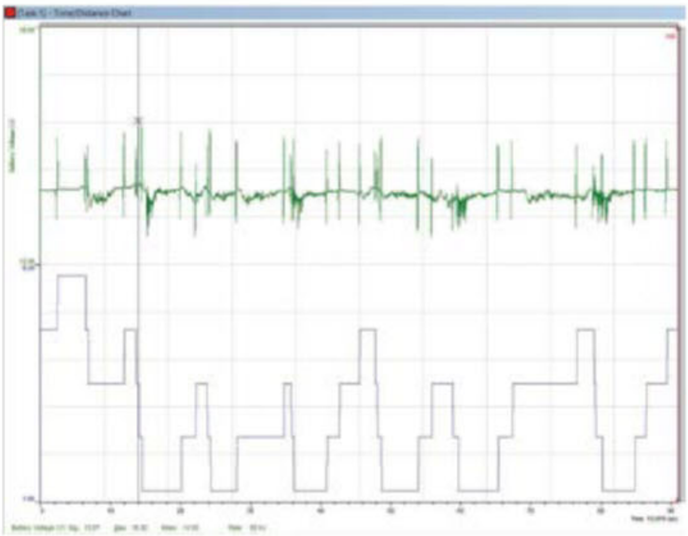

Figure 4: Voltage spike correlating with gear changes with an electric actuator

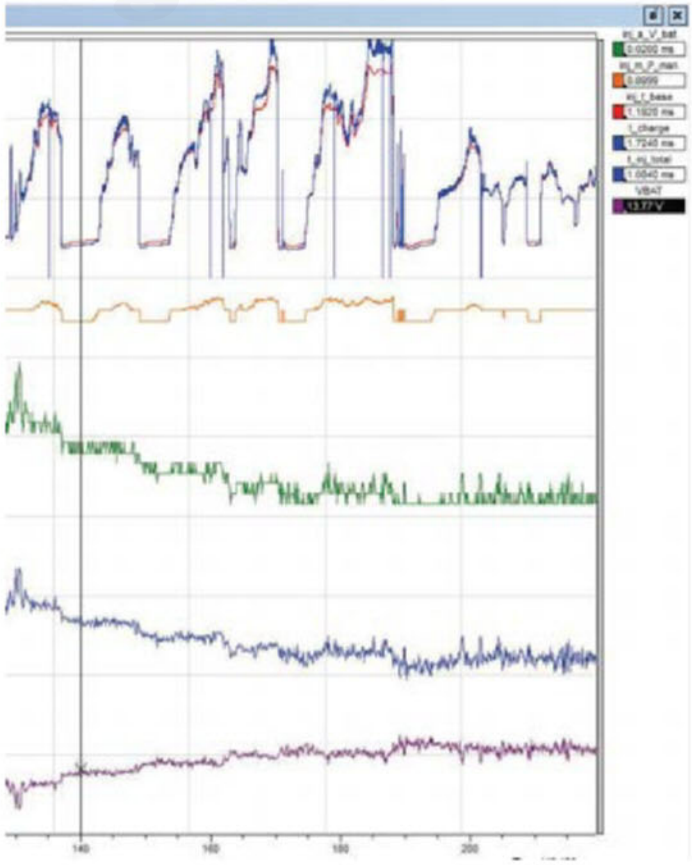

Figure 5: How battery voltage influences ignition and injection

combustion chamber, especially on a racecar going at speed on a circuit.

Monitoring the overall voltage from the electrical system is very important as it keeps the car alive. The voltage should be steady and at a level which charges the main battery of the car. If the voltage output from the alternator drops below that of the output of the battery, then we are likely to run into trouble sooner or later. Once the battery voltage drops below a certain level, the engine will misfire and ultimately stop. The charging of the battery through the alternator is directly linked to the engine rotation so we must always look at alternator voltage and engine rpm at the same time, otherwise it is possible to misdiagnose a problem. The issue of over-voltage is somewhat rare in most cases, but some electronic systems can introduce spikes into the system.

A good example of this is the electric gear shift actuator. As this uses a lot of current for a very small amount of time there can be a lot of hysteresis in the electrical system. In cars with such an installation, the battery voltage should be logged fast in order to catch the spikes. If the spikes are high enough they can cause all kinds of problems throughout the car, and potentially shut different parts of the control system down, **Figure 4.**

Turning to the effects of voltage ignition system monitoring, looking at how long it takes for the ignition coils to charge is of great interest. Normally when there is a problem with the electrical system, it will take longer to charge the ignition coils. The charge time can also give us a clue as to whether there is a problem with the coils themselves. Injection pulse width, or how long the injector stays open, can similarly tell us about the health of the injectors and the fuel system, but in both cases we must be careful as there are many different factors that influence both parameters and we must be aware of all of those, if we are to diagnose problems correctly. For example the airbox pressure has a direct effect on the fuel mixture. Above is an example that shows how battery voltage can influence both the injected fuel and ignition. We can see the battery voltage is going up and the two blue and green lines that go down correspondingly represent the coil charge time (blue) and the actual added value to the injection timing (green). At the top we see the base injection timing (red) and the total injection timing (blue) overlaid.

The total injection time takes into account the battery voltage correction as well as the airbox pressure multiplier. The effect of the battery voltage is clear and in the case of a failing alternator the ECU will compensate as much as possible but there comes a point where this is no longer possible and a misfire will occur, **Figure 5.**

Once the battery voltage drops below a certain level, the engine will misfire and ultimately stop

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Fine tuning a high downforce rear wing

Studies continue in the wind tunnel using Team Bath's TBR14

The University of Bath 2014 Formula Student entry was selected from the UK competition by the *Racecar Engineering* editorial team for a pre-booked half-day session in the MIRA full-scale wind tunnel just before they headed off to Germany for the next competition.

'TBR14' was the third car from the University of Bath to feature an aerodynamic package and, as well as incorporating an all-new hybrid composite/steel tubular chassis, there had been particular emphasis on developing new wings for its 2014 contender. The basic philosophy was high downforce and never mind the drag, so large plan area wings with aggressive profiles front and rear were developed. The front wing in particular was a cleverly made device with a number of interesting, tricky to manufacture features (See **Figures 1** and **2**).

As a reminder of last month's first episode on TBR14, the car set new Aerobytes records for drag and negative lift coefficients, so it certainly met its high downforce target, and calculations showed it had a 'Vceiling' (the speed at which it could generate downforce to match its weight and therefore stick to the ceiling) of just 86.8mph. While this was partly thanks to the car's low weight, aerodynamics played the major role.

Seeking balance

In baseline trim with 'trip strips' added to the tyres to better simulate the flow separations expected with rotating wheels, TBR14 was somewhat short of front downforce, the target '%front' figure being in the 45-50 per cent range as the car had a 50/50 front to rear weight distribution with driver aboard. So some rear wing adjustments were performed to gauge the level of response and gain more information about the effects of fine tuning towards a balance. The first adjustment involved reducing the overall rear wing angle one degree by shortening the rear mounting struts; the second adjustment required the fitment of new rear end plates that enabled a nine degree reduction of the flap angles, giving a 3.5 degree overall angle reduction (see **Figure 3**). The resulting data is shown in **Table 1**, with changes (except to %front) expressed as 'counts', where 1 count = a coefficient change of 0.001.

The changes in the coefficients suggested that the rear wing was quite near to its peak downforce setting at the steepest angle here (19.5 degrees), and although it is only a three point plot, the graph in **Figure 4** of –CLr versus overall wing angle supports that assertion, with perhaps another degree of adjustment

Table 1: the effects of reducing rear wing angle

	CD	-CL	-CLf	-CLr	%front	-L/D
Baseline data	1.401	2.409	0.946	1.463	39.26	1.719
-1deg	1.385	2.386	0.959	1.427	40.19	1.723
Change	-16	-23	+13	-36	+0.93	+4
-3.5deg	1.275	2.258	1.034	1.224	45.81	1.771
Change	-126	-151	+88	-239	+6.55	+52

Figure 1: The TBR14 featured a potent wing package

Figure 2: The front wing was particularly eye-catching

Figure 3: New rear end plates facilitated lower flap angles to be tested

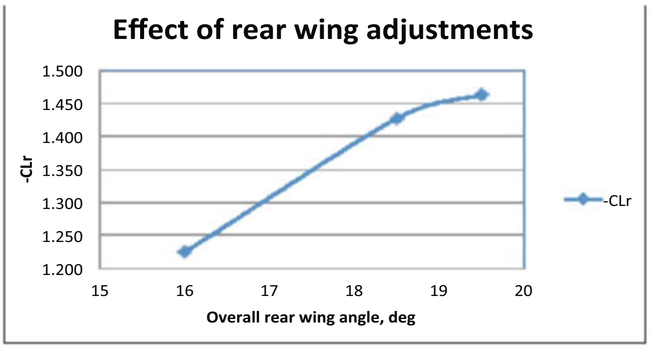

Figure 4: Rear wing adjustments showed where on the 'lift slope' the settings were

Figure 5: 'Low drag' mode for the acceleration test

Figure 6: Rear wing in the first dual-element configuration

Table 2: the effects of the low drag rear wing mode

	CD	-CL	-CLf	-CLr	%front	-L/D
Baseline	1.401	2.409	0.946	1.463	39.26	1.719
Low drag	0.834	1.289	1.421	+0.132	110.24	1.546
Change	-567	-1120	+475	-1595	+70.98	-173

Table 3: power absorbed with different drag coefficients, BHP

Speed, m/s (mph)	10 (22.4)	15 (33.6)	20 (44.8)	25 (56.0)	30 (67.2)
CD = 1.401	1.33	4.44	10.52	20.55	35.51
CD = 0.834	0.78	2.64	6.26	12.23	21.14
Extra BHP av.	0.55	1.80	4.26	8.32	14.37

Table 4: the effects of removing the upper rear flap

	CD	-CL	-CLf	-CLr	%front	-L/D
Baseline	1.320	2.385	1.165	1.221	48.83	1.807
Remove flap	1.053	1.937	1.417	0.520	73.15	1.839
Change	-267	-448	+252	-701	+24.32	+32

Table 5: effects of the steepest dual-element rear wing

	CD	-CL	-CLf	-CLr	%front	-L/D
Baseline	1.293	2.257	1.052	1.206	46.61	1.746
Max angle	1.181	2.044	1.222	0.822	59.80	1.731
Change	-112	-213	+170	-384	+13.19	-15

available before its peak was reached. By backing the wing off to 16 degrees overall a fairly well balanced set up was achieved. Nevertheless, achieving a balance by reducing total downforce was not the overall aim, and we'll come back to further investigations on this later.

Low(er) drag setting

For the 75m standing start acceleration test, the team adopted what it was hoped was a low drag configuration for the rear wing, akin in principal to the 'DRS open' arrangement seen in Formula 1, but with both flaps set more or less horizontal by raising their leading edges and thus completely opening up the slot gaps above the element in front (see **Figure 5**). The rules require all wing elements to be installed for all track events, and though driver operable DRS systems are permitted, Bath did not exploit this aspect. The data is shown in **Table 2**.

A 40 per cent reduction in drag coefficient was achieved with this rear wing setting then, which would indeed release more power during the latter phase of the acceleration test. **Table 3** shows the power absorbed in BHP at the two drag coefficients across a speed range, and the extra power available when running in the lower drag coefficient configuration. With just 62bhp peak power available, the percentage gains become quite significant. Academic readers will need to forgive the ongoing indiscriminate mixing of imperial and SI units!

Element removal

Although the aerodynamic philosophy behind TBR14 was to achieve maximum downforce, it was nevertheless very sensibly decided to evaluate a dual element rear wing configuration while the opportunity was available. The car was initially in a different configuration for the first adjustment to that used as a basis previously so the 'baseline' results in **Table 4** are somewhat different to those shown in earlier comparisons. Initially then the upper flap was removed and the first flap was also set to the maximum angle currently available (see **Figure 6**).

As might be expected, rear downforce decreased significantly with the removal of the upper flap, and balance shifted excessively to the front. Interestingly the front downforce coefficient was quite similar to the 'low drag' rear wing set up evaluated earlier, and although this in part a coincidence, it also demonstrated the potency of the front wing.

The flap looked as though it could be run steeper, so new adjustment holes that allowed a 50 degree angle (relative to the horizontal) on the flap were drilled, with the main element also adjusted on its support struts to the maximum possible angle again. This achieved an overall angle of 11.5 degrees, and the results are shown in **Table 5**, relative to a new baseline as ride heights had also come in for adjustment in the interim.

Once again rear downforce was a lot lower than with the three-element wing in any of the configurations tested, although by driving the dual element wing harder, to the point where wool tufts showed significant separation on the flap's suction surface, the excessive front bias from the previous configuration was redressed somewhat.

Still, the front end overpowered the rear, and although it would not be hard to attain a balance from this position if so desired, the high downforce package was still the configuration of choice.

NEXT MONTH we'll take a look at the quest for more front percentage downforce, and we will see how the car responded to rake changes.

Racecar Engineering's thanks to the staff and students at Team Bath Racing.

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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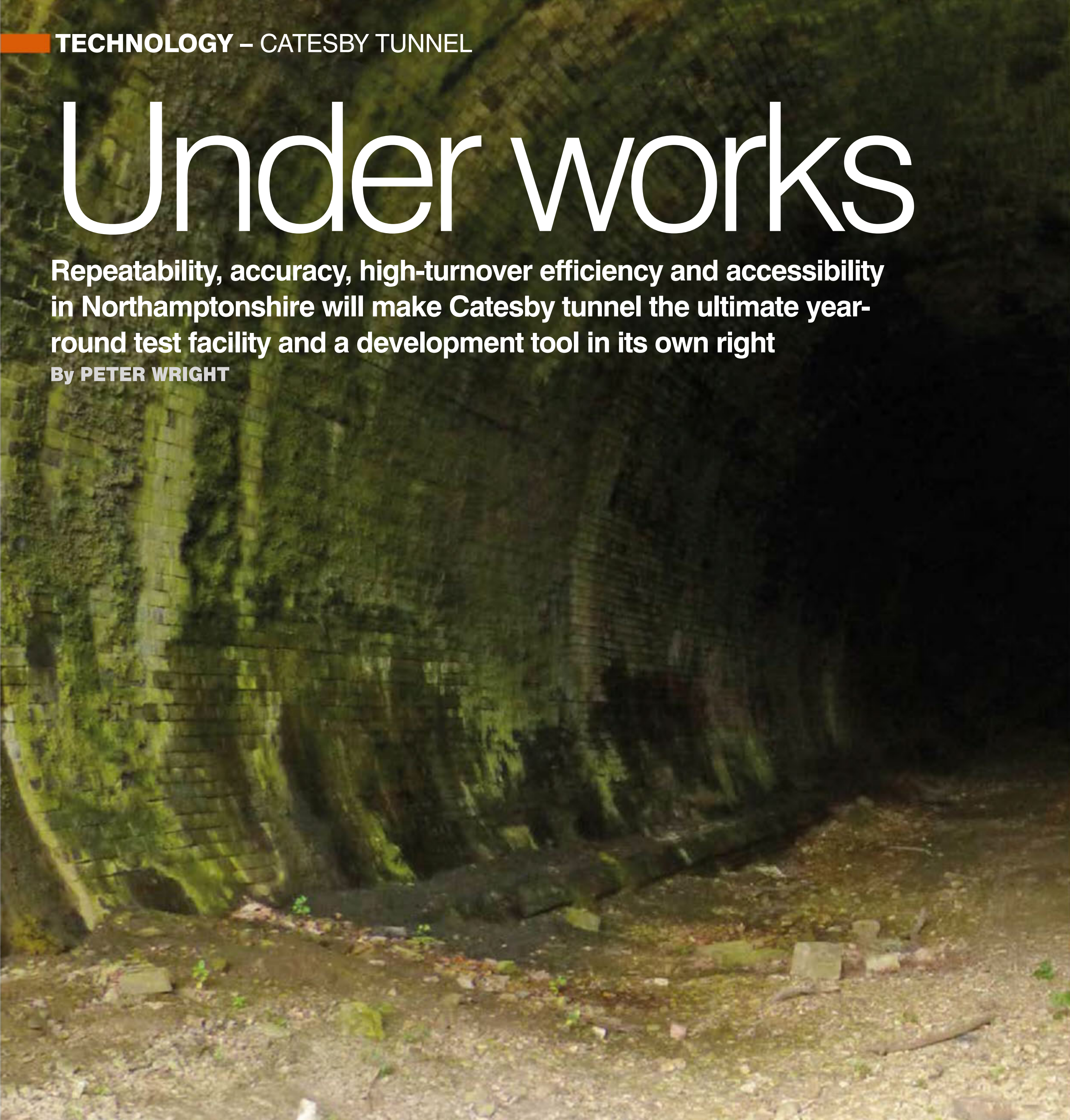


Under works

Repeatability, accuracy, high-turnover efficiency and accessibility in Northamptonshire will make Catesby tunnel the ultimate year-round test facility and a development tool in its own right

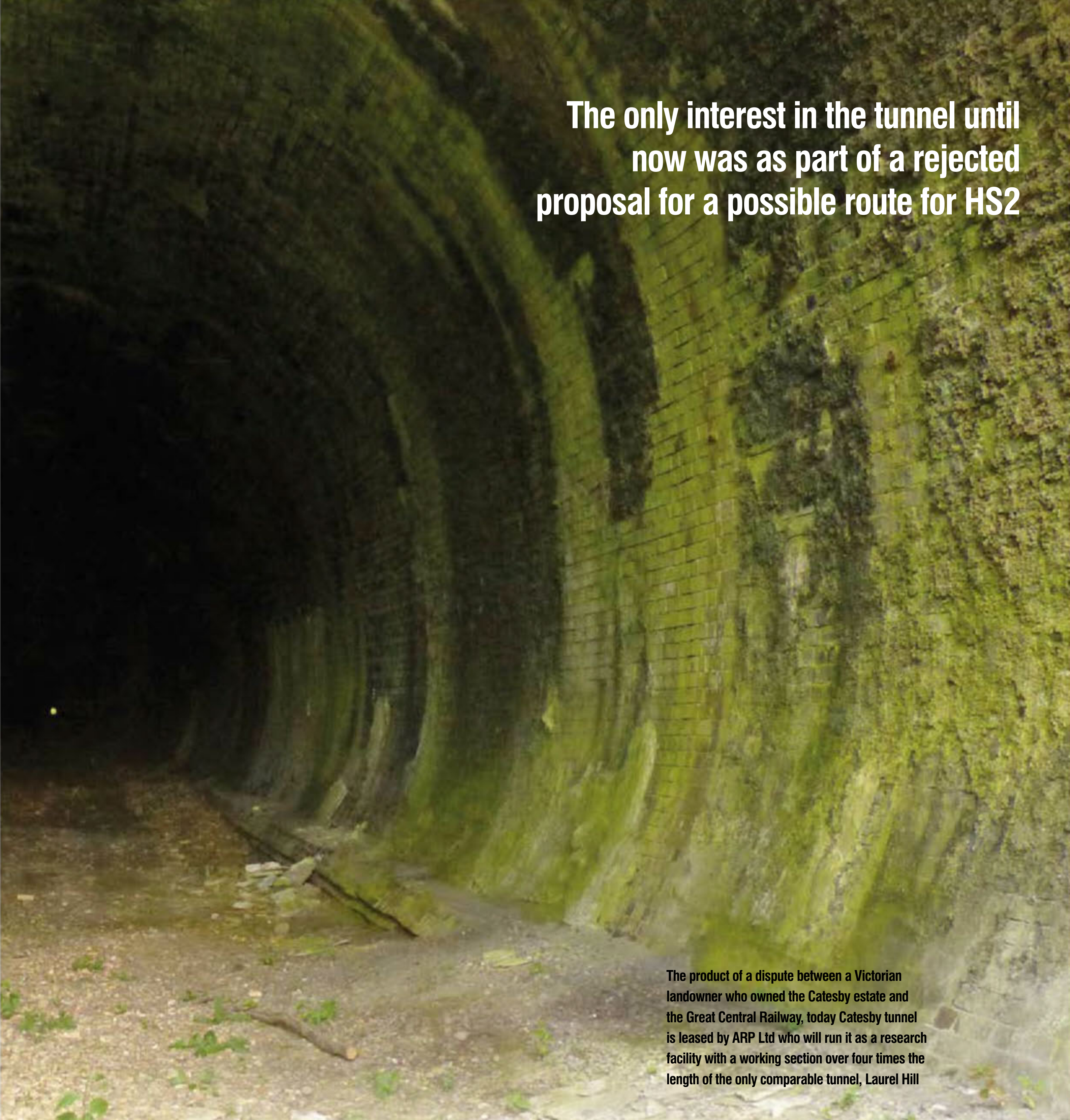
By PETER WRIGHT

The concept of running aerodynamic drag coastdown measurements in the controlled environment of an underground tunnel was first predicted by Paul Van Valkenburgh in *RE V5N3*. However, it wasn't until 2003 that the idea was taken up by Ben Bowlby, of Chip Ganassi's IRL and NASCAR teams. The facility that Ganassi developed in Pennsylvania, USA, is private, secretive, and just about the only information in the public domain is the article by Sam Collins in *RE V17N10*.

Now it has emerged that a 'bigger and better' similar facility is to be built in the Northamptonshire countryside, near the centre of the UK's motorsport industry, and it will be available for the use of Britain's automobile and motorsport industries. The core of the venture is the disused Catesby railway tunnel, acquired along with the nearby station yard by Aero Research Partners (ARP Ltd), namely George Howard-Chappell, who has a largely non-operational role (he is Multimatic Motorsports' business director) and latterly the team principal of Aston Martin Racing, and TotalSim, led by managing director Dr Robert Lewis.

With ever-more-sophisticated CFD complementing scale and full-size moving-road wind tunnel testing, why is there a need for such a tunnel facility? Does not straight-line testing fulfil any shortfall? The answer to the first question, according to Dr Lewis, is that neither CFD nor wind tunnels give the complete picture due to limitations in the simulation; and to the second is, 'no, the control of the environmental conditions is too difficult and leads to misleading results.' With TotalSim at the forefront of CFD development there are few people better placed to appreciate what a closed tunnel can provide. CFD and moving-road wind tunnels are always going to be simulations and, however good, they have their limitations; for example, the moving-road creates its own wind passing under the car. Only a full-size car, running at a representative

The only interest in the tunnel until now was as part of a rejected proposal for a possible route for HS2



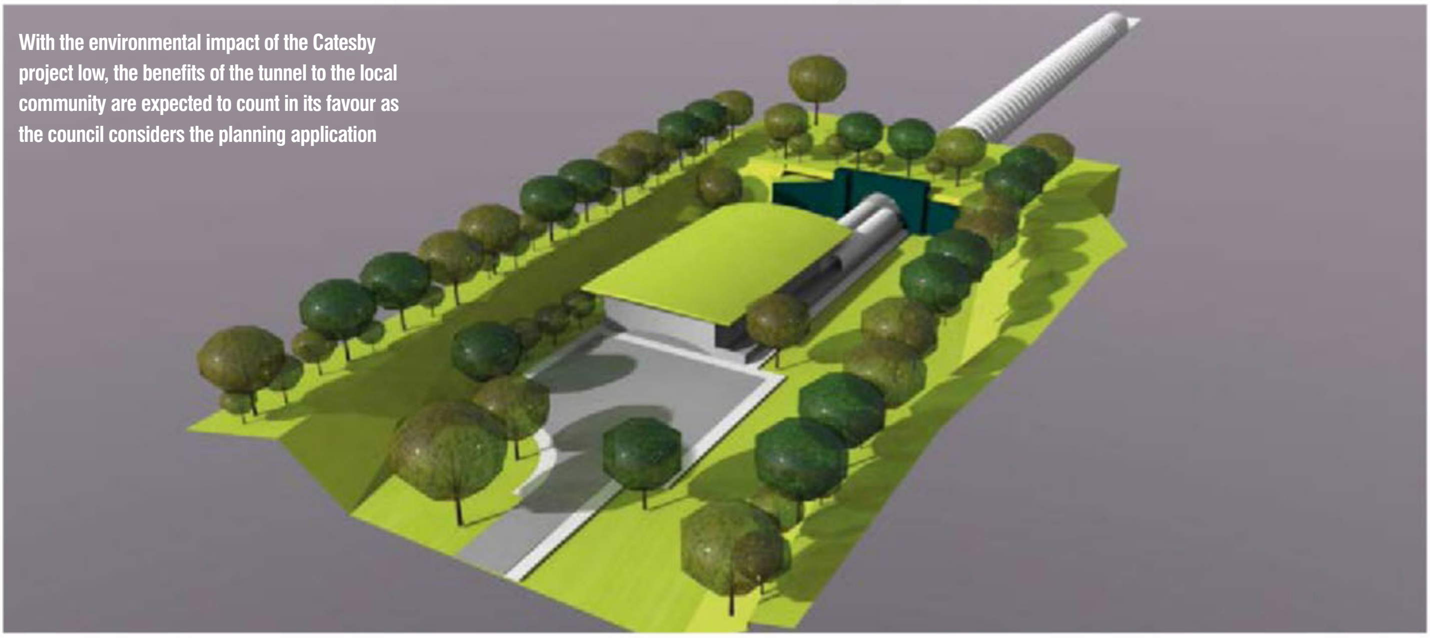
The product of a dispute between a Victorian landowner who owned the Catesby estate and the Great Central Railway, today Catesby tunnel is leased by ARP Ltd who will run it as a research facility with a working section over four times the length of the only comparable tunnel, Laurel Hill

speed on the road complete with cooling and ventilation air flows, exhaust, rotating wheels, leaks around shut lines and gaps, bodywork deformation under aero loads, vibration, and with every detail correct, represents the real car. The problem with running such tests is repeatability.

With motorsport aerodynamic development having reached such a high level that the only way to make significant gains is to assemble a series of one per cent or less increments to create an advantage on the track, and road car manufacturers having to scrape away at their drag coefficients to push down the critical fuel consumption and CO_2 ratings, the need to be able to resolve better than one per cent changes in aero coefficients requires a high degree of repeatability of the test method.

The fact that the 2.7km Catesby tunnel exists at all is down to the intransigence of one man, a certain landowner named Mr Attenborough, who owned the Catesby estate near Daventry, now between the M1 and M40. In 1895, when work started on the Great Central Railway's London extension from Sheffield and Nottingham to London, it was planned that the line should be in a cutting through the estate. Mr Attenborough however did not want 'unsightly trains blotting the landscape', so a tunnel was needed. In a wonderful example of Victorian engineering, this 2740m long by 8.2m wide by 7.8m high tunnel carries two lines and only slopes at a constant rate of 1:176 (0.5 per cent), rising to the south. It involved 220,000 cubic metres of mining, and was lined with Staffordshire brindle, engineering bricks, the whole construction requiring around 30 million bricks in all. It was completed in just over two years and served until Dr Beeching axed the line in 1966 and the tunnel was retired.

It has remained unused since then, but is in remarkably sound condition – testament to the men who designed and built it. The only interest in the tunnel until now was as part of a rejected proposal for a possible route for HS2.



With the environmental impact of the Catesby project low, the benefits of the tunnel to the local community are expected to count in its favour as the council considers the planning application

ARP has acquired the lease on the tunnel and bought the land, including the approach cutting at the southern end of the tunnel and the former station yard. Planning permission is being applied for, to turn the tunnel into a test facility and the station yard into a science park, with space for customers to have offices and workshops to complement the test facility. The local council has given the project its blessing for what it will bring to the county in terms of business and jobs. The environmental impact of the project is extremely low, so prospects for a speedy go-ahead look good. This project must be the largest up-cycling project ever!

The Catesby tunnel facility will offer three major advantages over Ganassi's Laurel Hill facility: it is in Europe; it is destined for public use, not private or exclusive; it will have a working section that is over four times the length, enabling cars to remain under test conditions for over four times as long.

The Laurel Hill tunnel is 1340m in length, with 460m acceleration/deceleration zones at each end, affording a working length of 420m. Catesby is 2740m long, but only requires the same acceleration/deceleration zones resulting in a working test section length of 1820m; it has a cross sectional area of 40m^2: See **Table 1.**

The facility is optimised for two main types of test: coastdown tests to measure drag; and steady-state to measure downforce. Typically for drag measurements, the car is accelerated to 160 or 240km/h and then allowed to coast for 4-500m with ground speed, air speed and acceleration data being collected, along with any other measurements such as surface pressures. For downforce/lift measurements, the vehicle must be fitted with a suspension load measurement system and ideally, a ride-height control system so that a map of downforce versus ride-height can be developed. With over 1800m of test length, a typical test would be to accelerate to 50-60km/h and take zeros, accelerate to the required test speed, measure downforce at a number of right heights, and finally if required, measure drag by coastdown over the last 4-500m.

There will be automated turntables at each end for quick turnaround and return testing. The 1:176 slope must be accommodated in the analysis, as must the approximately 0.5 per cent blockage.

One-minute runs

With a test run taking under one minute, it is certainly possible to run 10-12 tests/hour, or nearly 100 test runs in an eight-hour shift. If a manufacturer wants to calibrate a 10-car sample of a production car, to assess the average and the variation in the drag coefficient, it would be possible to run 10 one-way tests in under 30 minutes.

At the southern end there will be a car preparation area, where the vehicles are prepared and set up for testing, and warmed up on a rolling-road dynamometer so that all rotating parts are stabilised at the desired temperature. Such a high rate of throughput means there is likely to be a build-up of CO_2 and other exhaust gases in the tunnel. The drivers will be supplied with oxygen breathing equipment and, if it is necessary, air conditioning will be installed in the tunnel. Naturally stabilised at around 15degC by being buried underground, it is not always possible to simply purge the air in the tunnel occasionally with ambient air; a sudden drop in the temperature of warm, moist outside air would result in unwelcome rain.

ARP plans a number of special features to be incorporated into the test section of the tunnel:

A horizontal force measuring plate will be built into the road surface in a position(s) suitable for coastdown tests. This will measure the single wheel or axle thrust required to generate the tare torque. If the rolling bearing torque and tyre-rolling resistance are known (brake pads use a push-back mechanism to minimise brake drag) the remaining torque is a rotational aerodynamic resistance for the wheel, tyre and brake. From these measurements, different designs of wheel and brake cooling can be compared. The force plate also lets thrust force for drag be resolved from the tare rotational torque. Because of vehicle deformations and flow separations, drag is not a function of V^2 and allows the drag coefficient versus Reynolds number to be established.

Given sufficient demand, a semi-anechoic section will be built into the test length to enable exterior vehicle noise data to be taken under tightly controlled atmospheric conditions.

A suitable wetted area may provide the means of checking the depositions of rain and road dirt on the car surface, again under controlled conditions.

Manufacturers are beginning to seek transient aerodynamic characteristics to put into vehicle dynamic analysis. While wind tunnel and CFD can generate coefficients under yaw, roll, and front wheel steer angles, the phase lags as the aerodynamic coefficients change are difficult to compute or measure. The test track through the tunnel is sufficiently wide to allow limited transient steer inputs and the change

At the southern end will be a car preparation area, where the vehicles are prepared and warmed up on a rolling-road dynamometer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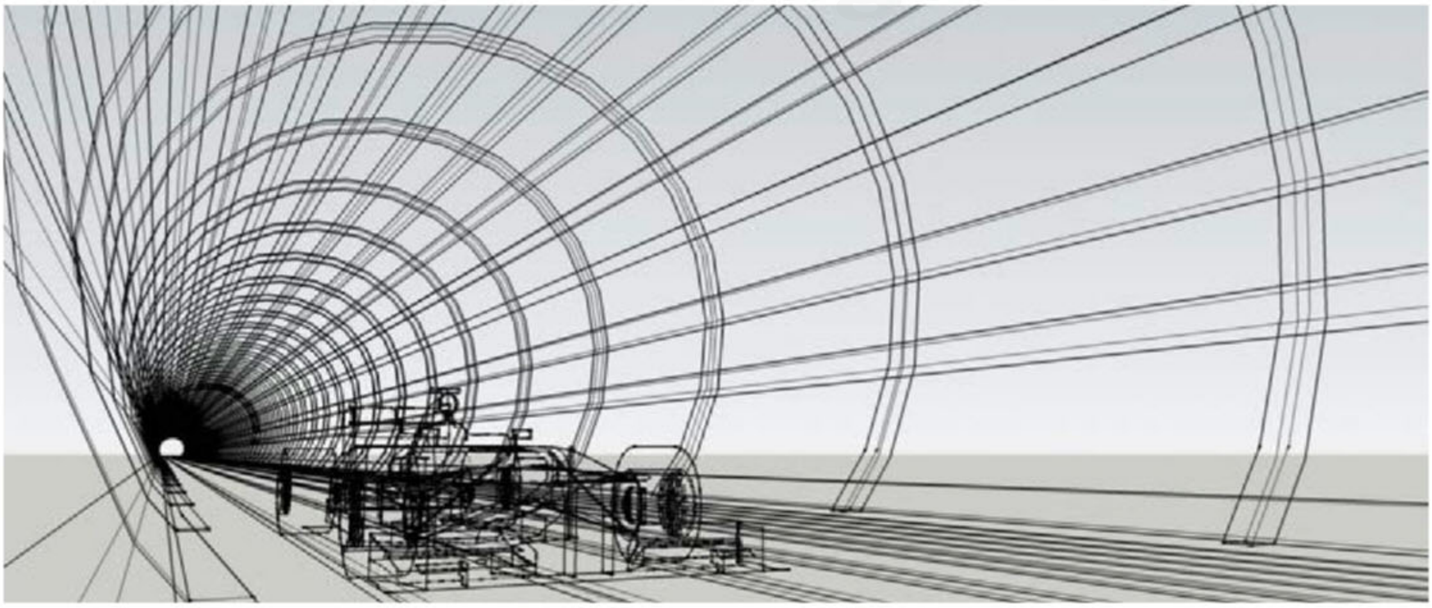
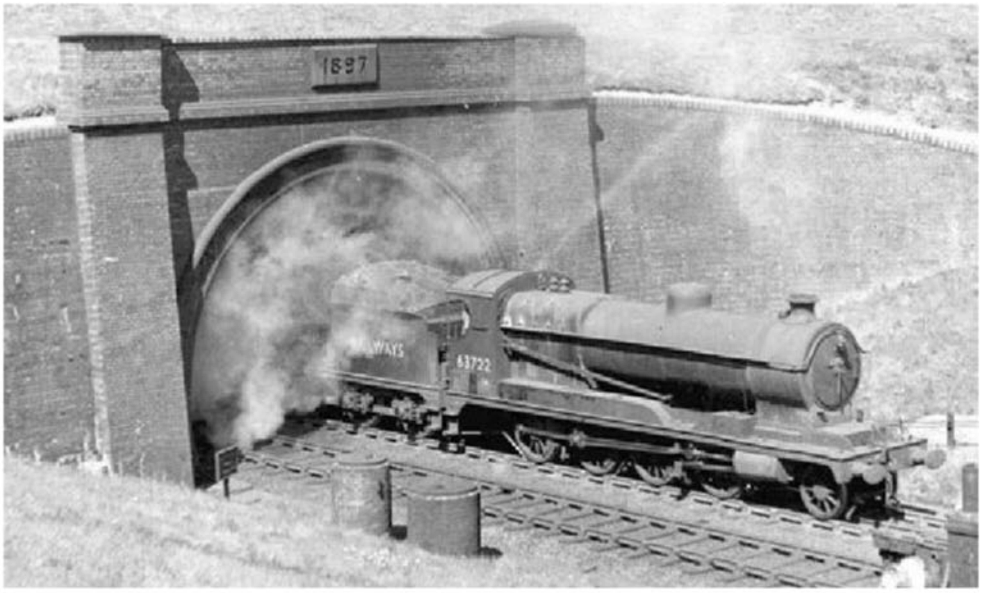


The tunnel is perfect for coast down testing and offers repeatability, protected from variable forces such as wind and temperature



Catesby tunnel was last used in 1966. It was built in 1897 to the highest engineering standards

of aero forces with time to be measured. The width is also sufficient to allow the car to be set up to run down the tunnel in a crabbed attitude to measure the effect of the yaw on the lift and drag forces. It is also just sufficient to allow side-by-side cars for overtaking effects, and for one car to follow another, to assess slipstreaming.

The UK has just one full-size vehicle windtunnel, MIRA, but this lacks a moving ground plane. Full-size aerodynamic tests are carried out on test tracks and disused airfields, with uneven surfaces, variable wind, rain, snow, fog, ice, and in winter, limited daylight hours. Airfields offer little privacy and may be noise limited for race car testing. The Catesby tunnel facility will have none of these limitations, thus providing the UK automobile and motorsport industries with potentially 24/7 use.

The ARP principals predict that take-up will be split one-third motorsport, two-thirds automobile industry, with motorcycle, racing pedal cycles, vans and filming taking a small percentage of the availability. Motorsport is likely to be fairly evenly split between racing car manufacturers and teams running spec cars. F1 may or may not become a major customer, depending on the development of the regulations governing aerodynamic resource utilisation, whereas Prodrive, RML, Wirth Research, M Sport and others are likely to be queueing up. Teams running spec formula cars, from GP2 to F4 and including Formula E, have little chance to build scale wind tunnel models and develop the aerodynamics within the limiting regulations. However, precise knowledge of the characteristics through full-scale testing allows many small, detailed improvements to accumulate into an advantage.

Balance of Performance, as applied to GT racing and to a lesser extent to Touring Cars, requires the regulator to measure the aerodynamic characteristics of the cars as presented. The Catesby tunnel facility will be for making these measurements precisely.

Whole Vehicle Type Approval requires automobile manufacturers (of which there are 35 in the UK, 14 with a significant production output) to measure and publish fuel consumption and CO_2 emission data.

The tests for this (NEDC in the EU) are widely regarded as unrepresentative of today's vehicle use on the road, being based on vehicles that were both lighter and less powerful, and equipped with many fewer power hungry systems such as air-conditioning.

As with any set of technical regulations, there is more than one way to interpret them, and manufacturers' engineers have become adept at gleaning the best possible figures, both to gain a marketing advantage and to minimise fines for exceeding fleet-wide CO_2 emission averages.

Hybrid systems offer a big opportunity to bring both fuel consumption and CO_2 figures way down when tested to this protocol, and

Too good to be true?

There is an obvious appeal of testing in an enclosed tunnel. The repeatability, accuracy and year round availability make it an ideal method of validation/bench marking to compliment the other aerodynamic tools. The lack of noise and level of realism are a step above the alternatives.

In reality, it quickly becomes apparent that it is also a very effective development tool in its own right. The turnaround can be very quick and range of tests that can be made (often incorporated in the same run) means that productivity is very high.

So, accurate, repeatable, efficient, high confidence level and available '365' days a year... sounds too good to be true, but that's our experience.

David Lapworth – technical director, Prodrive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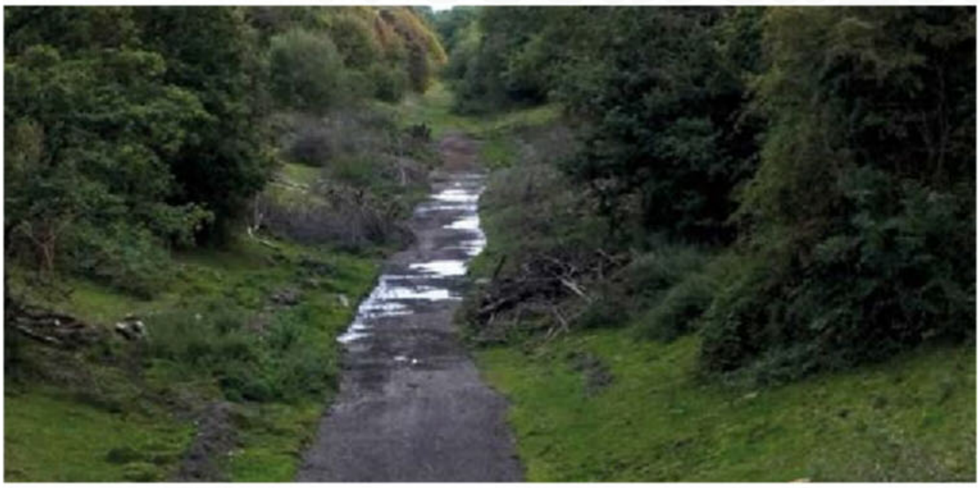


The Great Central line cuts through the countryside and will provide access to the facility

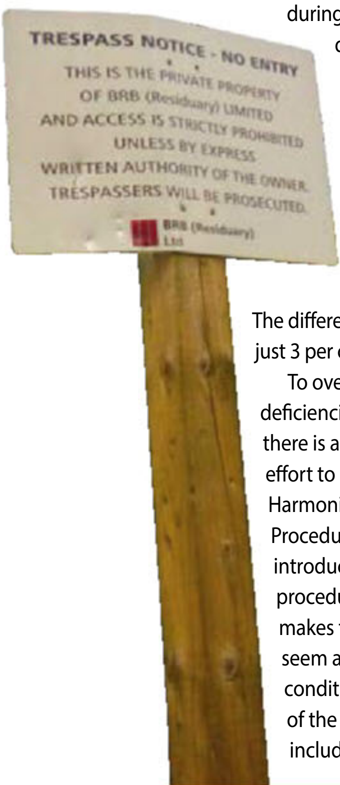
A Victorian aeration shaft on rising ground is the only clue to the hi-tech preparations going on below

the published numbers for some large SUVs and GT cars are quite impressive, given the size of their engines.

Discrepancies

Just how desperate manufacturers are to get good figures to use in marketing material became apparent in 2012 when US body the EPA found 'discrepancies between their measurements and the company's results' for Hyundai and Kia models for sale in the US.

These were apparently caused by 'procedural errors' in the way road load was measured. Road load includes drag and is put into the test protocol as a look-up table for the schedule of rolling road dynamometer load during the test sequence. The discrepancies resulted in Hyundai and Kia having to offer compensation to the customers who had bought the affected models for the cost of increased on-road fuel consumption compared to the advertised figures. The differences amounted to around just 3 per cent.



To overcome some of these deficiencies in the test protocol, there is an ongoing international effort to develop a World Harmonised Light Vehicle Test Procedure (WLTP) for planned introduction in 2015. The draft procedure runs to 234 pages and makes the WEC's EoT regulations seem almost elementary. The conditions for the derivation of the road load versus speed, including drag, are that the highest power variant of a model range must be measured by coastdown testing on a track, and the figures for variants derived from comparative windtunnel tests. Conditions for coastdown testing are:

The heritage of the railway tunnel at Catesby – and the condition of the facility as a 21st-century test facility, is testament to the engineers and men who built it over a century ago but also to the specialised outlook of the UK motorsport industry

Wind:	**<5m/s**
Temperature:	**278-313ºK (5-40ºC)**
Slope:	**<1%**
Wheels:	**highest drag/power consumption option**

The better a manufacturer knows its products and the contribution of all parts of a fully functioning car to the overall drag figure, the better able it will be to fine tune it for minimum drag, fuel consumption, and CO_2 emissions.

It is all too easy to attribute small changes in drag to changes in the ambient wind or even temperature. Too often such changes are a piece of sealing tape coming loose or small differences in vehicle set-up. Closed tunnel testing keeps engineers very honest. The example I like best is when a manufacturer tested its racing version of a road car in the Ganassi facility, attempting to establish the drag contribution of the protruding bonnet badge. Filling in the locating recess for the badge and replacing the enamailed badge with a sticker, they discovered a 0.7 per cent increase in drag. Not possible! Repeat tests gave exactly the same result and there followed a 'badge height-sensitivity' test session.

ARP's plan is to complete the Planning Consent process to develop the station yard site and restore and convert the tunnel. It expects the facility to be ready in 12-24 months from go-ahead, at a cost of £5-10m, depending on the finished level of development on opening. Funding could come from government grants and/or loans, investors, and advance commitments by customers. Compared to a full-size rolling-road wind tunnel, the cost is less then 10 per cent, which is probably why the UK does not have such a wind tunnel facility. Running costs are also significantly lower than a 14MW full-size tunnel, only requiring significant power while the car is running, which is of course supplied by the customer. Where a single case of CFD for a complete car costs of the order of £150, ARP believes it will be able to keep the cost of an eight-hour session to under £10,000, equivalent to around £100/run for an efficiently planned and executed test session. On a single shift, five-day week, the turnover would be almost £2.5m/year. If demand meets expectations, 24/7 use would be available, giving an excellent potential return on a quite limited investment.

The idea that this 3km long Victorian instrument can measure so precisely something as complex as the aerodynamic drag of a car really excites my imagination. If the UK automobile and motorsport industries are to maintain their specialised positions in an ever more competitive world market, tunnel vision of this magnitude is sorely needed.

TABLE 1: Catesby and Laurel Hill: a comparison

	Working length (m)	Time at 160kph (secs)	Time at 240kph (secs)
Laurel Hill	420	9.5	6.3
Catesby	1820	41.0	27.3

Straight-line aerodynamic testing in an enclosed tunnel: the benefits

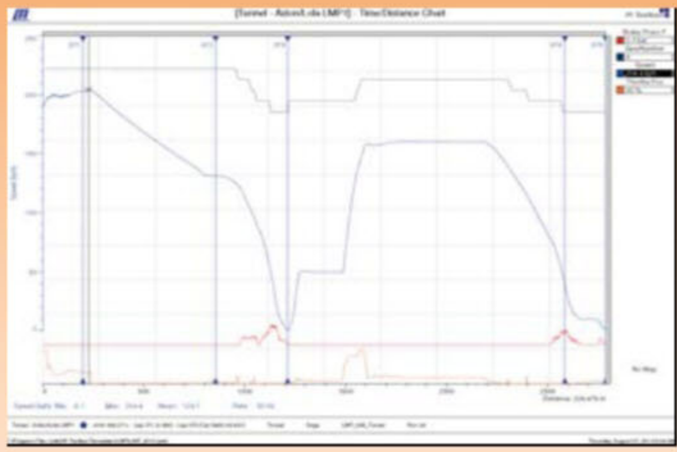
Prodrive has been carrying out straight-line aerodynamic testing since the 1990s. These tests have been done to measure downforce and drag on a variety of competition cars over the years. Clearly the aerodynamic characteristics of a competition car have a significant impact on the competitiveness of the vehicle. Traditionally the Prodrive data analysis group had been frustrated by trying to carry out these tests outside, due to varying weather conditions.

In 2006 a revelation took place when the team tested an Aston Martin DBR9 racing car in an enclosed tunnel for the first time. This immediately removed a number of variables and produced very accurate results – which in turn led to a much more competitive racing car (including two victories in the GT1 class at the Le Mans 24h).

Test method: Traditional straight-line test methods consist of driving an instrumented vehicle on a smooth track and measuring the downforce, or lift, and the drag. The downforce is normally measured by driving the car very slowly at a constant speed and taking a 'dynamic zero' reading from the load cells and/or potentiometers; followed by a reading at high speed (typically 100 or 150mph) averaged over several seconds. The drag is measured by accelerating the car to high speed (typically over 130mph) and then disengaging the gearbox/engine and measuring the coast down characteristics of the vehicle.

Quality of results vs outdoor testing: An enclosed test facility has the following advantages over traditional proving grounds or airfield venues:

1. No wind variations
2. Constant temperature
3. Perfectly dry roadway
4. Road texture perfect and, crucially, the same for every test
5. Real L/D measured
6. Blockage can be modelled extremely accurately



Example of data obtained (courtesy of Prodrive)

Advantages over traditional full and scale model wind tunnel testing:

1. Hot car
2. Real life shimmy and vibrations
3. Exhaust flow
4. Correct contact patch shape
5. Boundary layer correct
6. No sting effect c/w wind tunnel
7. Hot radiators.

Aero Test (tunnel) - Aston/Lola LMP1 - March 16th 2009

Run	Run Description / Vehicle Configuration	Vehicle Mass	Corrected Aero Forces At 160 kph (Delta) Front	Rear	Total	% Front	Drag	Front CzA	Rear CzA	Total CzA	Total CdA	Total L/D	Power Req'd
23	Run 34 - Rear Ride Height - 11.7mm from Ref.	1044.2	0.0	0.0	0.0	0.0	0.0	1.207	2.534	3.741	1.268	2.949	98.9
24	Run 35 - Rpt	1043.6	-5.3	17.0	11.7	-0.2	17.2	1.211	2.520	3.731	1.254	2.975	97.9
25	Run 36 - Rpt	1042.5	13.7	13.3	27.0	0.1	10.5	1.196	2.523	3.719	1.260	2.952	98.3
	Repeatability							0.94%	0.55%	0.60%	1.12%	0.86%	
		(kg)	(N)	(N)	(N)	(%)	(N)						(HP)

Ref. Air Temperature	15	(°C)
Ref. Air Pressure	1013.3	(mBar)
Ref. Relative Air Humidity	0	(%)
Ref. Air Density	1.2248	(kg/m3)

Reference Speed	160	(Km/h)
Ref. Dynamic Pressure	1209.7	(Pa)

Rolling Resistance	125	(N)

Aston Martin Lola B09/60 at Le Mans

Aerodynamic test tunnels: from dream to reality

What is thought to be the world's first fully enclosed coastdown or steady state aerodynamic test facility opened in 2004, and is the inspiration for the project at Catesby. Ben Bowlby, the innovative English engineer, had read Van Valkenburgh's article in the mid-1990s about the ultimate aerodynamic test facility and was inspired to attempt to construct one. The tunnel works in the opposite way to a conventional wind tunnel where air is forced around a static car. Instead, at Laurel Hill, a real full-size car is driven through the tunnel at aset speed and forces are measured.

The car is rolled into the tunnel from the workshop area through the main door, which is then sealed behind it. A systems check is performed on the logging electronics. When the green light is given, the driver accelerates up to the desired speed and then maintains it as the test section in entered, then starts to coast or run at a fixed speed.

As the car passes the first beacon, the logger picks it up. Then, in a similar fashion to a car finishing a lap, the second beacon is at the end of the test section. The driver then slows the car to a stop or to walking pace and the car is turned through 180 degrees on a turntable. Multi-car tests to simulate drafting and running side-by-side are possible in the tunnel.

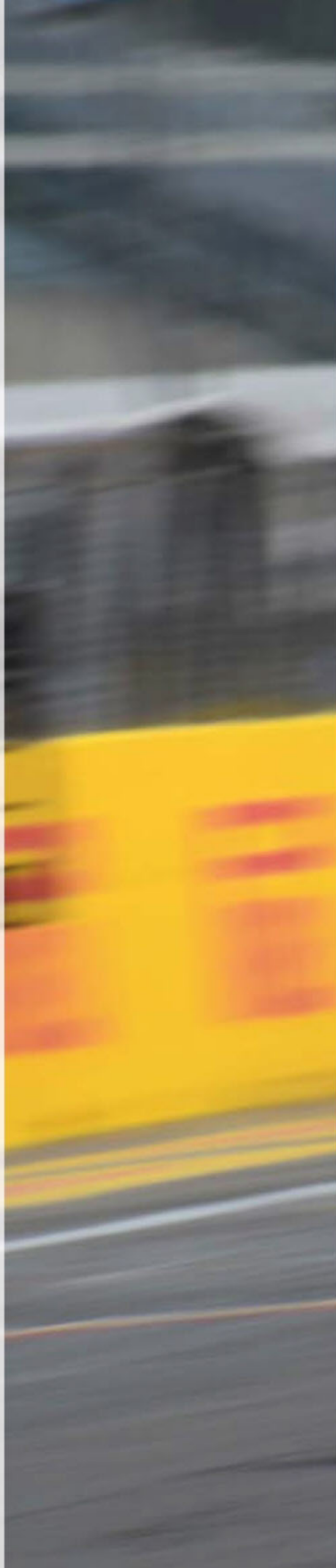
Even though the tunnel may not be perfectly sealed at each end, the centre section should always provide perfect conditions, to the point that testing is still possible even when one end is completely open. However, for extra atmospheric control Ganassi employs a double door at each end, rather like an airlock, so the car or personnel can enter the complex without exposing the interior to the external environment. When the car is running the roller doors at each end of the tunnel are opened half-way and the opening is covered with a clear film, allowing an out-of-control test car to exit the tunnel into the emergency run offs.

The data acquisition system used on the car is largely conventional, and the documentation shows that it is based on the proven Sigma system from Pi Research, though CGR and Pi declined to comment. Logging is carried out at both 500Hz and 1000Hz.

The tunnel now serves as Ganassi's primary aerodynamic tool for all of its projects, but by and large its use is restricted to those projects and it is not made commercially available.

When noisy data gets literal

Ferrari's new 'joker card' gear ratio was sensationally rumbled at the 2014 Italian Grand Prix – all thanks to acoustic analysis honed by a Cranfield University student



At the 2014 Italian Grand Prix Ferrari played its so-called joker card and changed the gear ratios in its cars. A new rule introduced at the start of the season forces all the teams to declare which eight gear ratios they will use all season, and they have to stick to them bar a single in-season change, the joker. Which ratios the teams use is a closely-guarded secret.

So it is not surprising, then, that there was consternation in the press room that within minutes of the Italian team's cars taking to the track with the new ratios fitted, a NBC Sports producer had the exact gear ratio data in his hands – in fact so did almost every other team on the grid.

The data in the television producer's hands had been supplied by one of Ferrari's rivals which had used acoustic analysis software to find out what the new ratios were. This is nothing new, acoustic analysis has been commonplace in Formula 1 for years and has been especially useful in 2014 with the introduction of three very different new power units. But until now the techniques and data have been the preserve of the engineering offices of grand prix teams.

A Cranfield University student, **Suyash Thorat-Gadgil**, has changed all of that. Using footage via YouTube he has developed his own acoustic analysis tool, which could be made available to anyone. The following article is based on his 2014 thesis.

Cranfield calling

The 2014 F1 rules restrict the fuel consumption of the conventional internal combustion engine part of the power unit, while doubling the capacity of energy recovery systems at the same time.

Hybrid powertrains are also becoming more common in other series such as the WEC. With more emphasis on hybridisation, the operation of the power units are becoming more and more complex. The limit on fuel consumption has forced the teams to run them at a lower rpm than the maximum allowed. This leads to a broad variety of different energy strategies employed by different teams and even different drivers. It also means that those energy strategies are likely to change during the race. This all highlights the need to develop a method to gain information about competitors' energy strategies in real time.

Before going into methods of analysing acoustic emissions from the engine, it is important to understand the different sources of noise within it.

Many researchers over the years have studied the engine sound-generating sources to minimise or characterise a particular engine sound. This can be summarised in **Figure 1** (see overleaf).

The engine noise can be categorised into two broad categories, structure-borne sound and air-borne sound. Structure-borne sound is the sound generated because of metal-to-metal contact, or combustion process, which then transmits through the body of the engine. On the other hand, air-borne noise is transmitted in the air flow passages in and out of the engine. Sound generated by intake and exhaust systems comes under this category. Air-borne noise is affected by the length of intake and exhaust systems and type of silencer (if any) installed.

The sound generated by an internal combustion engine is an amalgam of several noises. When the charge inside the cylinder is ignited, the charge burns in an explosive manner with a bang. This bang is propagated through the walls of the cylinder to the block and cylinder head. Other sources of sound are piston slap, valve train contacts and sounds from bearings. However, the loudest sound which we hear from outside the car is generated when the exhaust valve opens and expels the high-pressure gases from the cylinder. This sound passes through the exhaust system to the environment. As the exhaust valves are operated by camshafts which are in turn operated by the crankshaft, the duration between two valve openings is directly related to the crankshaft rotational speed. In other words, the sound coming out of the exhaust has a direct relationship with the rotational speed at which the engine is running, and while this seems obvious, what may be less obvious is that it also allows you to calculate the exact engine rpm.

The first step in obtaining the rpm is to perform a frequency analysis of the sound signal. As the sound

The data in the television producer’s hands had been supplied by one of Ferrari’s rivals, which had used acoustic analysis software

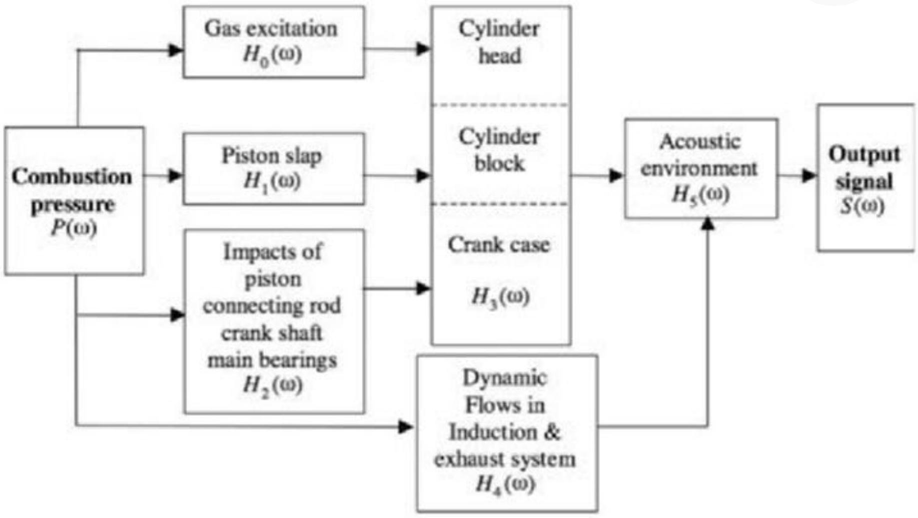


Figure 1: Engine sound-generating sources studied by researchers over the years

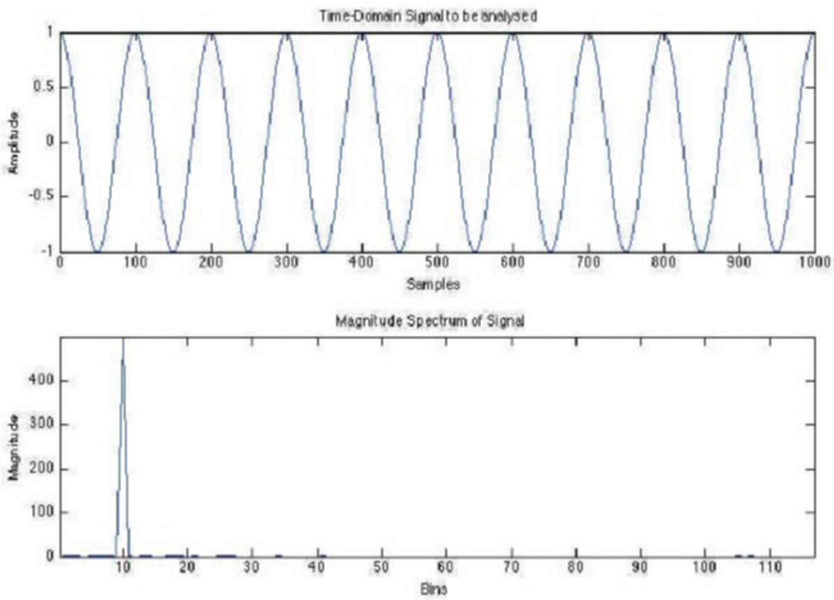


Figure 2: Frequency spectrums and sin waves of engine acoustics

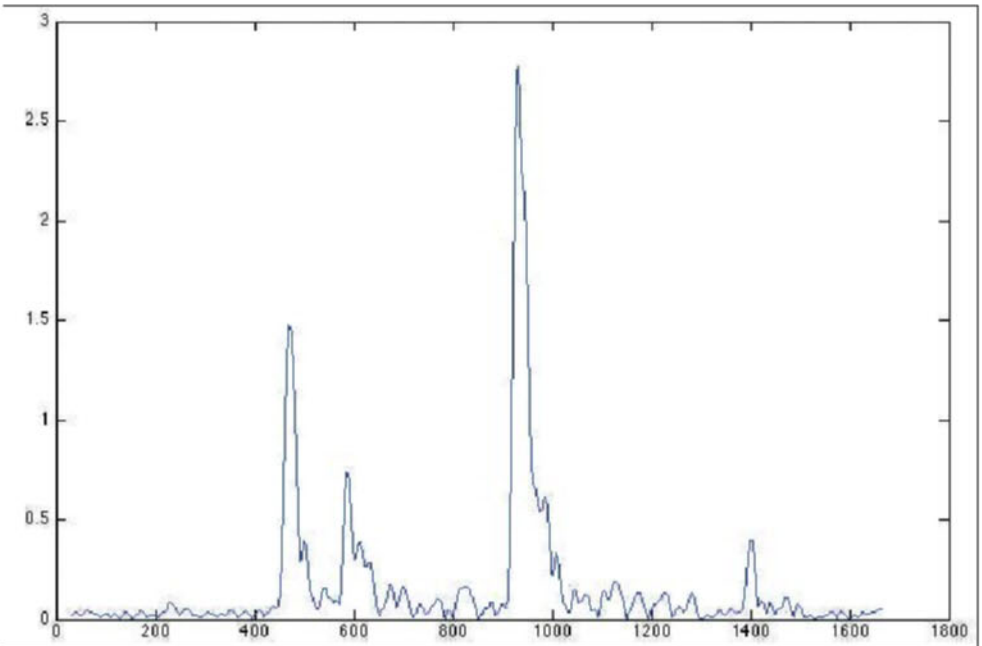


Figure 3: The frequency spectrum of one of the 0.1 second frames, the strongest peak relates to the exhaust valve opening

signal is recorded in a digital format at a specific sampling frequency, discrete time signal analysis processes have to be used. The most common method of analysing the frequency content of a signal is the Fourier transform.

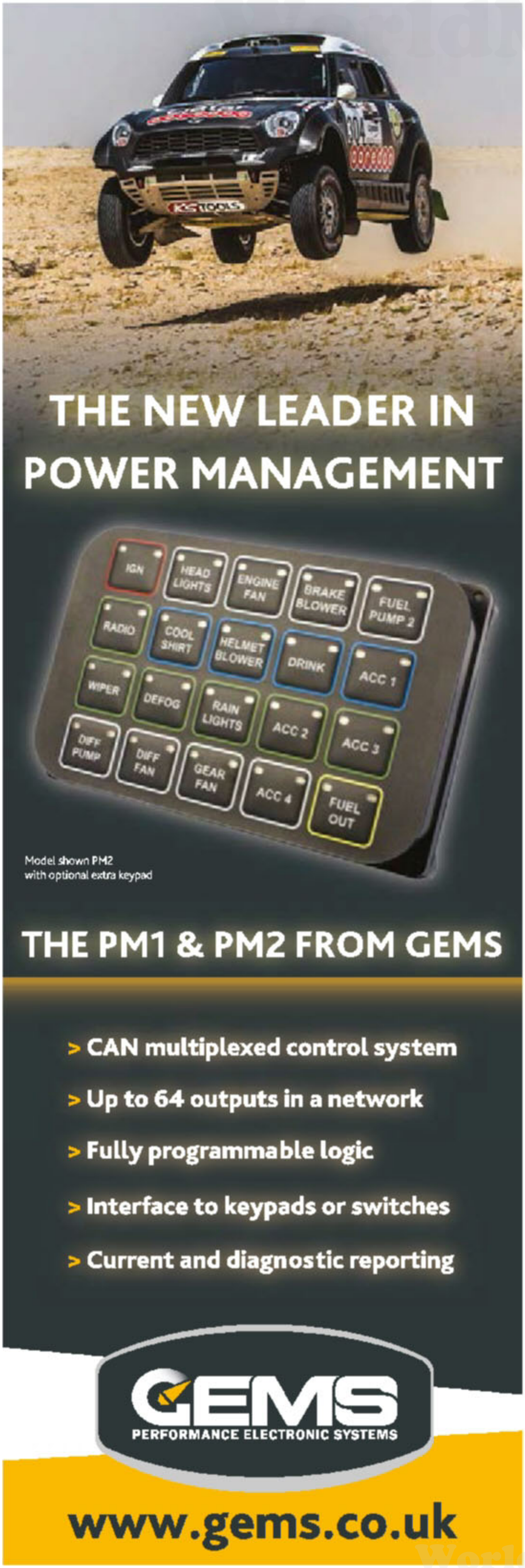
The Fourier transform is used to transform a signal from the time domain to frequency domain. When it is applied to a discrete time signal it is called the Discrete Time Fourier Transform (DTFT). Discrete Fourier transform is described by **Equation 1.**

$$F(j\omega) = \sum_{k=0}^{N-1} f[k]\, e^{-j\omega kT}$$

Where k represents the sample number, N is the total number of samples, and ω is the frequency, or bin number. The representation of a signal in frequency domain, graphs all the frequencies present in the signal and is known as 'frequency spectrum'. Details of the signal-like frequencies, amplitude and phase angles can be calculated from the frequency spectrum of that signal. To illustrate the concept **Figure 2** shows a simple sinusoidal signal with constant frequency in time domain and the corresponding frequency spectrum of the signal. The x-axis for the time domain signal shows number of samples and for frequency domain shows number of 'bins'. When multiplied with sampling frequency the unit of x-axis is converted from number of samples to time. In **Figure 2** the sin wave has 10 lobes, so the frequency spectrum shows high value at bin number 10. When x-axis in the time domain is time in *seconds*, x-axis in the frequency domain represents frequency in *Hertz*. The absolute magnitude of the frequency spectrum is plotted on the y-axis of the frequency domain plot, describing the relative amplitude of each component of the original signal.

The discrete Fourier transform requires a finite batch of time series samples to process together to identify frequency components. To track frequencies over time the signal is divided into a series of 'frames' on which Fourier transform can be applied individually. This particular adaptation of Fourier transform is known as Short Time Fourier Transform (STFT). For this to work, the best compromise between rapid updates and good frequency resolution was found by using by using a frame width of 0.1s – the exact number of samples varying with the sampling rate of the original video clip from which the sound is taken. To improve frequency resolution, and the detail which could be achieved in calculating rpm, further techniques such as zero-padding the signal and using a window function were found to be very useful.

Figure 3 shows the frequency spectrum of one of the 0.1 second frames used in the analysis. The frequency spectrum shows several peaks which correspond to the engine cycle frequencies. The highest peak in the spectrum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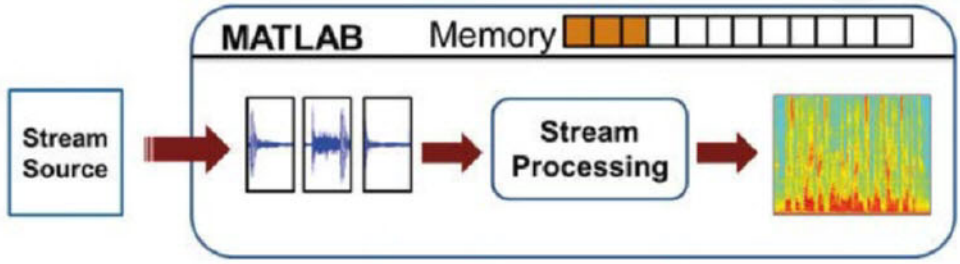


Figure 4: Matlab stream processing. *Image courtesy: MathWorks Inc.*

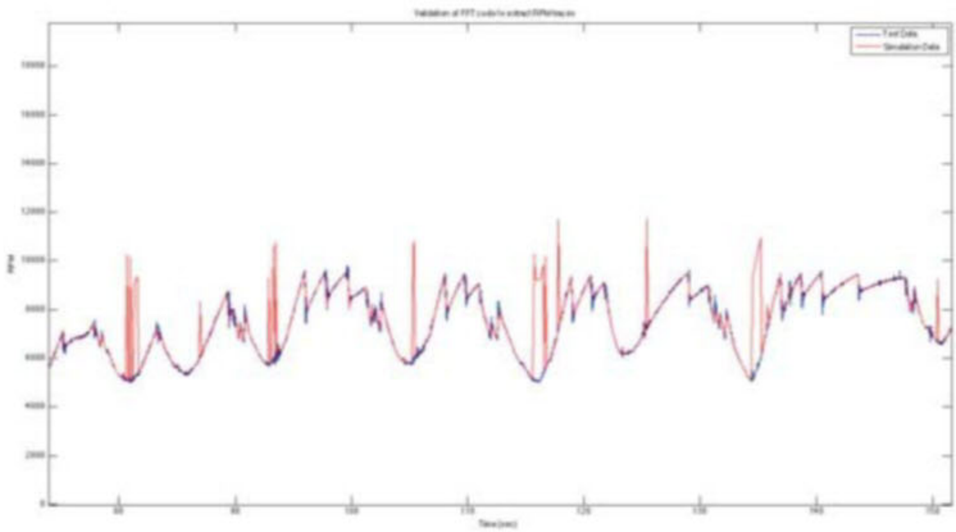


Figure 5: Validation

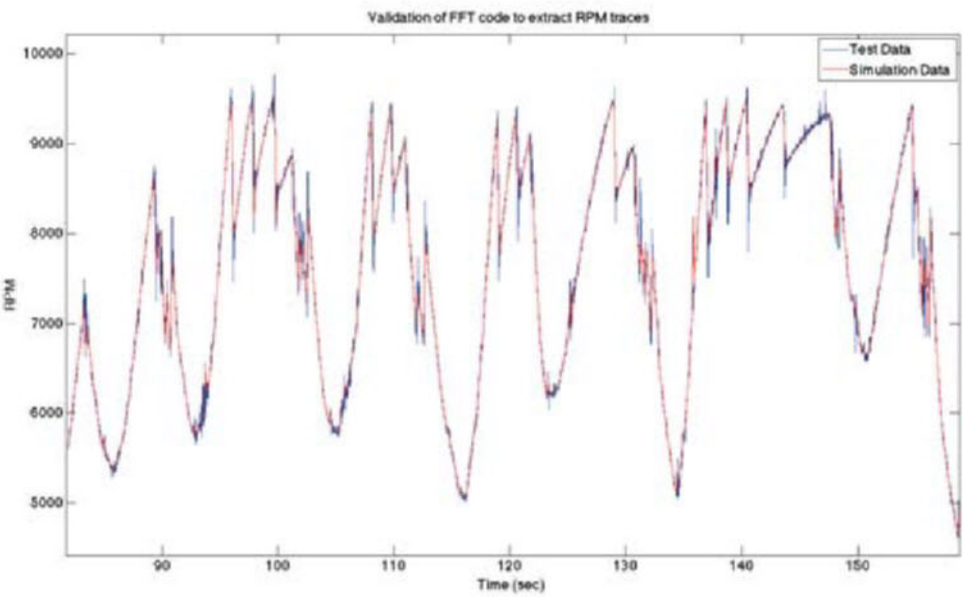


Figure 6: Extracting rpm traces

The time scope may have its own buffer to allow continuous display of the results, even in case of a delay in processing

represents the strongest source – in this case the exhaust valve opening frequency.

Calculation of rpm from frequency

As described earlier, the frequency of the engine sound is directly related to its rotational speed. The Equation below shows the relationship between engine rpm and engine cycle frequency for a four-stroke engine.

$$f_{cycle} = \frac{RPM}{2\times 60}$$

And the cycle frequency fcycle relates to the combustion frequency by the relation given in the following equation:

$$f_{combustion} = f_{cycle}\times N_{cyl}$$

fcombustion can be found from the dominant peak in the spectrum.

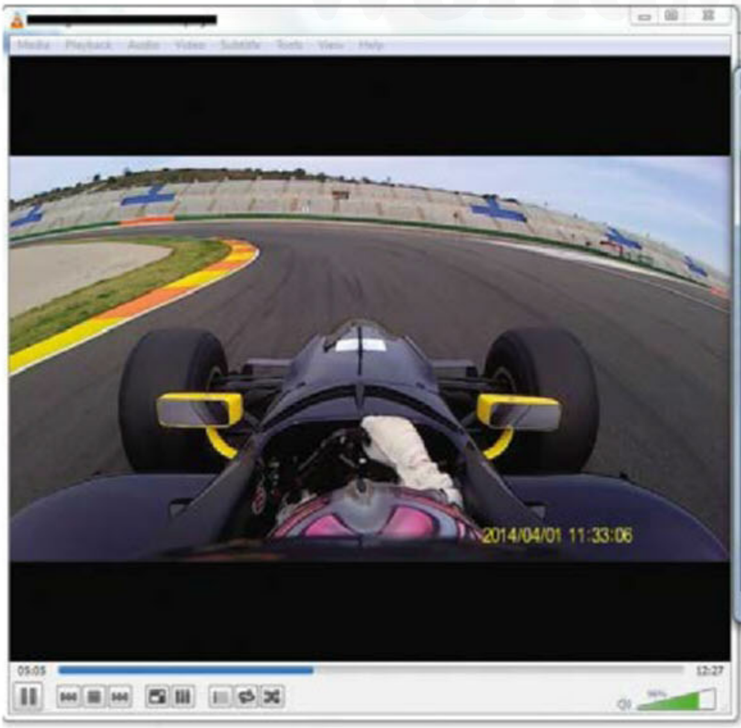
It is possible that, while analysing many frames, some frames might actually have a dominant frequency component other than the combustion frequency – other components with a higher amplitude at that point in time, literally noisy data! This may happen during the transient engine operation or an external noise factor – and may be complicated by the signal chain of listener, microphone and digital storage technique which often includes compression and frequency shaping functions. This is a major issue as it is critical to segregate the harmonic at half the combustion frequency from other harmonics which may be dominant at certain times. To make the rpm calculation accurate and reliable, this issue was addressed, and a model was developed with distinct capabilities of distinguishing and eliminating the undesirable harmonics.

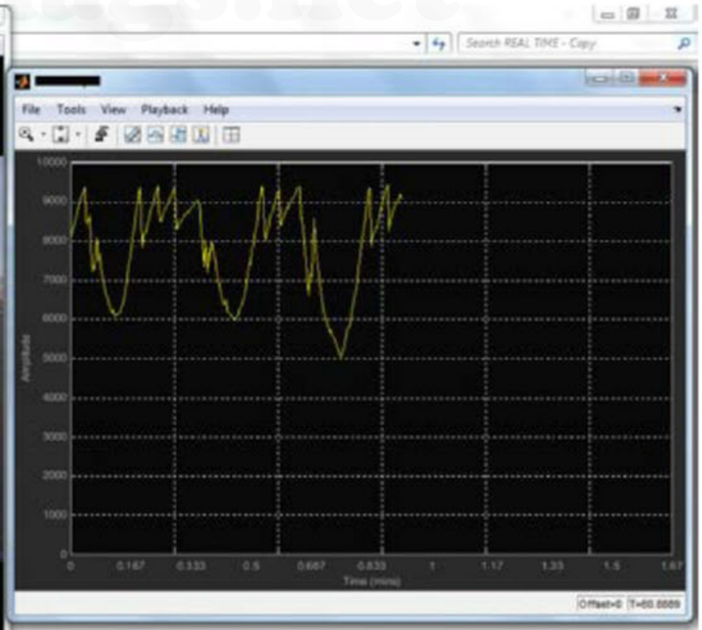
Once the mathematical elements of the concept had been calculated, real world testing was required to prove that it actually worked. Using MATLAB, it is possible to do data acquisition, analysis and post processing in the same environment. For the early tests the audio from on-board camera videos found on the internet was recorded by the laptop's internal microphone. The digitised data was saved in MATLAB to be used in the programme.

It should be noted that the prototype which has been developed is not exactly real time but *'quasi'* real time. A small delay is present due to the framing process and buffering. Even if applied live at the track the delay is not significant in practical terms.

Stream processing in MATLAB

Figure 4 shows the steps involved in stream processing in MATLAB. The data acquired from the laptop's built-in microphone was fed directly into the streaming programme. The programme breaks the incoming audio signal into frames of





Onboard video from the Auto GP series and the relevant rpm data was used in the research, the image above shows the tool out putting data in real time

pre-defined length. In the next step, a specified number of frames are saved in a buffer space where they wait until the processing of the earlier frame finishes. The processing is done on one frame at a time and the results are displayed on a continuous basis using a time scope. The time scope may have its own buffer to allow continuous display of the results even in case of a delay in processing.

Even with the availability of buffers, for continuous streaming the programme has to be efficient to keep up with the incoming data.

This test gave a clear result and, based on observations such as maximum rpm, number of gear changes and visual verification using the video, it was clear that the output was plausible.

It was thought, however, that the rpm obtained by this method should be compared with real world logged rpm data from a real car on a real track. A partnership was struck with the Super Nova team contesting the Auto GP championship with a Lola-Gibson (nee Zytek).

The team provided onboard video and the relevant rpm data for the same lap in order to compare the results of the method applied on on-board footage with the rpm sensor data.

Initially the acoustic analysis code was designed to detect the most dominant frequency in the frequency spectrum. This created a few errors in the results owing to intermittent domination of other frequency components. During events such as engine acceleration, it was observed that frequency components other than the combustion frequency component were becoming dominant. This was reflected in the results with overshoots of the rpm values in the event of engine acceleration, which can be seen in **Figure 5** where the red line is the rpm obtained from the method and blue line is the logged rpm.

The code was suitably optimised with a solution to prevent from detecting a wrong frequency harmonics. **Figure 6** shows the comparison of results between the logged rpm and the rpm obtained from acoustic emission method over approximately one lap.

As can be seen on the plot, the method reproduces rpm with a good correlation to the actual rpm. It was also observed that the actual rpm at the shifting point is slightly different than that of reproduced rpm. This is because the frequency of rpm logger is 100Hz whereas the rpm data produced from acoustic analysis only gives signal at 10Hz.

In a dynamic event like gear shift the logged rpm tends to pick up even small overshoots in the rpm which acoustic analysis is unable to detect. But this creates a little impact on the interpretation of the user as the pattern and top speeds are nearly equal.

Through this approach it was shown that a workable competitor analysis tool had been developed. The tool was shown to be successfully able to reproduce the competitor car's rpm in real time. Comparison of the rpm obtained from acoustic analysis with the logged rpm shows a very good correlation. Also, the feature of the programme to create rpm data points at 10hz allows the reproduced data to be directly overlaid with any logged rpm data.

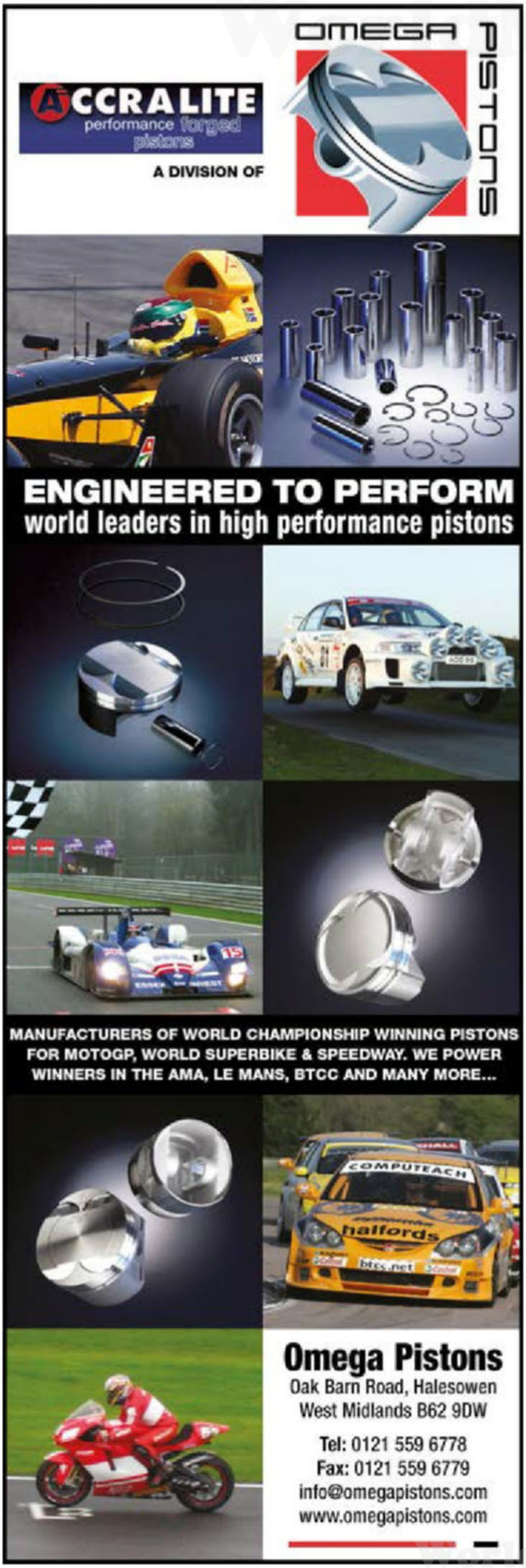
A variety of information about driver and car performance can be determined by directly overlaying the competitor's rpm with that of logged rpm. The real time performance of the programme was found to be satisfactory with only 0.2 seconds latency and nine frames lost per 100 frames, which has no significant effect on the results. In the data tested so far, the method seems robust against noise from other cars, both passing and being passed.

With a fully automated process, this method has proved to be capable of obtaining rpm traces in real time with a simple click of a button. When applied more widely, current limitations are with highly transient events such as pit-lane limiter operation where the rpm changes in small amounts at a very high frequency thus creating a jittery sound.

But these events would not prevent the software from mapping a competitor's rpm data from the relevant onboard footage which the tool requires. Notably in many major series including the NASCAR Sprint Cup, WEC, GP2 and Formula 1, either the series or teams have publically available live onboard feeds of the cars on track online. Using these openly available sources, standard data analysis software (Toolbox, Interpreter) and the acoustic analysis tool described here, it is possible to not only map the car's rpm data, but also its gear ratios and possibly even its energy recovery and fuel usage strategies. This is exactly what the F1 teams do using the FOM onboard camera feeds.

During engine acceleration, other frequency components were becoming dominant

Cranfield University is engaged in the process of commercialising the technology.
For further information, please contact motorsport@cranfield.ac.uk
This article is an edited and reformatted version of the thesis the author completed while at Cranfield University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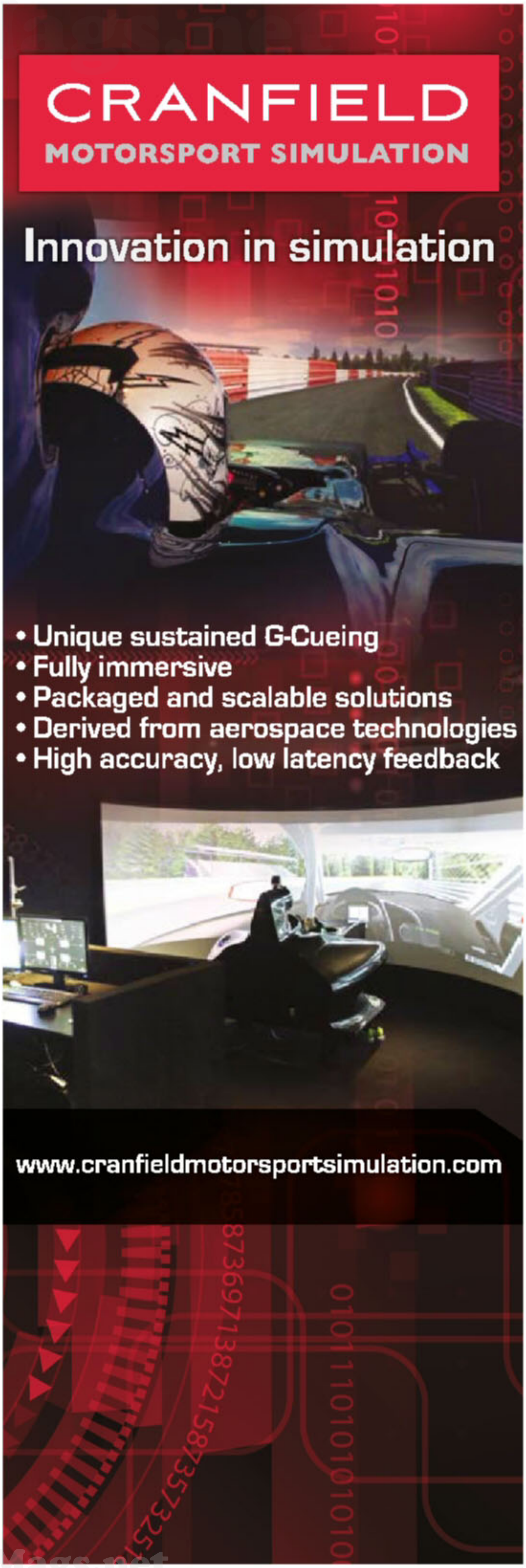
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Sim in motion

As the competitive nature of motorsport continues, more and more drivers are turning to simulators to give them the edge over their rivals. The question is whether simulators with motion are the answer.

By GEMMA HATTON

Toyota Motorsport GmbH's six degree of freedom simulator is so advanced that Toyota can actually utilise it as an engineering tool to determine set-up changes on the car

Practice makes perfect – and it is no different in motorsport which is why teams from F1 to club racers are all investing in simulator technology. 'For me personally, it's very useful,' F1's current Championship leader, Nico Rosberg said in a recent interview. 'There are a lot of strategic things I need to remember, like KERS boost. I need to boost in a very specific place and so if I practise that, it becomes instinct and I can move it out [of my head] so I have more space for other things.'

Practising such strategies and tactics on the simulator has become even more important in this year's F1 Championship, with the introduction of further complex systems that the drivers have to get used to, such as brake by wire. 'The driver needs to have a good feeling of retardation versus pressure that is not 'steppy' or moves around,' explains Williams Chief Test Engineer, Rod Nelson. 'It is key for the mapping and brake setup that when you come off the brakes there is no residual force that may give a little bit of instability or a lock up. Some drivers are very sensitive to this but we can model these brakes on the simulator.' However, it is not as simple as that, as there is a thermal effect where the stopping power of the brakes depends on the brake temperature and so cannot be fully simulated – another example of how simulators can represent scenarios relatively accurately, but are still not 100 per cent realistic. This debate on whether simulators will ever be completely reliable will continue for years. However it brings up a further discussion on whether simulators should include motion platforms at all if it is not completely realistic?

'A motion platform is a great thing only if you can actually do it right,' says double Le Mans winner, Darren Turner, who has more than 15 years' experience developing Formula 1 simulators, including being McLaren's F1 test driver from 1998 to 2005 and who now leads Base Performance Simulators. ' The F1 teams that put millions of dollars into their simulators are in a unique position because they are just concentrating on one car and tyre model and the aim of getting all of that to feel right through the motion. Even then, there may be 10 guys in their simulator program, so you can imagine the resources required to do a good job. I've been on the best motion platforms in the world, and if you can't do motion absolutely perfectly, then don't do it at all because more often than not, it can give you the wrong feeling of what the car model itself is doing.'

The Aston Martin Racing driver has used his unique insight into simulation technology to set up his own simulator company, Base Performance, which not only has both a single seater and GT simulator on site for hire, but also sell two types of simulators; an entry-model level for individuals (BPS 2.0) and a professional system with higher spec graphics (BPS 4.8). 'We've concentrated on the two elements that you can do really well; the visuals and the steering, which is where you'll get the most feedback from what is going on,' says Turner. 'A lot of drivers have experimented with other simulators with motion and then spent half a day with ours and said, "that is the best experience I've had because I can just concentrate on the driving rather than driving the platform and understanding the way it moves."

Base Performance's GT simulator offers the unique advantage of having the driver-coach or engineer next to the driver (top), as well as utilising a real GT chassis

Designed from the ground up, Base Performance simulators also have a single-seater model complete with a five metre wrap-around screen for the full visual experience

"You are probably looking at a quarter of a million for a decent setup, but that's come down from a million"

However, the cost of motion systems has been coming down, as Michael Japp, lead simulator technician for Base Performance, explains. 'You are now probably looking at around a quarter of a million for a decent setup, but that has come down from about a million and there are alternative ways of doing it, so you can get some motion without a full system. It is something that is becoming more commercially viable each year.'

A similar story is found at Pro-Sim, who are unique in that nearly every part of their simulator was made in-house.

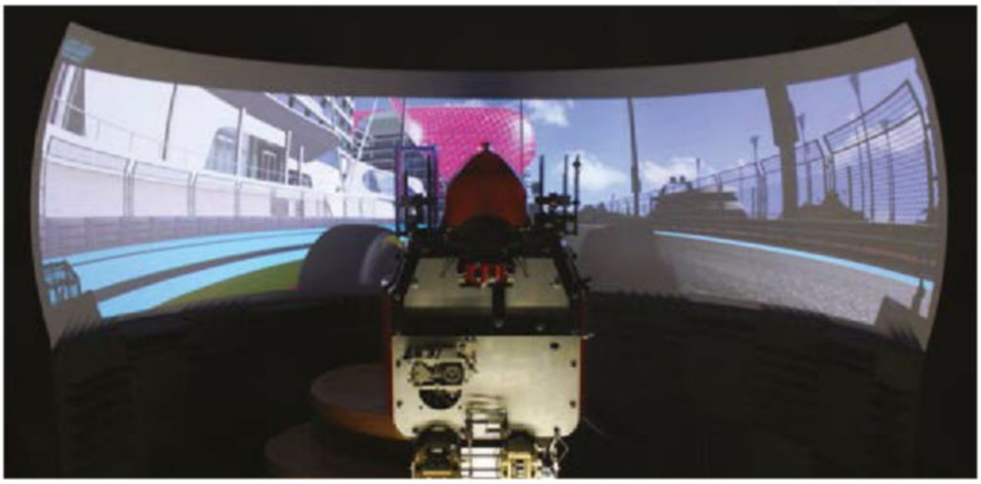
'We spent a lot of time researching various different options when we started our sim and were lucky to have Adrian Quaife-Hobbs (current GP2 driver for the Rapax team) involved in the design and development from a driver's point of view,' explains Michael Poole, Pro-Sim's performance director.

Like Turner, he has driven every kind of simulator including the full motion examples used in F1. He felt that as good as they were, a driver still had to ignore a lot of the effects. 'The simulator can only travel so far and has to stop at some point, which can be felt as grip loss,' he says. 'Commercially, there is only one choice, which is a static sim, so that is what we ended up with.'

Similar to Base Performance, Pro-Sim have concentrated on the most important sensory cue – the visuals. This led to investing in advanced projectors that have refresh rates over 120Hz to eliminate effects such as motion blur, as well as a double curved screen to ensure that every point on the screen is exactly the same distance away from the eye. Steering wheel and brake pedal feedback are also employed to help increase the realism of static simulators.

Military simulators

In contrast, one company that has researched heavily in achieving realistic motion through the detailed development of 'cues' is Cranfield Motorsport Simulation (CMS) at Cranfield University. CMS is a group within Cranfield Aerospace Limited (CAe) which is the global leader in hi-fidelity g-cueing products for the world's top-level fixed-base military simulators and has delivered 130 systems to 21 different armed forces around the world. In fact, some of their flight simulators are so realistic that pilots can be cleared to fly an aircraft having only used the simulator – with no in-flight training at all. 'CAe has four decades of g cueing



Another example of a static simulator from Pro-Sim which focused on the most important cue of the driver: the visuals

experience in fast jet and dynamic helicopter simulation systems which is directly transferable to race cars,' explains Graham Campion, Business Development Manager of CMS. 'To fully enhance the driving experience and provide added training value the vehicle and track models must be a very close representation of the real thing. If the models lack detail, the simulator will provide negative training value and can potentially put the driver at risk when out on the track. Many drivers have commented on the realism of the CMS system.'

This realism is achieved by carefully co-ordinated 'cues'. The primary sensory cues come from the visuals which provide the brain with the most information on the vehicles motion relative to the surroundings. A 'first level' simulation is achieved by using the visual display alongside aural inputs and force feedback to the muscles. However, for high-performance racing, the level of mental engagement between the driver and the simulator needs to be higher, which leads to 'second level' simulation. This is where a variety of co-ordinated cues that cover acceleration, deceleration, cornering forces, skidding and so on are provided to the driver to simulate the 'full' experience.

In racing, the important loads are experienced in the longitudinal and lateral directions with lateral loads of up to 5g. To accurately induce this perception of self-motion, not only do the vestibular, visual and auditory systems need to be stimulated, but also the effect on the whole body, particularly the upper torso. This is achieved by using actuators to provide a series of displacements to the vehicle itself, an onset cue, and through sensory stimuli which represents the forces experienced on the torso and legs. All these cues are provided by three sub-systems: the Sustained Motion Cueing System (SMCS), the Vehicle Actuator Frame (VAF) and Positional Rapid Onset (PRO).

The SMCS is composed of different motion cueing modules situated around the cockpit and seat where the driver experiences pressure due to the longitudinal and lateral forces at high speed. These cues are progressive and thus proportional to the relevant 'g' demand and are continued until the demand is removed. Any three demands can be combined on to any axis at any one time, so both sustained and vibration cues can act at the same time on one axis or the sum of two different frequencies and amplitude. Further techniques can be employed, such as thigh pads and harness tensioners which simulates the feeling of being forced into the seat pan during braking; a back pad which applies a slight pressure to the driver's back to represent being forced into the seat under acceleration and side pads for cornering forces.

Track undulation

The VAF is a combination of structures which provide displacement in the vertical, lateral or roll planes. The upper section of the VAF is mounted to the intermediate frame and locates the monocoque. Four actuators on the lower frame induce the motion of pitch and roll by short, high frequency strokes controlled by CMS control algorithms. Similar to the SMCS, demands of both elements can be combined to provide any combination on a particular axis. This can simulate vehicle pitch during acceleration and deceleration, kerbing, track undulation and roll during cornering. Added to this, the lower frame of the VAF uses a long stroke actuator to represent the feeling of yaw. This provides the driver with the differences between front and rear lateral yaw and slip angles. Finally, the PRO system complements the SMCS by providing the x, y and z axes with onset cues vibration and sustained cues to the driver's seat in under 20ms.

The vibration cues used by the above three systems can either be low frequency (less than 30Hz) or high frequency, with the former provided by an inertial vibrator and the latter with a tactile transducer bolted directly to the fixed structure of the seat; both work to simulate engine vibrations.

To summarise what actually happens during a manoeuvre, let's look at the scenario of decelerating before a corner. The SMCS will provide sustained cues by decreasing the skin pressure on the drivers back and thighs while changing the harness pressure in relation to the rate of acceleration. The VAF supports and moves the entire vehicle to provide the slower onset cues and pitch the front of the vehicle down. The PRO ensures rapid onset cues which are again, proportional to the acceleration as well as vibration cues whilst bringing the drivers

Cues cover acceleration, cornering forces, skidding and so on for the 'full' driving experience

History repeated

It's not just F1 and GT racers who want to benefit from the simulator world, but historic racers are now starting to get to grips with just how valuable a simulator session can be when out on track. Of course this not only poses new challenges for the vehicle models, but a different approach is required as Base Performance Simulators.

BPS Simulator Technician Michael Japp explains: 'Some of the historic drivers have perhaps never driven a simulator before, so we start them off with something easy to drive. This is opposite to reality because a lot of historic cars are 'tail happy', making it a struggle to drive on the simulator without crashing every lap which doesn't really help them learn the circuit.'

Both the GT and single seater Base Performance Simulators have removable gear sticks to convert them from a 'modern spec' paddle change and modern tools which aren't necessarily available for historic racers such as telemetry can help their development.

'Races like the Le Mans Classic and the Monaco Historic Grand Prix are there to be enjoyed by the drivers. We've found that those drivers who have visited BPS for a few hours before the event to really learn every inch of the circuit, arrive on race day confident that they can do the job behind the wheel. They enjoy these really unique and special events more because they are not worrying about which corner is coming up next and what gear they are supposed to be in,' says Turner.

The historic market is another slice of the simulator market that is expected to grow. Japp concludes: 'In general, there is a lot more money being thrown at historic racing then there was perhaps five years ago. It has become a lot more competitive, you have only got to look at Goodwood this year and the number of good drivers that are being paid to drive. We just help our guys to learn the circuit and make sure they know where they need to go.'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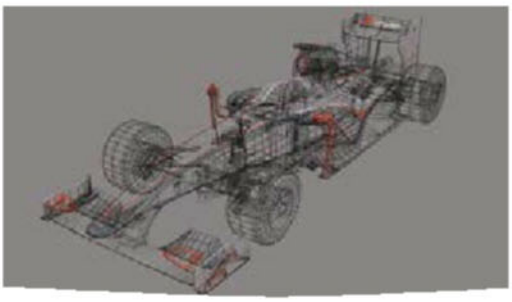

eye point forward and lower within the vehicle. Steering and braking cues will also be present.

'With the correct experience, in general the integration is relatively straightforward,' says Campion. 'But when assessing motion cueing algorithms the delay or latency of the execution time of the algorithms should be considered.' Latency is defined as the time interval between a stimulation and a response, in other words the time between when a driver sees an event, such as going over a kerb, to when the system responds and the actuators generate vibrations under the seat. 'Long latency causes the motion system response to be delayed relative to the motion of the simulated vehicle, which can lead to simulation sickness and unrealistic difficulties in controlling the vehicle.' This could be one of the reasons why some drivers suffer from motion sickness during simulator sessions.

The decision between motion or no motion depends on the purpose of the simulator; whether it is for driver development, or car development. For example, Base Performance's static simulators are purely for driver development says Japp: 'We work hard on making sure that it is as good as it can be for learning circuits and driver technique. It is not really at an engineering level, you can't walk away from the setup on the simulator and use the same on the circuit. But you can certainly validate your aero levels and more basic car setup work such as gear ratios.'

Visuals may be the most important driver cue but vibration and other dynamic models come into play

Toyota Motorsport GmbH (TMG), on the other hand, use their six degree of freedom simulator as a car development tool too. 'Our driving simulator is much more than a driver training tool,' explains Alastair Moffitt, marketing and communications manager for TMG. 'It is an engineering tool which is part of our "hardware in the loop" solution. We have dynamic models of various aspects of the car (engine, transmission, driver, chassis, ECU). Effectively HiL makes the main functions of the car modular in the virtual environment, so any one can be swapped for a real-life test item and the others function normally and behave according to the inputs. The driver is one of these 'modules'. Toyota's motion platform achieves +/-0.6m of lateral, longitudinal and vertical travel as well as 38 degrees of yaw and 27 degrees of pitch and roll. But their latency time is about 50 milliseconds – nearly double that of the Cranfield simulator.

Accuracy

To be able to use the simulator to evaluate car set-ups and developments, the motion system has to deliver accurate and dependable inputs to the driver. 'All major inputs are recorded from the car at the track, so we can extract the data and therefore know exactly how much vibration each corner of the car was experiencing at any given corner, for example,' says Moffitt. 'We spent a year fine-tuning the simulator model with our F1 drivers before it was signed off, and we also run a simulator session after every race and further fine-tune the model with the drivers, based on their experience of the car's behaviour.'

'There is certainly a case for stationary driving simulators for certain applications, but motion is highly beneficial – one might even say a requirement – if a driving simulator is to be used for vehicle dynamics engineering work. But it must be the correct kind of motion,' concludes Kia Cammaerts, technical director of Ansible Motion, which supplies simulators with six degree of freedom motion platforms with steering feedback and seatbelt loading.

'Our motion systems are visibly quite different, as they are developed exclusively for ground vehicles and are designed to provide vestibular cueing [canals and organs of the inner ear which react to inertial stimulants]. Unlike traditional "hexapod" motion bases, our unique motion architecture delivers linear command authority directly to the vehicle axes that are coupled most closely to a driver's sensation of vehicle steering and handling response characteristics.'

GT conversion

In a development of the simulator world, CMS has converted a Porsche 997 GT3 car into a simulator. 'CMS is always looking for the next innovation in motorsport simulation,' says Campion. 'Recently we completed CMS's first GT conversion using existing control systems and dash displays so the feel and environment is 100 per cent accurate to the car on the track.'

'It is accepted that current simulators are still not 100 per cent realistic and no one knows when or if this may ever happen,' says Japp. 'A company's available budget is clearly a factor. And some F1 teams still haven't embraced a full motion system. If they are struggling with their amount of technical and financial resources, then we are unlikely to be able to advance our systems to a good level for the near future.'

As drivers get less time on track, the simulator market continues to grow. 'Racing is getting more expensive per kilometer, so to practice your sport becomes even more difficult,' concludes Turner. 'Simulators give drivers an ideal way of getting a few extra hours in a week or a month, which keeps them ready to do it for real.'

In the cue

Simulator company Cruden has a flexibility that allows customers to adapt its technology for their own use. Their external physics package, ePyhse, can be used with the customer's in-house developed model, a commercially-sourced package or Cruden's own vehicle model, CSVM, a Simulink-based model that allows for internals to be examined, altered, or even replaced.

ePhyse can be extended with customer motion cueing capabilities, giving teams even more control. Engineers can bypass the standard cueing algorithms and command direct platform set points from within the Simulink environment. The motion-based software continues to manage the system's inverse kinematics, workspace and safety aspects. One example of a 'custom' algorithm design is the addition of vehicle side-slip angle and dynamic varying yaw pole to existing motion cues. This overcomes the limits of traditional acceleration cues on a simulator and is useful in providing simulator drivers with a realistic feel of over- and understeer.

'There are limits to how well a motion-based simulator can cue accelerations on the longitudinal and lateral direction because the available space is used quickly and accelerations cannot be sustained. We understand that some vehicle dynamics teams, particularly in motorsport and performance car applications, need more,' explains Edwin de Vries, senior vehicle dynamics engineer at Cruden. 'Our novel cueing method imposes the vehicle's side slip angle – a signal that fits, unmodified, within the motion space – on the platform's yaw angle to avoid washout – and high pass cueing filters, enriching the driver's handling perception.'

Using your head

Another revolution in simulator technology which is currently in the early phases of development is a specially-designed helmet that simulates G-force from Pro-Sim. 'Our helmet add-on that applies force to a helmet is still in the testing phase. We are getting very good results and we are excited with the prospect to finish this off and get it to our customers. At the moment we cannot go into too many details but we are hoping to have this ready for the public around the end of this year,' reveals Pro-Sim's Martin Poole. 'We feel that the helmet will provide a useful benefit in feeling the car through the corners as the force will be constant. The other benefit to this system will be that the driver can perform his neck training whilst on the simulator, driving his car at the circuit he will be racing on.'

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Simulation techniques for electric racing Part 2

How would an electric F3 car stack up against its ICE equivalent?

By DANNY NOWLAN

In part one of electric powertrains for motorsport we talked about the fundamentals of electric powertrains. We discussed some basic circuitry and equations for getting your head around current draws and voltages. We talked about how to read a voltage cell discharge diagram and what an electric engine torque diagram looked like. We then discussed an electric F3 conversion and how to calculate basic current draws. Finally we previewed the forthcoming electric vehicle powertrain module in ChassisSim.

This month, we will talk about the more advanced engineering ramifications for electric powertrains. We will look at aspects to consider when implementing electric powertrains and compare this to its internal combustion counterpart. There will be a lot to consider.

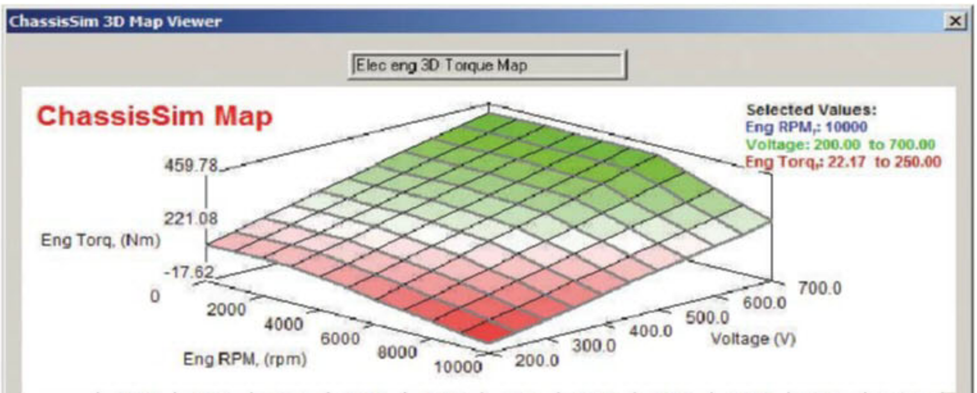
The first responsibility in any electric powertrain implementation is to specify the engine you need and the number of cells that are required. We touched upon this briefly in part one, but it is now time to fill in the blanks. To begin with, we need a good generic engine curve. To that end I would recommend a curve that looks like **Figure 1**. The big difference between this curve and the engine curve we presented in part one is that we have scaled the engine torque as a function of engine voltage. We selected our maximum torque at the peak voltage of the motor.

Rather than going through and manually entering the torque curve, this is a simple tool that you can do for a first cut analysis. As a rule of thumb, you scale zero torque at zero volts.

Your next goal is to determine the voltage and current draw and Ah used over a lap. This is where the ChassisSim electric powertrain module is your new best friend. What you want to be looking at is a plot like **Figure 2**.

The variables of the most immediate concern are the last three shown on this lap time simulation plot. These variables are pack voltage, current draw and Ah used. First things first, the critical things to pay attention to are the pack voltage and the current draw. You must always investigate this, without fail, to ensure it is within the specification of the engine and speed control as specified by the engine and or speed control supplier. They will usually specify a max voltage and maximum current draw. Under no circumstances should you go beyond these specifications. The next thing to pay attention to is the Ah pack plot that plots the Ah used over the lap. This will always be a trade-off between the performance you want and how long you need the pack to last. Again as a rule of thumb, I take the Ah used over a lap and divide it by the pack capacity. This will give you a rough idea of how many laps you can do.

When determining the performance you want, you always walk a fine line between



	200.0	250.0	300.0	350.0	400.0	450.0	500.0	550.0	600.0	650.0	700.0
0	147.00	174.30	201.60	228.90	256.20	283.50	310.80	338.10	365.40	392.70	420.00
1000	147.00	174.30	201.60	228.90	256.20	283.50	310.80	338.10	365.40	392.70	420.00
2000	147.00	174.30	201.60	228.90	256.20	283.50	310.80	338.10	365.40	392.70	420.00
3000	147.00	174.30	201.60	228.90	256.20	283.50	310.80	338.10	365.40	392.70	420.00
4000	129.17	158.25	187.33	216.42	245.50	274.58	303.67	332.75	361.83	390.92	420.00
5000	111.33	142.20	173.07	203.93	234.80	265.67	296.53	327.40	358.27	389.13	420.00
6000	93.50	126.15	158.80	191.45	224.10	256.75	289.40	322.05	354.70	387.35	420.00
7000	75.67	105.85	136.03	166.22	196.40	226.58	256.77	286.95	317.13	347.32	377.50
8000	57.83	85.55	113.27	140.98	168.70	196.42	224.13	251.85	279.57	307.28	335.00
9000	40.00	65.25	90.50	115.75	141.00	166.25	191.50	216.75	242.00	267.25	292.50
10000	22.167	44.950	67.733	90.517	113.300	136.083	158.867	181.650	204.433	227.217	250.000

Figure 1: Suggested electric engine curve

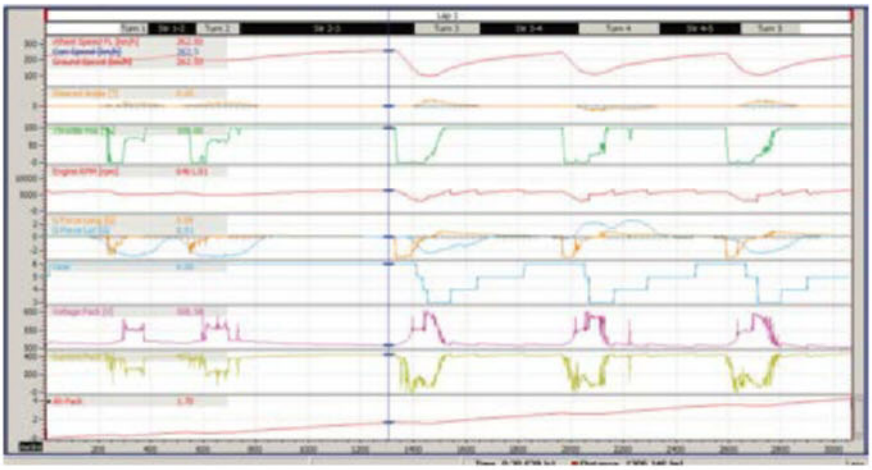


Figure 2: Electric variables you need to be paying attention to, particularly the bottom three traces

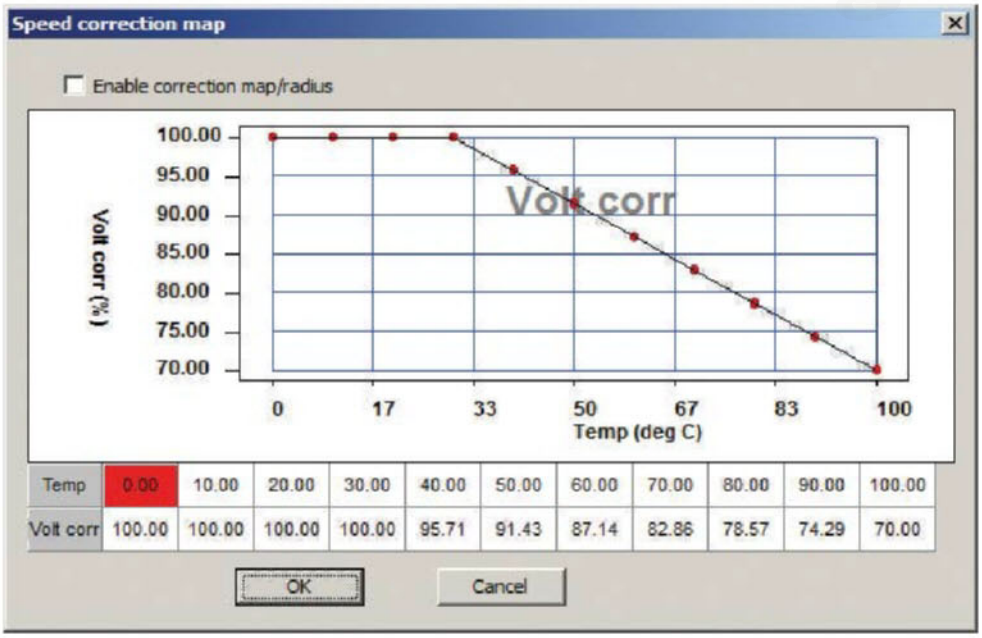


Figure 3: Cell voltage percentage as a function of temperature

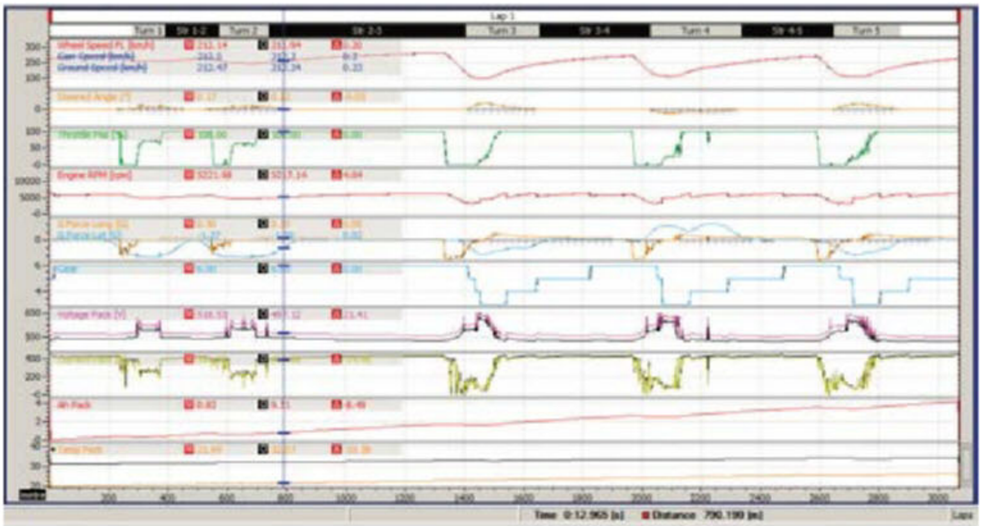


Figure 4: Pack temperature comparison between different laps

EQUATIONS

EQUATION 1

$$(I_{pack})^2 \cdot R_{INT\_PACK} = K \cdot (T_{PACK} - T_{AMB})$$

$$R_{INT\_PACK} = No\_Series \cdot \frac{R_{INT\_CELL}}{No\_Parallel}$$

Here we have,

I_{PACK}	= Pack Current draw (A)
R_{INT_CELL}	= Internal resistance of the cell (Ohms)
K	= Cooling factor of the pack (W/K)
T_{PACK}	= Temperature of the Pack (deg K)
T_{AMB}	= Ambient Temperature (deg K)
No_Series	= No of cells in series of the pack.
No_Parallel	= No of cells in parallel in the pack.

Table 1: F3 car parameters

Parameter	Quantity
Weight	550kg
Peak engine Power	166kW
cg height	0.3m

pushing the motor and speed control as hard as you can and seeing how much battery capacity you can conserve. It's going to take a few goes to get right and it's also important to take into account the mass of the battery pack you are using. We'll be discussing the full ramifications of this a bit later.

The next thing to keep in mind when considering electric powertrains is the temperature of the pack. While internal combustion engines have an optimum operating temperature, it is critical to keep a battery pack and electric motor as cool as possible. The reason for this is that cell voltage drops with rising temperatures.

An example of this is shown in **Figure 3**. As we can see, as the temperature goes up, the cell voltage drops off dramatically. For anecdotal evidence, I have seen radio-controlled aircraft that look like boxes, but will happily keep pace with their more streamlined counterparts because their pack and engine cooling was first rate. This can be quantified so you have something to go on. The formula for this is shown in **Equation 1.**

In terms of some rough numbers, the internal resistance of a lithium polymer cell is 4-6 x 10^{-3} Ohms and K is a direct function of the cooling efficiency of the system. You will tune K depending on how effective your air cooling is but you are looking at around 1000W/K.

Remember also that heat will build up over a number of laps. This is a direct function of the specific heat of a lithium polymer cell which is in the order of 800 to 1000 J/kgK. As an example, here is a comparison of the temperature build from lap one vs lap three of our example F3 car, clearly shown in **Figure 4.**

The first lap is coloured and the third lap is black. By lap three, the pack temperature is 10degC higher and the voltage of the pack has dropped by 20V. The overall performance has not been affected, because I was too optimistic with the engine curve. However, as can be seen, the control of engine and pack temperature will be of the utmost importance for electric powertrain implementation.

Power to weight

For perspective, it is now time to do a serious comparison between a standard F3 car and its electric powered equivalent. First of all, let's consider some numbers for a standard F3 car. This is shown in **Table 1**.

There are two key reasons for choosing an F3 car. First, because of its modest power, an F3 car lends itself to an electric conversion. Also, Formula E shares a lot of performance parallels with an F3 car, which makes it a useful basis for comparison. To start this process, we need to get a good handle on what the electric F3 car will weigh. To calculate this we need to strip away the internal combustion elements of the F3 car. An F3 engine weighs approximately 90kg. By the time you add in the exhaust system, it will take this to 100kg. In terms of fuel, depending on the configuration, it will carry about 20 to 30 litres of fuel so we are looking at a fuel load of about 20kg. So, all up, we have an internal combustion weight of 120kg. This gives us a weight of the engine and a few ancillaries of 130kg, so an F3 car will weigh 550kg, minus the fuel and engine.

Now we can factor in the weight of the battery and engine of our electric car. From our last article we calculated a pack weight of about 143kg based on numbers from Thunder Power for a 143 S5P pack. With a protective casing and ancillaries, that would bring us to about 160kg. An equivalent spec F3 motor in terms of engine power is a Remy HVH250 motor which weighs 43kg. So, all up, the electric propulsion system weighs in at 203kg, giving a car mass of 620 kg.

Things get interesting when we compare the simulation results between the standard and electric F3 car. This is shown in **Figure 5**.

Not surprisingly the standard F3 car (shown in colour) pulls significantly away from the

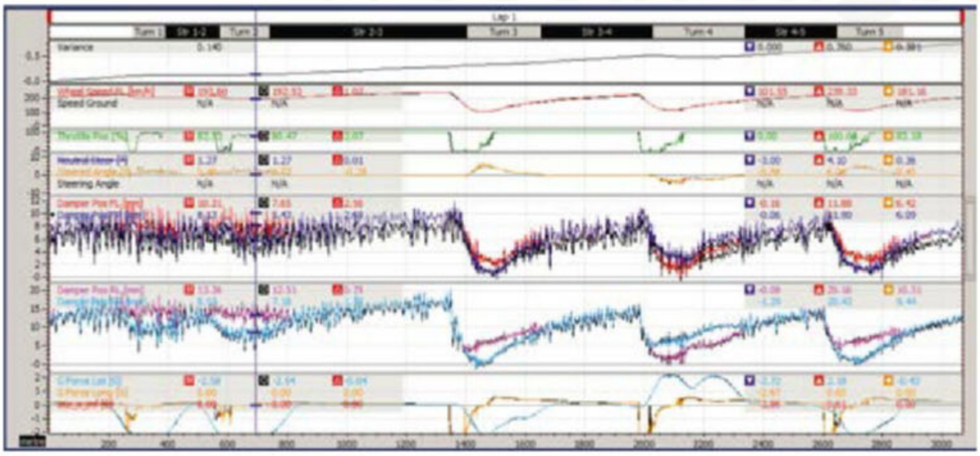


Figure 5: Standard F3 car vs electric

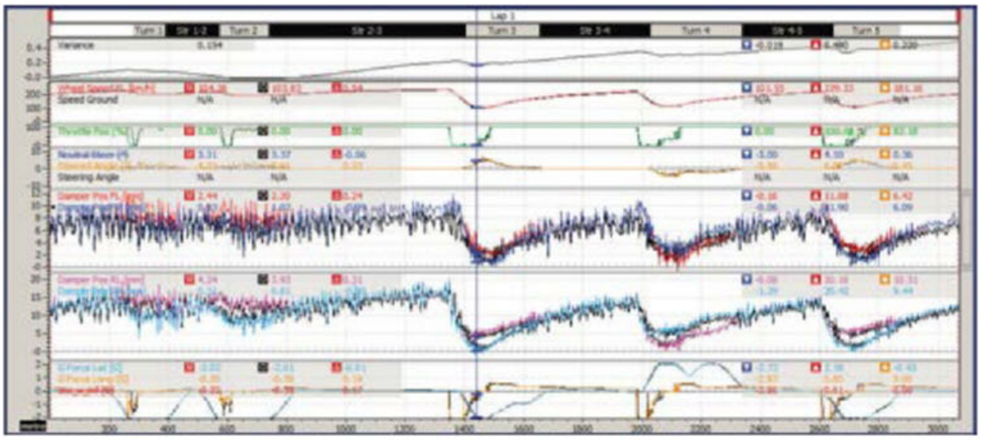


Figure 6: Revised comparison using an F3 standard vs F3 electric with a lower cg height of 0.2m

electric F3 car. In terms of lap time, the standard F3 car recorded a lap time of 61.25s and the electric F3 car had a lap time of 62s. As we can see on the time comparison chart, we lose time everywhere. This is particularly apparent in the corners, where it is losing, on average, 1-2km/h per corner. What we are paying for here is the weight penalty of the battery pack.

However, the packaging you can do on an electric car can significantly lower the centre of gravity. For example, the Remy motor has dimensions of 180mm x 242mm. Most engine builders would kill for that sort of packaging.

Also, let's look at what you can do packaging the cells. In our last article we were looking at a Thunder Power 70C G8 7700mAh cells. This has dimensions of 32mm x 44mm x 137mm. In a 5P configuration this gives us a cell block of 160mm so the dimensions of the cell pack would be 160mm x 44mm x 137mm. We needed 143 cells.

You don't need to be Adrian Newey to work out you have a lot of flexibility placing these cells. For example we could split this up into 2 cell packs of dimensions 0.45 x 0.2 x 0.5m. Just imagine the ramifications of that on cg height and using pack location as a cg tuning tool. So, to quantify this, let's drop our cg height on our electric F3 car from 0.3m to 0.2m. The results are shown in **Figure 6**.

Again, the standard is coloured and our electric engine car is black. The lap time of the electric car dropped to 61.75s, and in some corners the cornering performance was very similar. There is a lot more detailed analysis we could do here, but in terms of performance over a single lap the electric car doesn't compare too badly to its internal combustion counterpart and there is plenty of room for tuning. Also, just imagine the under-body aero options this opens up because you don't have to carry a big motor and exhaust system.

However, electric power is not without its drawbacks. This is all down to energy density.

The current Achilles heel of electric powered race cars is endurance. Over the course of the lap, we are drawing 3.16 Ah. For this one minute lap on a pack capacity of 40Ah we are looking at an endurance of 11 laps or 11 minutes (this is assuming we are using 85 per cent of the battery pack capacity). This is the current hurt point with electrics for race car use. You get away with this for road car use because for a road car most of the time you are at idle or part throttle and under brakes you can recover a lot of the energy you have discharged. Even with throttle management, you might be able to extend the endurance to 15 or 20 minutes, but the performance will suffer.

The other problem that needs to be tackled when designing an electric powertrain becomes obvious when comparing it with more powerful combustion engines. As an example, let's look at an electric powered GP2 car. A GP2 V8 has engine power in the order of 450kW. This is three times the power level of an F3 engine, but it need not be much heavier. In electric racing, if we want to keep the same current draw we need to triple the voltage.

This means tripling the cells in series. That would push the pack weight to 450kg, and this is far too much of a weight penalty. Also, the voltages we would require would be in the order of 1200 to 1600V. With today's technology, an electric powered GP2 car remains a bridge too far.

The next level

However, one thing that is clear from this analysis is that there is enormous potential in electric powertrains. There is just one catch; we have to let race teams off the leash.

Don't get me wrong, Formula E is a necessary and timely first step. But what has fuelled the development of electric propulsion and cell technology so far has been big kids like me wanting to fly harder, faster and longer.

What is so exciting is that electric propulsion in motorsport will take this to the next level. For example, energy density needs to be double what we currently have. Also, as discussed, managing cell temperature and arrangement of cell packs offer exciting areas of car development. It would allow motorsport to fully regain the technological lead and will make us truly relevant again.

Unfortunately, long term, this cannot be done under a spec formula umbrella.

In closing, we have discussed a lot of aspects about the application of electric powertrains in motorsport. In particular we have discussed what you look for from simulation results, the importance of pack temperature and how electrically powered racecars stack up against their internal combustion powered counterparts. While the performance is equivalent, endurance and energy density still remain an issue.

However, electric powertrains in motorsport remind me of the state of radio-controlled electric flying in the mid 1990s. It was not the finished article, but the writing was on the wall. This genie is about to be let out of the bottle.

It is clear that there is enormous potential in electric powertrains. There is just one catch; we have to let race teams off the leash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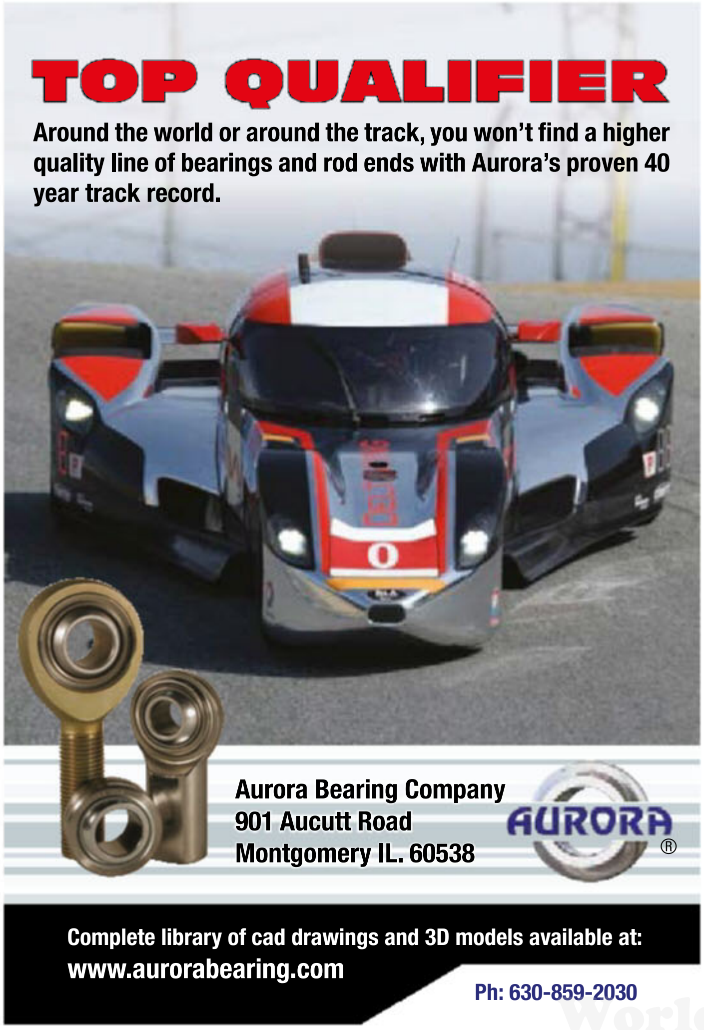
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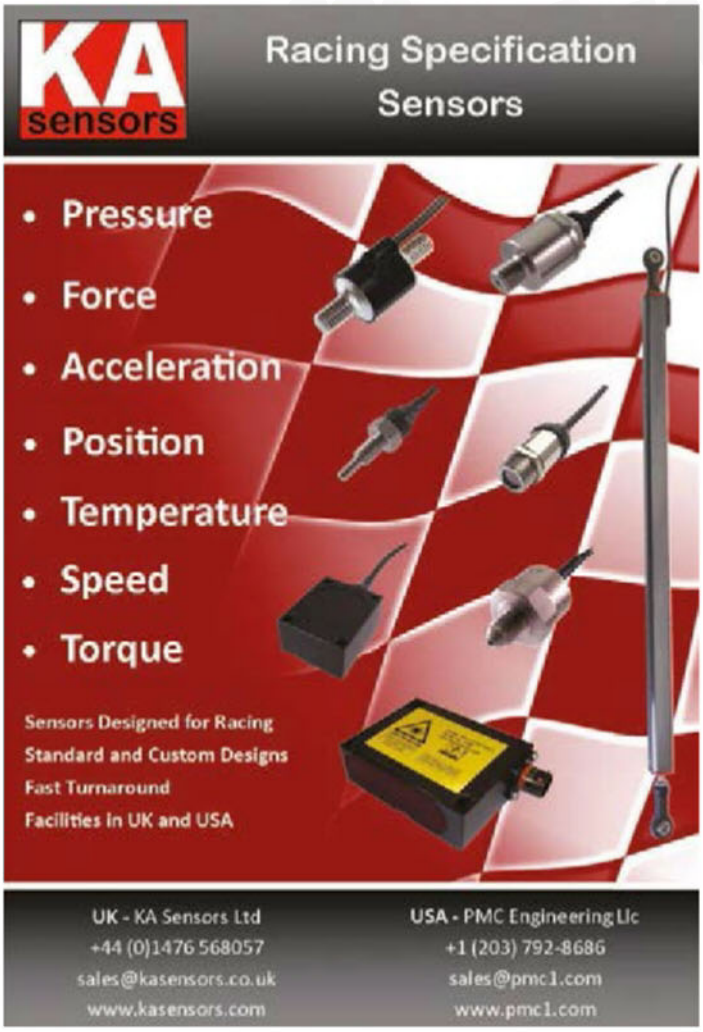

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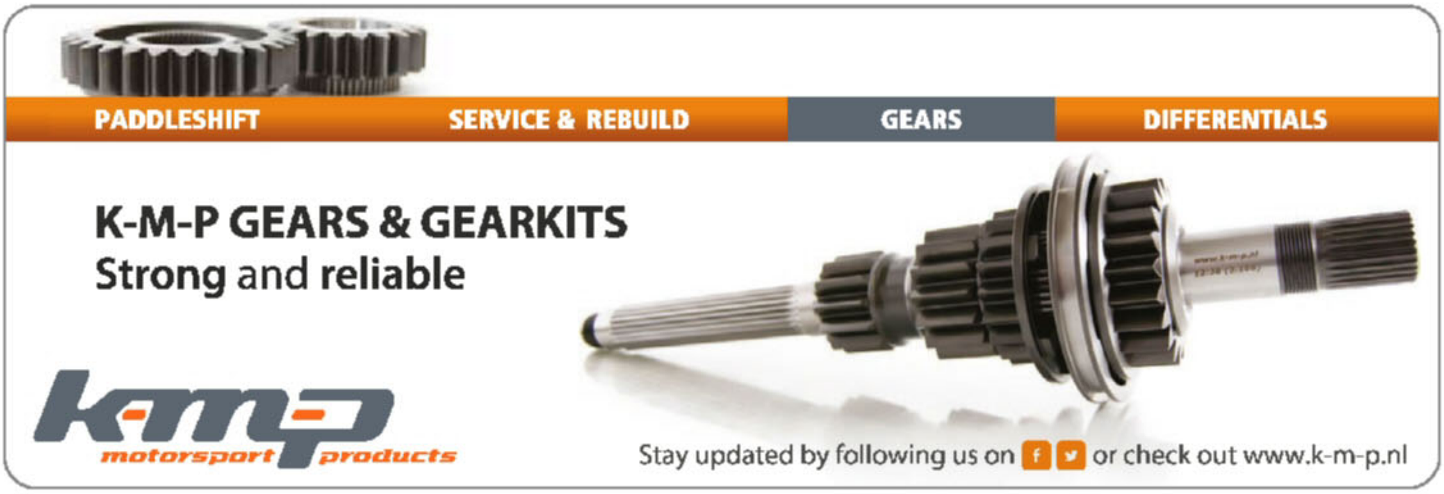

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Doubling up

Not just a supercar but a hypercar – engineering innovation is key to the Motion's impressive 0-60mph in under 2.5 seconds

When Russ Wicks, one of few people to have set records of more than 200mph on land and water, set his sights on producing a supercar like no other, he was determined to incorporate state-of-the-art automotive engineering and applied science materials with the latest advanced technologies available to produce a road car with unprecedented performance, style, safety, and efficiency. He linked with Kepler Motors and produced the Motion, which features an innovative hybrid drive concept.

The rear wheels are driven by a modified Ford EcoBoost 3.5 litre V6 engine which produces a stated 550bhp. Two REMY electric motors are mounted on the front axle, totalling 250hp delivered to the front wheels. The combined 800bhp launches the car from 0-60mph in a quoted 2.5 seconds, giving it extraordinary performance

What makes this hypercar unique (and exclusive as only 50 are to be produced) and so impressive is the engineering innovation. Rather than adapting previously designed high-performance cars, the Kepler engineers and aerodynamicist analysed each component and material going into the design of the hypercar with the objective of obtaining peak performance.

From the beginning of the design process, the engineering team knew they would incorporate additive manufacturing for the production of low-run parts. However, what they discovered was additive manufacturing could be used to produce 3-D printed patterns for investment casting.

This capability prompted the engineering team to re-evaluate and re-design parts without traditional manufacturing limitations. Leverage additive manufacturing technology allowed the team to create a cast titanium upright. Kepler

Main picture: Kepler Motors are hand-assembling only 50 of their Motion high-performance cars
Above: 3-D printing, rapid casting and precision CNC machining allowed engineers on the project to design intricate parts

The Motion sits on a carbon-fibre composite monocoque chassis and body, F1-style double wishbone, and pushrod suspension with cast titanium uprights

The upright of the Motion was designed to withstand the loads from all components effectively with minimum weight

Motors sought out experts with Formula 1 and additive manufacturing technology know-how to assist with the cast uprights. The Kepler team quickly came to view the CRP Group as the vendor of choice.

By partnering with CRP Group, Kepler Motors was tapped into a network of companies that could provide a custom solution. Two specific divisions within CRP Group were placed on the project team: CRP USA and CRP Meccanica. CRP USA coordinated the project between Kepler, the various divisions within CRP Group, and the design consultants, leveraging their Formula 1 and additive manufacturing expertise. CRP Meccanica was selected for the project to provide cooperative design expertise for the uprights, as well as guidance on how to combine the use of additive manufacturing, rapid casting and precision CNC machining.

More and more, designers, engineers and manufacturers are examining the potential of using additive manufacturing technology to 3-D print parts for low-run production of parts. The perception of how to design for manufacturing is changing.

'It is very common for a company to rethink their design as soon as they understand the potential with 3-D printing,' said Stewart Davis, Director of Operations, CRP USA. 'Once an engineer understands the possibility of manufacturing highly-complex designs and shapes using additive manufacturing technology and applications, shapes that could not be manufactured by traditional processes, they begin designing without limitations. By combining 3-D printing, rapid casting and precision CNC machining, engineers can think outside of traditional manufacturing methods and design complex, intricate parts.'

In order to remove preconceived design elements, Kepler Motors engineering director Derk Hartland focused on designing the hypercar from the inside out. Knowing what they wanted to achieve, the Kepler design team knew they would need to look at alternative manufacturing methods to achieve the quality and innovative hypercar they envisioned.

The innovative Motion is designed with best-in-class features. Along with its impressive performance figures, the Motion sits on a carbon-fibre composite monocoque chassis and body, F1 style double wishbone, and pushrod suspension with cast titanium uprights.

The cast titanium uprights are just one component that makes the hypercar unique. Because the suspension of this hypercar is exposed to all of the loads associated with cornering, downforce, braking and acceleration (which can occur in various combinations with each other), the uprights connect the wheel and half-shafts to the wishbones – one of the most complex and critical parts of the car. Multiple load scenarios were used with Finite Element Analysis (FEA) to ensure an optimal design that is strong, lightweight and elegant.

Along with strength, weight is a critical aspect of any car's suspension. In the case of the Motion hypercar, the suspension performance is critical. The upright of the Motion was designed to withstand the loads from all components effectively with minimum weight. The shape is complex as it secures multiple components.

'Lightweight strength and durability is essential for the hypercar to achieve its performance,' says Wicks (who founded Kepler Motors). 'Cast titanium is top-of-the-line technology for this application, which for the Kepler Motion was the only choice. Other cars use aluminium cast or billet for this application with a bulky, weaker and heavier result.

'Typically, aluminium is used for the uprights and the material thickness is increased, which reduces the flexibility of the design,' says Wicks. 'Because of the increased material thickness, accuracy of the machining is critical to ensure correct positioning of components as well as complicated angles of machined faces. This makes CNC machining imperative, yet can restrict our design creativity.

'Working with CRP Meccanica allowed us to streamline the process. Using their laser sintering additive manufacturing technology to 3-D-print the pattern for casting the upright in titanium allowed us to design an optimal lightweight and strong part with no compromises. CRP Meccanica managed the entire production process – from design to finish. They took the 3-D printed upright patterns to the foundry, cast the upright patterns in titanium, precision CNC machined the titanium uprights, conducted the FEA analysis and inspected the final uprights. The results were better than we could have imagined.'

Telling tailfins

Two players in the world land speed record sector joust in the less formal wings of the consultancy arena

The Bullet Project's RV1 Silver Bullet is equipped with two smaller Concorde-style tailfins, as testing and operational eperience shows these are not prone to shedding unstable vortices that lead to flutter

A few days ago I remembered that back in 1984, ten years before Thrust SSC was initiated, Rosco McGlashan had in his possession a set of drawings for a jet land speed car with twin front-mounted engines, a wide front track, and a narrow rear track. I know this because I made the drawings, although I hadn't thought about this in quite a few years.

Loyd Coleman, a friend of mine from here in Orlando, had travelled to Australia, became acquainted with Rosco, and started working with him in an effort to find sponsorship for a land speed record project. Loyd contacted his girlfriend here in Orlando who, in turn, asked me to come by their home with any material that might help guide them in building a land speed car.

I gave them the article from *Mechanical Engineering* on The Blue Flame and a copy of my drawings for a twin-engine jet car with front-mounted General Electric J-85 turbojets. The whole car, if built, probably would have weighed only about as much as one of the Speys in Thrust SSC.

If a pair of wheels is set close enough together, torsional rigidity becomes much less critical thus allowing a much lighter chassis. This is the principle behind the DeltaWing car, designed to run the same lap speeds with half the weight and half the horsepower of a conventional LMP1 car. The DeltaWing has less torsional rigidity at the front where it does not need it, and more at the back where it does.

This same principle is being incorporated into The Bullet Project's RV1 vehicle, where only the front wheels are set wide apart. Reducing the potential for aero-elastic deformation and flutter is one of the reasons the RV1 will have two smaller tail fins instead of one big one. The tail fins on RV1 use the same shape as the wings on Concorde.

A previous land speed car that used twin tail fins was Richard Noble's Thrust 2. The one jet land speed car where frame flex has been mentioned in the historical accounts is Craig Breedlove's Sonic 1, a conventional four-wheeler.

We selected the Concorde wing shape for the tail fins on the RV1 because extensive development testing and operational experience has shown it is not prone to shedding the sort of unstable vortices that lead to flutter.

Additionally, the aerodynamic neutral point shifts much less on delta wings than on trapezoidal or swept wings, particularly in the transonic regime, thus further reducing any twist or deformation that can set off flutter. Also with the shorter span made possible by using two smaller tail fins instead of one big one it is easier to make the tail fins more rigid.

Sincerely,
Franklin Ratliff

Thrust 2, with tail fins, which held the WLSR before Thrust SSC

I had not heard of this one, although Rosco has previously consulted me on the aerodynamic design of other WLSR projects he has tried. The arrangement was that I did not charge for my consultancy, but whenever we meet – he can buy the beer!

I agree with you that other designs can be much lighter than Thrust SSC – although I would remind you that not one of these lighter designs has got near to matching the performance of TSSC, so perhaps there is a good reason for this.

One such reason is that applying simple scaling laws to a subsonic car does not result in a supersonic car. In particular, other designers have failed to learn that going at much higher speeds requires much stiffer structures that are therefore much heavier, so performance requirements are much more difficult to achieve than you would expect from simple scaling laws.

Have you ever included detailed aero-elastic deformation and flutter calculations in your designs, I wonder? These considerations result in substantial weight increases. I have seen no evidence that other designers have even considered such factors.

Incidentally, using Concorde wings as a pattern is not necessarily going to help you. The dynamic pressure on Concorde wings was nothing like as great as the dynamic pressure on a supersonic ground vehicle. I am not criticising your design – the shape may well do the job for you – but I suggest that you would be wise to check out the stiffness requirements at high dynamic pressures.

Your two smaller tail fins are just as likely to flutter, or distort, as one big one, so they will need to match the same stiffness criteria to survive. Similarly, body-bending stiffness must be much greater to prevent body-bending modes being forced by ground noise. After all, our WLSR vehicles are invariably long and thin, so bending modes are generally an issue.

Torsion mode is not relevant as almost all WLSR vehicles have either the front wheels or the rear wheel close together, so torsion mode is not normally forced. Thus, whatever design shape you use, the structure must be stiffer and heavier at high speeds than at low speeds. That is why normal scaling laws cannot be used. Aero-elastics specialists and structural dynamicists have their own scaling laws.

With Thrust SSC we first did a theoretical modal analysis and identified six different vibration modes and their natural frequencies. When the car was built and ready to run I then got the Structural Dynamics Department at Farnborough to do a complete physical resonance test analysis of the structure. They identified the same six vibration modes, confirmed their natural frequencies, and gave us the damping factor for each. Thus

"In retrospect, it was probably not a good idea to commence my automobile career by designing a supersonic car…"

we knew which ones mattered and whether more design/engineering work was needed. It wasn't. This knowledge was essential for the safe running of the car. I will do the same with Bloodhound; it's standard engineering practice.

A final reason why TSSC was so heavy is that it was the very first car that I had ever designed, so I was at the wrong end of the learning curve. In retrospect, it was probably not a good idea to commence my automobile career by designing a supersonic car but that is just the way it occurred. By the time I had finished it, I knew I could have done a much better, and lighter, job. But after 17 years of holding the supersonic record (I believe that the 17 years is itself a record, as the longest period any one car has held it) still no-one else has got near to beating it so perhaps I should not be so self-critical.

If you want more reasons why my designs are so heavy, have a look on the Bloodhound SSC website at Andy Green's August 2014 blog. It tells you much about our design philosophy.

Meanwhile, I will give you the same deal that I gave to Rosco. If you want some design consultancy, you can buy the beer. At least, we are trading in an international currency!

Ron Ayers,
Thrust SSC & Bloodhound SSC designer

Two-wheel mission

Weald Technologies is targeting an ambitious world record with electric motorcycles

A quarter mile in six seconds at 200mph, 1000hp zero emissions. This is the mission statement for the next undertaking by Sussex-based electronic powertrain company Weald Technology. It is a far cry from the ugly 'eco box' designs, and much to be desired in the way of power and speed that usually comes into mind when thinking about electric cars.

Weald Technology consists of designers and engineers with a long history in high-technology business from aerospace, defence, and motorsport, and have a lot of experience in projects where safety, durability, light weight, and high performance are critical.

In 2010, Weald Technology began building their first electric motorcycle for the Alternative Energy Racing event at Santa Pod and in May 2011, set the quickest time in the UK for electric motorcycles. After conquering the records in the UK, 2012 brought on the new challenge of conquering the world. After being awarded a grant from Innovate UK in the MIA Motorsport Valley Launchpad competition, which encourages motorsport businesses to develop low-carbon and energy-efficient products for use in motorsport, Weald Technology set out to develop a new generation of speed machines.

Weald Technology are designing and building the complete electric powertrain and component parts for a bike that will attempt to claim records for bikes, including the energy capture and storage devices, control systems and software, and electric motors. 'We've set ourselves the goal of building the most efficient electric powertrain seen to date,' says director of Weald Technology, Phil Edwards.

The power for the world's fastest electric bike will be stored in a huge bank of ultracapacitors rather than batteries, and delivered through high efficiency controllers and a novel high-efficiency induction motor. Ultracapacitors have been selected over batteries for several reasons; specifically for the motorsport application this includes high-power density and efficiency, and for commercial products that the team are working on, they offer extremely high cycle life, and are almost totally recyclable. Ultracapacitors, with their much lower internal resistance than batteries, usually 0.2mOhm to 4mOhm depending on cell size/design, are quicker to recharge, resulting in an increase in the amount of energy that can be recovered during a KERS phase. Ultracapacitors are the safest energy storage technology, with the capability to accept and provide high current (amperage) with lower cooling requirements, leading to less cooling requirements in applications such as eBoosting or KERS.

Equally important is the ability to push that energy back out to get it onto the track. The ideal for these applications is a symmetrical charge/discharge capability, with a very high throughput capacity; being able to accept or provide hundreds of Amps at a time. At present, only ultracapacitors can do this.

Ultracapacitors have a symmetrical charge/discharge capability, meaning you can charge them as hard as you discharge them. Typical cells in the 3,000F range can handle 100A RMS continuously without much cooling, and voltage tolerance is fairly high for short periods, meaning temperature monitoring is very simple.

Resistors can be used individually to ensure cell-to-cell balancing is achieved, and the ultracapacitors can be discharged to 0.0V with no degradation.

'Through our UK supplier – Advanced Power Components – we have good access to the manufacturers and engineers in America so we can look at some of their leading edge designs before they hit the market,' continues Edwards.

The project is also pushing to demonstrate new technology designed to deliver very rapid recharge capability – and that has a place in e-motorsport as well as on the high street.

Efficient use of energy is a priority for this project, and a holistic approach to the design, manufacture, operation, and disposal of products and is the focus for the engineers who will be pushing the limits of what is currently possible with this bike be it a weight saving, or a reduction on the amount of energy used.

'This kind if technology isn't isolated to Motorsport,' continues Edwards. 'It is also gaining interest from companies in the HGV, off-highway, and defence sectors, as they too are looking for a very responsive, high-energy, source of boost power.' This demonstrates the importance of the motorsport market with the premise of the competition providing the perfect platform for new technology and then sharing that knowledge across other sectors.

In future, Weald Technology looks to educate engineers and motorsport industry professionals on this technology, and the ways to keep it safe, while always striving to take on more new electronic powertrain projects. You can follow the progress and even get involved with the world record-breaking electric motorcycle project on FastCharge.org

"This technology is also gaining interest in the HGV, off-highway and defence sectors as they look for a high-energy source of power"

Formula E composites

In a world that is constantly looking for sustainability without giving up the adrenaline of the motor sport, Italian company HP Composites offers its extensive experience in the design and manufacturing of advanced composite material parts in order to obtain lighter and always better-performing structures.

It's not a coincidence that HP Composites is taking part in the new FIA Formula E Championship, which started in September in Beijing. For this new challenge, HP Composites has been selected by Spark Racing Technology to manufacture the complete bodywork – entirely made of carbon fibre – of the Spark-Renault SRT_01E single-seater.

The project has been managed by HP Composites in its Ascoli facilities, starting from surfaces and aerodynamic loads, then passing through each stage of composites engineering, until the final step of getting the parts ready to be assembled on the cars. In this way, HP Composites is fully equipped to answer all customers' requirements from design to serial production.

Thanks to the deep knowledge of the various types of fibre and resin available on a global scale and also to the vast experience in process and technologies, HP Composites can offer the best solutions for structural parts. A good example is the Spark rear wing, which has a stiffness of more than 700N/mm with a mass of just over 1kg.

Ascoli Piceno

Gravel Trap – Sam Collins

In the run up to the first-ever Formula E Prix there were seemingly endless discussions about the new series, and many tended to centre not so much around the various pros and cons of the new series but rather how the first event would end in disaster, and how all the car would break down, if indeed they started at all.

With Beijing behind us its possible to look back at what can only be described as a success. The cars on the whole were reliable and the final corner crash not only proved the crash worthiness of the Dallara chassis and the Williams battery, but also got the new class exposure around the world in mass media news outlets.

The race was watched by a claimed 40 million people worldwide, likely more after the crash went viral, but there were some complaints about the sound of the cars, and even more about the dance music soundtrack played throughout the race by the 'Formula E Jay', who looked rather like a Smash Alien.

'I thought the racing was ok but it's a shame the cars were all the same and couldn't pass that much,' one casual viewer called Simon told me. 'My wife made me turn it off because she couldn't stand the whine of the cars though.' It is clear that Formula E needs some more technical variety, but season two of the series is meant to address that as the class is to be opened up to other chassis, battery and motor suppliers. At least that is what we were lead to believe at the launch of the championship in late 2013.

However, recently it has come to light that in season two the spec battery pack will still have to be used, this is a major setback for the chance of the series having real technical variety. The shape and concept of the battery pack forces the chassis to have a cantilever roll hoop something Dallara says makes it 'the most difficult monocoque it has ever made.'

This really makes it rather pointless to develop an alternative chassis to the Dallara, as the cost of doing so is not likely to give any great return in terms of performance. Indeed Alejandro Agag, the series boss, has even gone on the record to say that he would prefer that people did not make their own chassis but focused instead on the powertrain.

There is nothing in the rules that says that the Williams battery must be used, but we are reliably informed that it is the case. If the chassis and battery are fixed then it would suggest that the only performance differential will come from the electric motor, but with the McLaren product optimised around the Williams battery it again seems like it will be hard to improve upon. It would probably be possible to get a slightly lighter motor – after all the one in the cars was developed for a road car (the P1 supercar) not pure racing. But again the gains here are perhaps negated slightly. In season two the weight distribution is fixed at 37-39 per cent front with a minimum weight of 888kg.

Considering that the cars racing are homologated, the regulations do not say for how long but one assumes a season, it starts to raise the question of why bother developing your own cars for season two? Sure, there are perhaps some aerodynamic gains to be made, and brand identity to be improved (Audi Sport Team Abt running a Renault?) but it seems a lot of work for little gain. Electric motor suppliers aside the big development area in EV's is battery technology.

When Super Formula introduces its hybrid systems the teams will have a fixed spec electric motor (probably from Gibson) but freedom over battery technology withing safety regulations 'because there are many battery suppliers who want to race' according to Shirai-san, the series boss. In Formula 1 there is more than one battery solution on display, the same is true for WEC and even Formula Student. So why does Formula E not do the same?

The minimum weight of the cars was increased by 88kg in July, and I wager that the exact weight of the Spark-Renault 01E is 888kg (and falls in that weight distribution window). This removes another reason to do anything different in season two.

Consider this; the TU Delft DUT-14 FSAE car developed by students on a limited budget tips the scales at 155kg has four 30kW electric hub motors, a significantly better power to weight ration and can run for 45 minutes. Even if you introduce the safety specifications used in Formula E and scale up the powertrain to match the weight increase it seems to be a much more potent package.

One of the biggest complaints about Formula E from casual fans is that the cars 'looked a bit slow', but if the regulations opened up there would be a huge step forward in performance even within the 400,000 euro cost cap (a brilliant idea by the way).

So it seems a shame that Formula E, which has so much going for it, so much of the concept right and World Championship status aspiration restricts the one area that could give it a real boost from the industry and fans alike.

"In season two the battery pack will still have to be used – this is a setback for the chance of the series having real technical variety"

Mercedes open to lifting Formula 1 engine development freeze

XPB

Ferrari team principal Matteo Mattiacci says that a move to allow more development would be more in line with F1's 'DNA'

The freeze on engine development in F1 could now be lifted after Mercedes boss Toto Wolff stated his team would not necessarily oppose such a move.

The development freeze, which was introduced to stop spiralling costs, has been brought in to question lately after both Ferrari and Renault-equipped teams have been out-paced by rival outfits powered by Mercedes engines this season.

As things stand the regulations prohibit changes to the engines' architecture, unless they are on safety or cost grounds, or to do with improving reliability. However, Ferrari team principal Matteo Mattiacci has recently made it clear that he believes a move to allow more development would be more in line with F1's 'DNA', while Renault has said it would support such a change, as long as this did not result in a spending war between the engine manufacturers.

This topic was discussed at a meeting of the F1 Strategy Group during the Italian Grand Prix weekend and speaking afterwards Wolff revealed that Mercedes was open to further discussions on this subject: 'Obviously we have a competitive advantage but we would take the challenge [of competition from other teams] on,' he said. 'Is it the time to change the rules? Maybe. The discussions we've had so far were pretty open.'

But Wolff also said F1 should be careful not to initiate an engine spending war if changes are made: 'There are various concepts on the table and if we decide to go completely in the opposite direction and open it up completely, this will increase costs quite dramatically,' he said.

Red Bull boss Christian Horner, whose cars are powered by Renault, said: 'With the engine all we need to consider – without hopefully having a significant effect on costs – is perhaps more freedom to allow manufacturers to develop in order for that competition to be there at the front.'

In other engine news it has been confirmed that the new US F1 operation, which is now to be called Haas Formula 1 Team, will be entering into a technical partnership with Ferrari when it enters the sport in 2016. Meanwhile, Honda has made it known that it will be open to supplying other teams in 2016, with McLaren only enjoying its exclusive deal throughout the 2015 season.

BRDC Formula 4 to switch to FIA rules

The BRDC Formula 4 Championship is to switch to a carbon-fibre monocoque produced by Tatuus at the end of next season.

BRDC F4, which for the past two years has raced with a spaceframe chassis built by Van Diemen founder Ralph Firman's RFR concern, has agreed an exclusive UK deal with the Italian company, in which it will use the carbon chassis from next season's autumn championship onwards.

Tatuus carbon monocoque is to be spec chassis in BRDC Formula 4 from the 2015 autumn championship

Motor Sport Vision (MSV), the company that runs the championship, has ordered 26 cars from Tatuus, with the option of a further four should they be required. The car is already being used in FIA Formula 4 in Italy, but FIA Formula 4 in the UK – which UK Formula Ford will switch to next year – is expected to opt for a Mygale chassis.

Current BRDC Formula 4 teams welcomed the move. Graham Johnson, the boss of Lanan Racing, told *Racecar*: 'I think it's a good move, and we have ordered three of the new cars already. If they could have produced them earlier it would have been nice to get them out for the beginning of next year, but for Tatuus to have to come up with, effectively, 26 cars overnight, was a bit of a tall order.'

MSV boss Jonathan Palmer said: 'It was always planned that we would have a new car to replace our existing chassis after three years.' Yet it's believed the MSV announcement may well have been brought forward after the MSA agreed to allow 15-year-old drivers to race single-seaters, provided they were of carbon construction – as is the FIA F4. To help the teams MSV has said it will buy back the old cars for £15,000, and Johnson believes that although the new cars will be more expensive (it will cost £20,000 to upgrade including the buy-back) the budgets should only go up by about £5000 a year, as the increase will be spread over the life of the car. Current BRDC F4 budgets are around the £120,000 mark.

MSV says it will retain the current 185bhp 2-litre Ford Duratec engine and also the SADEV six-speed paddleshift gearbox in the new car. The Tatuus will make its UK race debut in an expanded BRDC F4 Winter Series in the autumn of 2015.

NASCAR heads west in rush for sponsorship

XPB

NASCAR will start 2015 at Daytona, as tradition dictates, before heading out west for three races early in the schedule

The 2015 NASCAR Sprint Cup schedule will feature a three-race 'swing' out west as the sport tries to make the most of what is seen as a rich vein of prospective sponsorship.

NASCAR's gold rush comes early in a 36-race calendar, which also features a return to its traditional Labour Day weekend for Darlington in early September for the first time in 11 years, while Bristol's spring race will be moved back a few weeks from mid-March to mid-April.

The west coast schedule comes after the season-opening Daytona 500 (February 22) and the second race at Atlanta. The series will then visit Las Vegas, Phoenix and Fontana on consecutive weekends in March – it will then head west again in August for the Sonoma road course race.

NASCAR explained that the location and timing was to help boost a growing fan base and make the most of sponsorship opportunities, saying it is: 'a big "west-coast swing" during the schedule's early stages [to] spotlight markets where NASCAR's fan base is growing and sponsor opportunities are on the rise.'

The 2015 NASCAR Sprint Cup Series will also include two standout non-points races – the Sprint Unlimited on February 14 at Daytona and the 31st annual NASCAR Sprint All-Star Race at Charlotte Motor Speedway on May 16.

The NASCAR Xfinity Series (the new name for Nationwide, see separate story) will once again contest 33 races, while the NASCAR Camping World Truck Series increases to 23 events, including an additional race at Atlanta.

Brian France, NASCAR chairman and chief executive officer, said of next year's Sprint Cup, Xfinity and Truck calendars: 'The 2015 NASCAR national series schedules promise to provide our fans with the compelling competition and storylines they so richly deserve. These enhancements to our race dates, particularly in the NASCAR Sprint Cup Series, will be of benefit to our fans and other stakeholders in our industry.'

Audi Sport facility opens for business

Audi has officially opened its new motorsport base, complete with its own bespoke 3.4km test track.

The new facility is located in Neuburg, Bavaria, 20km from the organisation's long-time headquarters in the city of Ingolstadt. The facility is spread across 47 hectares and Audi Sport will be moving in before the end of this year, with Audi Sport Customer Racing following in the first half of 2015.

The new 'Competence Centre Motorsport', which is 300m long and 100m wide, includes workshops, a test-bench facility and a warehouse/logistics hall, as well as the main building housing the engineering offices. Race engines will continue to be built at Audi's Neckarsulm plant. Audi Sport boss Dr Wolfgang Ulrich said building a new HQ had been a long-held ambition of his. 'Relatively soon after I started as head of motorsport at Audi 21 years ago, discussions about a centre of our own began. The former supermarket we were located in was always just intended to be a provisional facility. The aim was to find a location in Ingolstadt and to be close to [the] Technical Development, TE.

'But Audi kept growing during this time,' continued Ullrich. 'As a result, it became increasingly difficult to find facilities in Ingolstadt. When the opportunity in Neuburg arose, we realised that it provided many advantages and accepted that we wouldn't be in immediate proximity to TE. However, we shall obviously continue to be closely associated with TE in organisational and technological respects.'

Ulrich added that the new facility offered a number of advantages over its present base, not least of which has to be the 3.4km test track on which it can privately test its race cars. 'We now have adequate grounds and perfect facilities to set ourselves up. Personnel can now be accommodated in accordance with our operational processes – that wasn't always the case in the past. In the future, various functions that are distributed to Audi Sport and individual TE departments today will be concentrated at a single complex here in Neuburg. The fact that we now have a track for initial functional tests of our racecars directly on our doorstep is another advantage.'

IN BRIEF

Holden out for more

Australian GM brand Holden has signed a multi-year extension to its works deal with Holden Racing Team (HRT) in the V8 Supercars Championship. Next year marks the 25th anniversary season for the partnership, which has secured six V8 championships (including those when it was known as Australian Touring Cars), seven victories at the Bathurst 1000, and more than 200 race wins – a record in the premier Australian motor racing series. HRT is also the only team to have won championship races in Australia, New Zealand, China, the UAE and Bahrain.

Jaguar's lair

Jaguar Land Rover (JLR) has announced it is to base its new Special Vehicle Operations Technical centre at Ryton, near its historic Coventry base. The centre will be the 'global centre of excellence' for developing the company's 'extreme' performance vehicles and bespoke high-end luxury commissions. JLR tells us £20m is earmarked to kit out the facility with equipment, a customer commissioning suite, and F1-inspired flexible workshops. A team of 150 Jaguar and Land Rover specialists will work at the base, which is at Prologis Park in Ryton, and JLR says 100 of these jobs will be new.

Williams blames £20m loss on ‘ambitious’ push for pace

Williams has explained away a £20m loss for the first part of 2014 by pointing to the sustained investment programme that has returned it to the front of the F1 grid.

The Grove-based company’s interim results showed losses of £20.7m for the F1 team and £18.8m for the group as a whole over the first half of 2014. Losses have been partly put down to an increase in engine costs of £8m, after the team switched from Renault to Mercedes this year, plus the loss of the PDVSA sponsorship that former driver Pastor Maldonado took to Lotus.

But Williams says the decision to invest in the future of both the team and the group is the main reason behind the negative results. Group chief executive officer Mike O’Driscoll said: ‘At the beginning of the second half of last year we began an ambitious strategy to rebuild the Formula 1 organisation, develop a strong Advanced Engineering division, and divest non-core operations. We have already made substantial progress towards our objectives. This strategy has required significant investment, as illustrated by our first-half results, and it is anticipated that this will also impact the full year results.’

XPB

Williams has shown great pace in 2014 but its improvement in form has come at a multi-million-pound cost

O’Driscoll added that new partnerships have now put the team in a far stronger position, which has been reflected in a flurry of podium finishes this year: ‘After a number of disappointing seasons, our Formula 1 team has been significantly strengthened across all key functions. Our long-term power unit supply agreement with Mercedes provides strength and stability. As a consequence we have made a significant step-change in our on-track performance. We have also made great progress commercially, underscored by our title partnership agreement with Martini.’

Despite the losses the future for Williams appears bright. It now seems likely to secure more financial support on the back of its on-track success this year, while it is also in the running for £14m in increased commercial rights revenues from Formula 1.

McLaren Group increases profits and revenues in 2013

Despite enduring a tough time on track during the past two seasons the McLaren Group has posted an increase in both profits and revenues for last year.

The headline figures in the group’s recently published 2013 accounts show a total group turnover of £268m – an increase from £249m in 2012 – revenue up 7.5 per cent, a pre-tax profit of £18.8m, and an operating profit of £22.5m.

Much of the profit was generated by McLaren applying its technology in new markets, although it tells us it has also seen increasing income from sponsorship and F1 prize money – despite a less-than-competitive performance on the race track these past two seasons.

Ron Dennis, chief executive and chairman, said: ‘McLaren has a long-term strategy to diversify the business by capitalising upon our world-class expertise and technology to target a wide range of industries outside Formula 1. That approach is already helping us to increase revenues and, combined with improved income from Formula 1, demonstrates that McLaren is on a solid financial footing and is well placed to achieve significant long-term growth.’

Dennis added: ‘Sadly, strong financial performance during 2013 was not matched by on track success. However, McLaren has a proud and victorious record at the pinnacle of Formula 1 and I am confident that the actions we are taking will enable the team to regain competitiveness in time. Our growing revenue and robust financial position will ensure that McLaren Racing has the resources it requires to win races, while enabling us to develop and expand the entire McLaren Group as an internationally recognised technology company.’

XPB

Ron Dennis says diversification and improved F1 income are driving McLaren’s business success

IN BRIEF

UBS set to scale-back F1 backing

According to reports in Switzerland one of Formula 1’s major sponsors, the financial services giant UBS, is planning to scale back its spend on the sport. The Swiss-based global company entered F1 in 2010 after an agreement was made with Oswald Grubel, its then chief executive, and Formula One Management (FOM). But in the four years since, UBS has appointed a new CEO, Swiss banker Sergio Ermotti, who instigated a review into the company’s F1 sponsorship in 2013. Swiss newspaper *Blick* has now reported that UBS is to end its title sponsorship of the Chinese Grand Prix and will also cut back on its annual trackside advertising spend at all races, from $54m now to $32m next season.

Test cap

IndyCar teams are now limited to just 14 test days and no in-season test days whatsoever under new legislation that aims to reduce costs in the top US single-seater series. The new restrictions, that came into force at the end of August and will be in force until September 2015, are applicable to engine manufacturer tests, open tests and full-size windtunnel testing. Those taking part in the full season will be capped at 10,000 miles for all track running – this will apply from the first race of 2015 until the end of the season – although provisions will be made for new teams and drivers, and for tyre tests.


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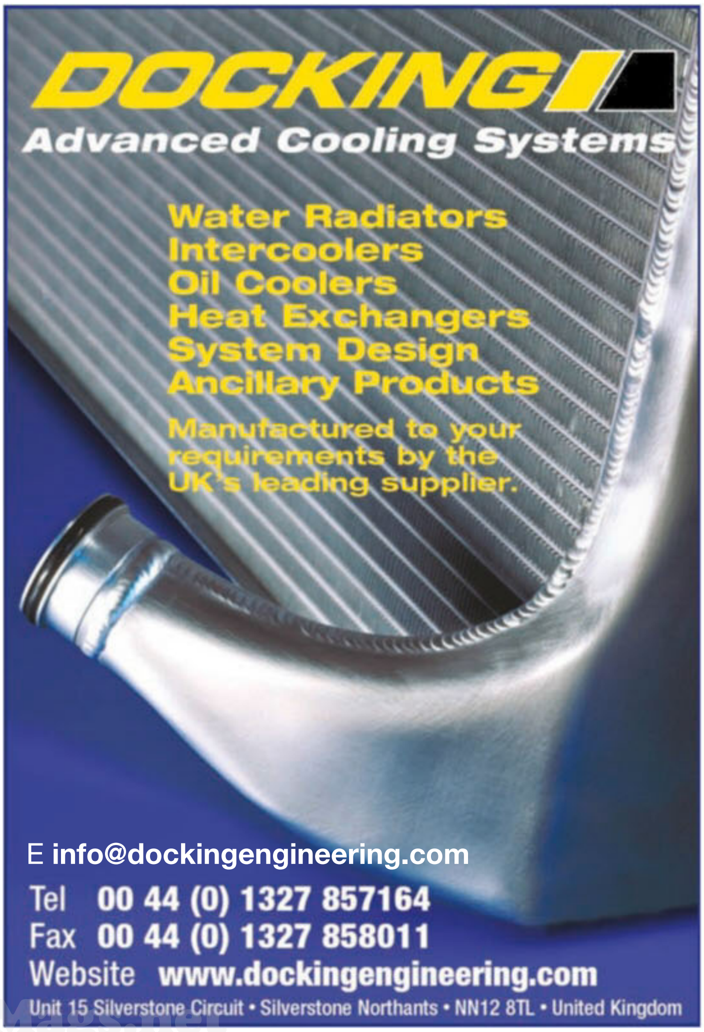
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NASCAR goes from Nationwide to Xfinity and beyond

NASCAR's Nationwide series will gain a new name next season as the Xfinity internet provider comes on board as the title sponsor for the second tier US national stock car series.

The NASCAR Nationwide Series will be known as the Xfinity Series from 2015

The deal was struck with Xfinity owner Comcast, and Xfinity now becomes just the third title sponsor of the series in its history – Anheuser-Busch was the first. The tie-up is set to run for 10 seasons, taking the NASCAR Xfinity Series, as it will now be known, through to 2024 – the longest title sponsor agreement in NASCAR's history.

While the financial details of the deal have not been made public, analysts in the US have valued it at around £123m ($200m), part of which is £6.1m ($10m) in marketing Comcast was already obliged to spend through its share of a 10-year, £5bn ($8.2bn) TV contract – Comcast also owns NBC, which will share NASCAR broadcasts with Fox from next year.

Xfinity is Comcast's residential service and the United States' largest video and high-speed internet provider. Comcast itself is the biggest broadcasting and cable company in the world by revenue and the largest cable company and home Internet service provider, and third largest home telephone service provider, in the US. Revenues for 2013 were $56bn, with a net income of $6.8bn.

Dave Watson, executive vice-president and chief operating officer for Comcast Cable, said of the deal: 'Technology lives at the heart of NASCAR, just as it does for Xfinity. NASCAR provides an exciting environment in which to showcase our video and Internet products and we look forward to further enhancing the fan experience at home, at the track and on the go for years to come.'

Brian France, NASCAR chairman and CEO, said: 'We're proud to welcome Xfinity to the NASCAR community as title sponsor of the NASCAR Xfinity Series for the next decade. NASCAR and Xfinity are each leader brands with much in common. Both are focused on innovation and have products built for speed. Together, we will work to take this series to new heights and elevate one of the most unique and powerful partnerships in all of sports.'

Melbourne's Formula 1 race posts record losses

Just a month after securing a five-year deal to keep the Australian Grand Prix in Melbourne the Victoria State Government has posted a record loss of £34.2m for the 2014 race, the bill for which will now have to be picked up by tax-payers.

This is the largest loss in the Melbourne race's 19-year history and it's compounded when the cost for the 2013 Australian Motorcycle Grand Prix – which was held at Phillip Island – is taken into account, bringing the total loss up to £40.5m.

The £5.3m increase in the amount paid out for the F1 race in 2014 has been put down to the increased cost of staging the event and also a decline in ticket sales. Victoria's tourism and major events minister, Louise Asher, said: 'Our sales revenue is down $2m (£1.1m) and our expenditure is up $7.5million (£4.3m).'

The Victorian government justifies the grand prix on the grounds of the economic benefits it brings to the state – which it estimates at £22.2m – and the value of the media coverage for Victoria and for Melbourne which the race generates – said to be worth £19.9m.

Industry insiders say the rights to hold the Australian Grand Prix costs Victoria around £21.5m, which makes this the seventh most expensive race on the Formula 1 calendar.

This year's Australian Grand Prix cost Victoria State tax-payers over £30m

CAUGHT

Joel Shear, the crew chief on the Haas Racing Development No.00 Chevrolet in the NASCAR Camping World Truck Series, has been fined $5000 after the truck he tends failed to meet the post-race height requirements at the Bristol Motor Speedway round of the championship. Driver Cole Custer and team owner Gene Haas were both docked 10 points in their respective championships as a result of the infraction.
FINE: $5000 PENALTY: 10 points

Also found to be running at the incorrect height at the Bristol truck counter (see above) was the No.19 Ford run by Brad Keselowski Racing. Crew chief Doug Randolph was hit with a $5000 fine while team owner Brad Keselowski was penalised with the loss of 10 owners' championship points.
FINE: $5000 PENALTY: 10 points

The No.30 Turner Scott Motorsports Chevrolet was the third truck to fall foul of the post-race height checks at the Bristol Motor Speedway round of the NASCAR Truck Series. Crew chief Doug George was fined $5000 while team boss Steve Turner lost 10 points in the owners' championship and driver Ron Hornaday Jr. was docked 10 points in the drivers' championship.
FINE: $5000 PENALTY: 10 points

SPONSORSHIP

The No.16 Roush Fenway Racing Ford, driven by Greg Biffle in the NASCAR Sprint Cup Series, will sport primary sponsorship from Ortho Insect Control for half of the 2015 Cup races. The news came shortly after it was announced that Biffle's long-time primary sponsor, 3M, was switching its backing to Jeff Gordon (Hendrick Motorsports) next year.

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New Cosworth facility to create 70 jobs and apprenticeships

Cosworth, the world-renowned performance engineering and manufacturing group, has confirmed that its flagship £22m Advanced Manufacturing Centre (AMC) is on target for completion in January 2015.

The building's structure is complete and work is underway inside of the facility that will start fulfilling contracts with three automotive vehicle manufacturers. These partnerships will provide Cosworth with a projected order book of £75m.

Cosworth's new facility will be completed in January 2015

The new state-of-the-art 38,000 square foot facility, which is being developed with support from local and national government, will house an advanced flexible manufacturing system capable of producing complex machined components for high-performance limited production road vehicles.

Located in the Waterside Enterprise Zone in Northampton, adjacent to Cosworth's existing St James Mill Road site, the new facility will create around 70 new jobs and apprenticeships. Although the headquarters is in Northampton, the company employs staff in Europe and the US.

The leading edge informatics and simulation systems that will play key roles in the AMC are being developed within Cosworth's Centre of Excellence for Niche Volume Manufacturing, which is supported by a grant from the UK Government's Advanced Manufacturing and Supply Chain Initiative (AMSCI).

In partnership with Cranfield University and Flexeye Ltd, the Centre will help OEMs bring new technologies and innovations to market by enabling the cost-effective manufacture of advanced components through the use of Flexible Manufacturing Systems.

'Cosworth is uniquely positioned to provide complete powertrain consultancy, component manufacture and engine assembly services for vehicle makers seeking to create high performance vehicles,' says Hal Reisiger, Chief Executive of Cosworth Group Holdings. 'Our Advanced Manufacturing Centre is a striking example of the strategic focus and investment that is developing our business with global automotive OEMs. The new facility will enable us to begin work on new contracts with three automotive manufacturers. We have restructured Cosworth's business over the past 18 months to support delivery of a new business strategy, focusing on automotive OEMs, motorsport and the performance aftermarket. The completion of the AMC will allow Cosworth to enter an exciting new period of growth.'

Goodbye Zytek Engineering... Hello Gibson Technology Limited!

Leading UK motorsport and powertrain specialist Zytek Engineering will officially embrace its new company name and branding from October 1 2014. Following the separation of the Zytek Group of companies during 2014, Zytek Engineering Limited will change its name to Gibson Technology Limited, leading to a re-name of all future products. Zytek Automotive, based in Lichfield, Staffordshire, is now wholly owned by German company Continental AG.

Bill Gibson, founder of Zytek and owner of Gibson Technology, said: 'We are very excited about the new branding of the company but want all our customers and suppliers to understand that we have made these changes to clarify our identity following Zytek Group's separation and we can assure them that everything else here at Repton will remain totally unchanged. I intend to ensure that we remain at the forefront of the motorsport world, in both current and new technologies.'

Gibson Technology's core motorsport activity will continue to be the design, production and support of LMP2 racecars and engines, with which it won the 24 hours of Le Mans this year, and also supplying teams in the World Endurance Championship, TUSCC and the ELMS. In addition, they design, manufacture and maintain the 530 bhp V8 engines to the entire Renault World FR3.5 Series, Auto GP and FA1 Championships and will shortly be announcing some other new projects.

SEEN: Lada Vesta

Lada revealed its 2015 World Touring Car Championship contender at the Moscow motorshow in late August. The new car, called the Vesta, is aimed at moving the Russian brand, something of a WTCC also ran, up the grid so it can challenge Honda and Citroen.

Compared to its predecessor and LADA's current WTCC racer, the Granta, the new Vesta has a longer wheelbase and more efficient aerodynamic package. Autovaz (LADA) will also race Vesta's in the Russian Touring Car Championship.

NASCAR briefs

Wood Brothers Racing have formed a technical alliance with Penske Racing ending it's same agreement with Roush Fenway Racing at the end of 2014. With the alliance, Wood Bros will field rookie Penske contracted driver Ryan Blaney in the famed number 21 Fords next year. Engines will continued to be supplied by Roush Yates, but chassis and bodies will be supplied by Penske along with engineering help.

Ten NASCAR Sprint Cup teams tested six different aerodynamic configurations at Michigan Speedway following the August race at the two-mile track with the idea of utilizing the information gained for the 2015 Gen-6 rules package. Several 15-lap mock races were held with the different set ups, with cars running in single and double file formations. In addition different horsepower levels of 750, 800 and 850 bhp were tested using restrictor plates. A second test is a possibility for the end of the year at Charlotte Motor Speedway.

Race Team Alliance, Inc. has expanded its membership to 18 full-time NASCAR Sprint Cup teams, comprising 37 full-time entries in the Series. The only full time team not to have joined the RTA, which was formed in July, is Denver Colorado based Furniture Row Racing. Teams that don't currently run the full 36 championship race series could be brought into the fold at a later date with the formation of Associate Memberships within the RTA.

INTERVIEW – David Brabham

Brabham is back!

The Le Mans 24 hours winner is breaking new ground, putting an LMP2 team on-track via a portal inclusive of fans, engineers and drivers

By ANDREW COTTON

"The Brabham name has a lot of strength in it, but it is still working in the same tough business model"

Mention the name Brabham, and immediately people delve into their own memory banks. Some remember Sir Jack Brabham who, in 1966, became the first and only man to win the Formula 1 World Championship in a car of his own construction. Others think of his two sons, Geoff and David, who won the Le Mans 24 hours for Peugeot. Now, David is about to turn that history into a new future with a digitally-driven programme that will see a team on track at Le Mans with an LMP2 car, and has a longer term plan to go to LMP1 and ultimately, Formula 1.

Openness and transparency will be at the core of the new Brabham Racing team. Giving fans unrivalled behind-the-scenes access will, says David, provide a greater racing experience, incredible insight and knowledge about the team and the wider sport, while Brabham also plans to inspire drivers and engineers across the globe.

Brabham Racing together

Central to the team's return is Brabham-Digital; three immersive web applications comprising Brabham-Fan, Brabham-Driver and Brabham-Engineer. The advanced portal will allow members to engage with Brabham on a new level, to live, breathe and learn through the highs and lows of creating, managing and sustaining a professional racing team.

Members of Brabham-Fan will interact and contribute towards collaborative decisions in a way no racing team has attempted before, in turn tapping into the power of collective thinking. Brabham will share everything from its investor search, driver selection process and building its premises, to the first car build, test and race. On race weekends Brabham-Fan will become the gateway for live telemetry, behind-the-scenes footage, radio communications and even race strategy. Brabham-Driver is for those who want to know what it takes, technically and professionally, to become the ultimate racing driver. Via online training, Brabham will provide the means to develop car set-up, learn how to develop a winning mentality, get advice from nutritional experts and sports psychologists, and receive training regimes from specialist coaches.

Brabham-Engineer will involve the community in the development of the team's racing technology while providing a series of e-learning modules around what it takes to reach the pinnacle of motorsport engineering. Project challenges will cover all aspects of aerodynamics, CFD, suspension geometry and gearboxes, where members can get involved in the development of specific parts or even a future Brabham prototype, with certification of their achievements.

Through the Brabham-Digital portal, members will become an essential part of the team's journey back to victory and share in its collective success. Brabham crowdfunding supporters can be the first to sign-up and get lifetime access to just one or all three of the Brabham-Digital web applications through various packages on the Project Brabham Indiegogo crowdfunding page http://igg.me/at/project-brabham

Stretching people's thinking

'When I was racing, people would ask would you do a team, and a lot of people said I would be a good team manager, but there was always something holding me back and I couldn't figure out what that was,' says David Brabham. 'One thing that I found out driving for teams for 31 years, and looking at how the current model of how a race team operates, it is a tough business. A lot of teams are struggling financially and why would I want to go into that arena? The Brabham name has a lot of strength to it, but it is still working in the same model.

'I thought about whether or not there was another way of doing that. I put a team together to see if we could explore and see if this might work, and here we are. I have a real conviction and confidence that this is the way to go for Brabham.

'Nearly nine years ago I said to Dad that we don't do anything with the name, and when we realised that we didn't own all of it I had to get it back because I couldn't do anything with the name until we had full control. We went through the process, it was long, but ownership came through on December 25, 2012, and then the momentum started to build and we had the confidence. We had to understand it. We did a 12-15 month branding exercise to understand what the name meant to them, one of the consistencies that people said were what people said when Dad died – inspirational, pioneering, innovative, engineering. We took that and thought if we build something and go into racing, we need to have these elements to it as our core values and the way that we do things. This is different, it will stretch people's thinking, but as soon as we started to look

Interacting with the Brabham-Digital portal will allow members to be part of David's ambitious racing plans at becoming open and transparent, and use the race team as a vehicle for people to learn and experience differently, it has opened up a world of opportunity, particularly commercially.

'People are more receptive to it because of that. We are building a community first, getting people behind project Brabham. People can buy packages in terms of experiences, learning modules for fans, drivers and engineers. We have done the research with people in different markets, got their feedback on what we are doing and the response has been fantastic. If we can generate interest in getting the Brabham name back and get people access through learning modules for drivers, budding engineers and we can provide them a learning environment, all of a sudden, companies get interested because they see the reach you can potentially get. As a race team you are fighting everyone else trying to do the same thing. I can see so many more advantages to doing it this way.'

The team is looking at raising the money to buy an LMP2 car and engine for next year, and David says that the team has the support of the ACO. Whether or not it has an entry for the Le Mans 24 hours, traditionally a major source of revenue for a team, is part of the challenge.

'We would like people to be part of the journey, not only bringing the name back but participating in it, and that then becomes a big project,' says Brabham. 'We cannot do anything unless we get the money. Let's build the community, get people behind it, get crowdfunding, and once we have built the community, it is easier for us to go to investors with numbers, and prove that there is an appetite for this. This is not just for engineers, this can be for people studying human performance.'

There are others chasing this same market – Nicolas Perrin has an established project underway and is seeking to go straight into LMP1 with his project – but with the Brabham name behind it, David is hoping that he will have the money together quickly enough to race next year. Whether it is for the first or last race of the year, it is all about sustainability.

'It all depends on how much money is raised. If we don't make the first one, as long as I have a model in place that is sustainable, then whether we start in March, June or September, this is a long-term programme.' Going forward, the sustainability for the project will come from subscriptions, from drivers, fans and engineers all buying the packages. 'We don't know what a subscription is going to cost yet, but that is part of the journey. There is a path down the road, we are not sure what it is going to look like but if we work together we can make it happen.'

RACE MOVES

XPB

Christijan Albers has stepped down from the post of team principal at the Caterham Formula 1 operation after just two months in the job. The former F1 driver said his sudden departure from the team was for 'private reasons'. Albers will be replaced by Manfredi Ravetto, who was previously his deputy.

Sebastian Vettel will have a new race engineer in 2015, with **Gianpiero Lambiase** – who is moving to Red Bull from Force India – taking over from **Guillaume Rocquelin**. Rocquelin, more commonly known as Rocky, is to move up to the post of head of race engineering at Red Bull next year.

Ernie Cope is to be the crew chief on the No.9 JR Motorsports Chevrolet in the NASCAR Xfinity (formerly Nationwide) Series in 2015. Cope replaces **Greg Ives** in the role – Ives is moving up to the Sprint Cup to crew chief for **Dale Earnhardt Jr** next year. Cope started his career as a NASCAR crew chief in 1997 and has experience in all three of its national series.

The 'Run that Track' charity, which sees members of the Formula 1 paddock running around each grand prix circuit in the evenings after practice and qualifying, has broken through the $1m barrier in terms of money raised. The four-year-old initiative was set up by McLaren engineer **Simon Morillas**. For every timed lap run, F1 sponsor UBS donates $100 to the Make a Wish Foundation.

Infiniti has appointed **Tommaso Volpe** as its new Formula 1 global director and he will now be responsible for those activities of the Nissan luxury arm based around its title sponsorship of the Red Bull F1 team. Volpe comes to Infiniti from Lotus Cars and succeeds **Andreas Sigi** in the F1 role, who moves to another job within Infiniti.

Former McLaren F1 team boss **Martin Whitmarsh** has now officially parted company with the Woking group. Whitmarsh lost his place at the head of the F1 team at the start of this season, with **Eric Boullier** coming in as racing director and **Jonathan Neale** taking the position of Group F1 CEO, but he had remained under contract until a settlement was reached.

Former racing driver, team boss and engine constructor **Martino Finotto** has died at the age of 80. Finotto raced self-run entries in touring cars and sportscars while his CARMA organisation also built a bespoke four-cylinder turbocharged engine for Group C Junior in the early 1980s.

Jean Marchioni is now general manager of Multimatic's European Technical Centre in Thetford, Norfolk (UK). Marchioni joined the Canadian motorsport and automotive engineering company from Lola in 2012.

Multimatic has appointed **Nick Langley** to head up its European motorsport business activities. Langley has previously held senior commercial positions at Dallara, Lola Cars and, most recently, Zytek.

The head of Nissan Motorsport's V8 Supercar team, **John Crennan**, has stepped down from his role as CEO at the **Todd** and **Rick Kelly**-owned outfit. The move is part of what was a planned phasing out of the position, which he had held for the past four years.

Bjorn Waldegaard, who won the inaugural drivers' World Rally Championship, has died at the age of 71 after losing his battle with cancer. Waldegaard, a driver especially well-known for his expertise in, and love of, African-based rallies, retired from topline competition in 1992.

It's been reported that **Jimmy Fennig**, the crew chief on the No.99 Roush Fenway NASCAR Sprint Cup car, will be calling time on his career on the pit wall at the end of this season, although he intends to stay on with Roush Fenway in another role. Fennig started out as a crew chief in 1986.

OBITUARY – John Crossle

John Crossle, a man perhaps best known for the series of successful Formula Ford cars that bore his name, has died at the age of 82.

Crossle operated his eponymous racecar business from Hollywood in his native Northern Ireland from 1957, before selling it on in 2002. While the company made its mark with Formula Ford, Crossle's first foray into the world of racecar building was with a Ford-powered special which he raced himself. Such was the pace of the home-built car that subsequent demand for replicas gave birth to the Crossle marque.

After a succession of front- and rear-engined racers for local competition, there came a number of sportscars, which found success both at home and abroad, and big-power single seaters such as the 12F, which went well in Formula B in North America.

When Formula Ford arrived in 1967 Crossle built the successful 16F, the first of a long line of Crossle FF1600s, while the company was also able to establish itself as a supplier of school cars, its 30F and 32F mainstays of both the Skip Barber and the Bob Bondurant racing driver schools in the USA.

After selling the company to long-time customer Arnie Black in 2002 – it was sold on again to Paul McMorran in 2012 – Crossle concentrated on producing sporting trials cars and spending much of his time tending his beloved collection of vintage farming machinery, although he also always remained involved with the company that he founded.

John Crossle 1931-2014

OBITUARY – Len Terry

Len Terry, the man who changed the face of the Indianapolis 500 and also created one of the most beautiful single-seater racecars of all time, has died at the age of 90.

Terry started his engineering career in the RAF during the Second World War and then went on to work in various engineering jobs throughout the 1950s, before he began racing as a hobby in 1957.

After working on some collaborative build projects, his first full racecar design was the Terrier Mk1, which he campaigned himself in Clubmans 1172cc racing, before moving to Lotus to work full time. His first stint at the legendary constructor lasted until 1959, with Terry working as the company's senior designer before Lotus founder Colin Chapman fired him – both strong personalities, their working relationship was seldom a bed of roses.

After waving goodbye to Lotus Terry joined Gilby Engineering, working on its sportscar and Formula 1 projects, the latter appearing in 1961 and 1962 – a car that hardly set the world alight yet was highly regarded within the paddock.

Terry returned to Lotus at the end of 1962, following the closure of the Gilby concern, and from then until he left again in 1965 he worked on some of the marque's greatest cars, including the Indianapolis 500-winning Lotus 38. With Jim Clark at the wheel in 1965 this was the first mid-engined car to triumph at the Brickyard, and it is said that Terry conceived and designed the 38 almost single-handedly, and within four months.

He went on to work for Dan Gurney, designing the Eagle T1G, which was not only one of the most aesthetically pleasing racecars ever built, but also a grand prix winner (Belgium, 1967).

Terry finished his Formula 1 design career at BRM in 1977, but throughout the late 1960s and the 1970s he was involved in a number of projects outside of F1, including the BMW 269 F2 car, an F5000 for Surtees, and the Gulf Mirage sportscars.

Until his retirement Terry concentrated on contract design work, but more recently he had been involved with Classic Team Lotus and he even helped out with its restoration of the Lotus 38 he and Jim Clark made famous at Indy back in 1965.

Len Terry 1923-2014

RACE MOVES – continued

XPB

Emilio Botin, the chairman of Santander and the man behind the bank's high profile Formula 1 sponsorship, has died at the age of 79. Botin brought the Spanish bank into F1 in 2007, and it is now involved with Ferrari and McLaren, while it is also title sponsor to a number of grands prix.

Andy Palmer has left Nissan, where he was chief planning officer and effectively number-two in the organisation. He has now joined Aston Martin as its new CEO. Palmer is believed to have pushed for the Nissan LMP1 project, which hits the tracks next year, and he is known to be a motorsport enthusiast.

Turner Scott Motorsports has closed down its No.30 NASCAR truck operation, a move that has led to the laying off of 18 staff within the organisation. The company will continue to campaign its other entries in the series, as well as its cars in the Nationwide and the K&N championships.

Beaux Barfield has left his position as race director at IndyCar to take on the same role at IMSA, the body behind the United Sportscar Championship (USC). Barfield was previously race director for the American Le Mans Series (from 2008 until 2010), which merged with GrandAm to form the TUSCC.

Andre Dietzel is the new head of communication and marketing at Volkswagen Motorsport. Dietzel has filed the role in an acting capacity since March, and has been with the VW Motorsport PR department since 2005.

From next year **David Sonenscher** is to take charge of the TC3 Asia Series, a new touring car category that is a spinoff of the upcoming 2015 global TC3 initiative. Sonenscher has a good track record in Asia, having run the Asian Touring Car Series from 1997 until the end of 2011 through his company, Motorsport Asia, which also promotes the GT Asia Series and Porsche Carrera Cup Asia.

Steve Phelps, NASCAR's executive vice president and chief marketing officer, has been given a wider role in the organisation and now leads the company's operations in Charlotte, North Carolina. Phelps, who continues to report to NASCAR chief operating officer **Brent Dewar**, retains all of his previous responsibilities.

Steve O'Donnell now heads NASCAR's Research and Development Centre in Concord, North Carolina. He oversees all operations at the facility, including Racing Development and Innovation, as well as Competition. In addition to his new responsibilities O'Donnell will continue to oversee Racing Operations, Industry Services, Green Innovation, Touring/Weekly Series and Membership Services.

Gene Stefanyshyn, who leads NASCAR's Racing Development and Innovation group, and **Robin Pemberton**, who heads the Competition department, have been promoted to senior vice president. They will report to **Steve O'Donnell**. **Tom Swindell** will work with O'Donnell in Concord on short and long-term projects.

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

Sensors
Kistler Instruments range

Kistler Instruments has added to its range of sensors and systems. The maXYmos XY monitors make it possible to check and evaluate the quality of all manufactured products on the basis of a force-displacement curve. The user can apply evaluation objects to adapt the curve evaluation to the individual monitoring task. Based on this specification, the maXYmos can check each workpiece and decide whether the part is good or bad.

The new maXYmos NC (Numeric Control) replaces the widely-used Kistler DMF-P force/displacement monitoring device and is a development of the well proven Kistler maXYmos technology designed specifically for use with the Kistler NCF servo actuators. The colour touchscreen used with the menu structure, PLC communications and improved data export facility.

The Kistler KiBox To-Go provides a complete combustion analysis system for mobile and test bed applications. Building on its extensive engine testing and analysis experience, Kistler Instruments developed the KiBox mobile engine combustion analysis system, which integrates with other mobile systems for ECU development and diagnostics.

The KiBox system is compatible with PiezoSmart and TEDS (Transducer Electronic Data Sheet) sensor identification to simplify set-up and operation. Automatic plausibility checks guarantee prompt measurement availability and high-quality data. Using the signals from the vehicle's sensor, CrankSmart technology provides TDC (top dead centre) crank position to an accuracy of better than 0.1 degree with automatic error indication for both diesel and petrol engines. This simplifies installation and maintenance by eliminating the need for a separate optical crank angle encoder.

www.kistler.com

Transmission
Weddle Racing R&P

Weddle Racing has a heavy duty LQ R&P set with one-piece pinion shaft available. The standard LQ pinion shaft is a two-piece unit, prone to fatigue cracks at the weld. All Weddle Racing R&Ps are made from a proprietry specification, fine grain vacuum-melt steel, each bar of which is ultrasound tested for internal defects prior to machining. All Weddle Racing R&Ps go through a special multiphase heat-treat and cryogenic process that greatly increases tooth strength and fatigue resistance. Finally, Weddle Racing R&Ps are deburred, shot-peened, and precision ground to combat fatigue and increase gear life.

www.weddleindustries.com

Electrical
Automotive and wiring tool

Cadonix, a specialist in electrical design and project management software for the automotive industry, has launched the world's first cloud-based CAD tool for automotive and electrical wiring design, analysis and report documentation. Arcadia was developed from scratch, and designed with ease of use in mind. The first sale of Arcadia has been made to one of the leading global manufacturers of cabling systems for the automotive industry, AQ Wiring Systems.

Arcadia CAD is an easy-to-use, ground breaking software tool offering schematic design, animated circuit simulation and analysis, electrical networking, harness design and full design rule checking for wire harness layout and manufacture.

Using the integrated simulation capabilities, engineers can be assured that their design intent is carried through into the physical implementation. Arcadia interfaces with the most popular 3D MCAD and enterprise wide PLM and ERP tools, allowing projects to transition easily and smoothly into manufacture. A particular strength of Arcadia is real-time animated simulation which paints a clear virtual picture of the electrical system and how it will behave in deployment. Using Arcadia's simulation capabilities, engineers can be confident that the design will work as intended – eliminating the need for a physical prototype. Any errors are trapped early in the design process, reducing the design cycle and improving design quality.

Using Cadonix-patented cloud based technology customers can access Arcadia from any HTML5 compliant web browser once the license has been activated on the server. Customers have the option of hosting the tool on their own internal server, or accessing it securely from a Cadonix geographically collocated server.

www.cadonix.com

Acoustic
Microphone sets

GRAS UK is a newly formed subsidiary of Denmark-based G.R.A.S Sound and Vibration and will be highlighting its range of acoustic front end products for the precise and reliable measurement and recording of acoustic signals. These include microphones, pre-amplifiers and signal conditioning devices.

The company's 46AE microphone sets are manufactured from stainless steel to ensure superior stability and less sensitivity to fluctuations in temperature. The 46AE is a plug and play IEEE 1451.4 accredited system. The underlying mechanism for plug and play identification is the standardisation of a Transducer Electronic Data Sheet (TEDS1).The 46AE sets are IEPE/ICP compatible which means that they can be connected direct to a range of front ends for easy setup.

www.acsoft.co.uk

Suspension
DW12 pushrod loadcells

Front and rear IndyCar DW12 pushrod loadcells are going to be really relevant with the introduction of the aero kits for the DW12 in 2015, and the fact that the teams will be relying on good quality data from their suspension loadcells more than ever to get to grips with these aero kits.

The bf1systems DW12 front and rear pushrod loadcells have been designed from scratch to be an instrumented suspension component incorporating bf1systems' microprocessor controlled Intelligent Amplifier to provide accurate data unaffected by ride height or temperature changes.

The fact that the part has been designed from the outset to be an instrumented, coupled with the Intelligent Amplifier which is mounted inside the loadcell, (and therefore measures the strain gauge temperature directly, applying a correction at each temperature step for offset and span errors in the calibration), means that the bf1systems push road loadcells have gain errors of only ± 0.2 percent over their full operating temperature range, while the standard parts that teams have had to previously use exhibit gain errors of up to 5 percent in comparable conditions.

As well as offering far higher levels of accuracy than the standard DW12 loadcells, the bf1systems parts come with standard calibrations for front and rear parts, meaning that if a part is swapped on the car, the team know that the new part they will be fitting to the car will contain the same calibration, meaning that the calibration in the logger does not need to be changed, saving the team time. Each part is individually calibrated at bf1systems in a computer-controlled calibration rig, over a full load and temperature range.
www.bf1stysems.com

Brakes
Kit car pedal box

Obp Motorsport has released a new version of its kit car pedal box. The V2 has an aluminium billet brake pedal with adjustable billet pads, an aluminium billet clutch pedal, also with adjustable billet pads. The brake pedal ratio is adjustable from 4.9:1 to 5.24:1, while the pedal pads are adjustable up and down, side to side brake and clutch pedal pads. It features a strong and rigid box with a 25mm by 25mm cut out for the chassis rail.
www.obpltd.com

From Formula 1 to E

The Autosport Engineering Show nurtures the traditional basics of racing and once again will make this the event that keeps its feet on the ground

The Autosport Engineering Show, held in association with *Racecar Engineering*, has become a traditional place to start the racing year. While the attention of the racing world has focused on the new technology, including hybrid and energy management, as Renault Sport's Rob White points out in this edition of the magazine, there is still a need for the more traditional skills, including engine builders, aerodynamicists and chassis designers.

Although great strides have been made with the introduction of this new technology in Formula 1, endurance racing and in Formula E, there are plenty more steps to be taken in years two and three as the technology matures and the performance between power units from different manufacturers narrows. Knowledge of the technology and the desire to find the 'unfair advantage' will still be critical to on-track success.

But, beyond racing, there is a need to transfer the technology into other sectors. Racing companies are developing wheels for the military, for example, and it is in this transfer that money is made that can keep a racing team alive. As fossil fuels become ever more scarce, the desire to find new solutions to our transport needs will become more pressing and prototype racing, be it Formula 1, LMP1 or the Land Speed Record, will find ways of experimentation.

You cannot get away from the basic engineering principles no matter how far you push the envelope. Within these pages, Ricardo Divila discusses the headache caused by using an organic material such as rubber to keep the car on the road in racing conditions, while Peter Wright looks at a new use for the Catesby railway tunnel, offering a more stable test platform for a car, be it production or racing, than a windy airfield more traditionally used for coastdown testing.

There are new ways of achieving the same goal – Nicolas Perrin and David Brabham are targeting a new approach to raising the money for their racing programmes, generating a fan base before the cars are even built and then marketing them through the digital media. The existing model of raising funds, either through driver or team sponsorship, is not appealing to teams looking to start afresh. A new way needs to be found, but there is still a need for basic marketing, just on a new platform.

Nicolas Perrin and David Brabham are targeting a new way to raise funds for racing

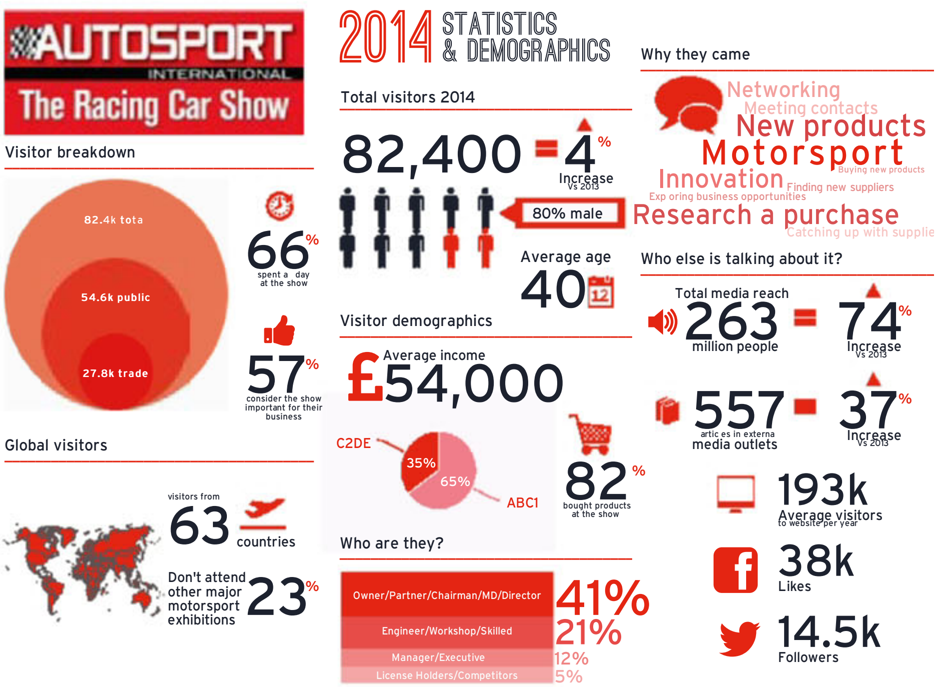
The Autosport Engineering Show has always been the meeting point for great ideas, and there will be opportunities at the show not only to meet with fellow racers, but also through companies such as the Motorsport Industry Association (MIA) the opportunity to go further. In September, the MIA's School of Race Engineering saw students introduced to the world of high-performance technology using Formula 1 simulation. Delegates used the Force India simulator, alongside a classroom environment, to learn from current race engineers. The MIA is highly active at the Autosport Show and is well worth a visit, regardless of whether or not you are a student or a compnay looking to make a new connection.

New cars, new technologies and sometimes new teams emerge from the depths of Birmingham's NEC. Of course, it is not necessarily the place to begin and end the discussion (unless it is a particularly brilliant programme and you are lucky enough to meet the right people), but it is a place to bring parties together. The 2014 show also had the Formula Student UK winning team, and trophy, on the stand to promote themselves, the IMechE, and to give the students valuable access to companies who might seek to employ them but whose schedules didn't allow them to see the British competition in July.

For more than two decades the show has been growing and developing and is now a fixed part of the motorsport year. This year, the Low Carbon Racing and Automotive show seeks to recognise the contribution made by racing companies towards environmental sustainability, a factor that reaches all parts of the sport, from composite materials to ICEs and hybrid systems.

Ian France, Autosport International Show Director, said: 'Over its 25-year history, Autosport International has established itself as the principal networking opportunity for companies, engineers, trade buyers and decision makers and 2015 looks set to be no different. There has been some stand-out moments over the years, including the unveiling of a ground-breaking all-electric prototype racing car by Drayson Racing Technologies, the introduction of the R40 concept car from Quaife, along with a host of other product launches that have since gone on to help change the face of the motorsport industry.

'With the introduction of the Low Carbon Racing and Automotive Show, along with the exciting range of exhibitors already signed up for Autosport Engineering 2015, the future of the show looks bright. We look forward to continuing to play a key role in helping to develop the partnerships that will help change the face of motorsport over the next 25 years.'



Q&A WITH MILLERS OILS

Millers Oils has provided support to a number of drivers and teams within motorsport for many years and Jason Lavender, business development manager of motorsport and classic at Millers Oils, is perfectly placed to discuss the industry and what the future holds.

Q. What are your thoughts on the need for the motorsport industry to continue to attract skilled talent and graduates?
A. Motorsport has traditionally been a platform on which vehicle manufacturers introduce next-generation technologies so it is crucial to continue attracting new talent. The key is to inspire innovation and R&D; the industry must continue developing fresh ideas and new technologies to keep people interested.

Q. What are you doing to attract and inspire the next generation of engineers?
A. At Millers Oils we believe in developing and providing innovative solutions to industry problems, frequently introducing new and exciting projects. This, along with our long-standing heritage in the lubricants sector, award-winning products and development of employees' potential and careers, helps to attract the new talent needed in the industry.

Q. How successful was Autosport International 2014 for Millers Oils?
A. The Millers Oils brand is continuously growing and Autosport International helps to get the name to a wider audience. The 2014 show enabled us to build relationships with existing customers and present the innovative products that were developed over the course of the year.

Q. Autosport International is celebrating its 25th anniversary in January 2015, what has been the most significant anniversary for Millers Oils so far?
A. In 2012 we celebrated our 125th anniversary and since then we have launched some of our most advanced and innovative products including our Nanodrive® range, which reduces friction without compromising film strength, reducing power loss and improving fuel consumption, available power and torque. In 2012 we also won the Queen's Award for Enterprise and the MIA award for Innovation, making this anniversary particularly special for us.

Q. Since the inception of Autosport International, the motorsport industry has changed considerably, what one element do you feel will change most over the next 25 years?
A. We feel that over the next 25 years the industry will see an increasing expectation for components and lubricants to work harder for longer, placing added pressure on suppliers to develop advanced technologies. Motorsport will also continue to adopt low carbon and renewable energy technologies at a growing rate such as Formula E, requiring suppliers to adapt to this and offer solutions quickly.

Q. With regard to engine performance, what do you feel has been the biggest technological advancement within the motorsport industry over the past few years?
A. The move towards combining hybrids and turbochargers in motorsport has introduced additional heat and transmission issues. With hybrid transmissions there is a huge level of torque involved, which increases the stress placed on the gearbox. Lubricants are required to work harder to address cooling issues and reduce gearbox component wear.

Q. What can we look forward to seeing from Millers Oils over the coming years?
A. We will be increasing our participation in motorsport over the next few years, nurturing up-and-coming talent and helping teams to exceed performance expectations by providing Nanodrive® oils that provide the power gains and durability improvements teams are looking for. This participation allows us to continue developing innovative products that are transferrable to more general road-going applications.

Q. What can we expect from Millers Oils at Autosport International 2015?
A. We are hoping to launch our innovative Flowcontrol® bottle into our popular motorsport range, allowing teams to top-up engine oils straight from the bottle with a reduced risk of spillage or contamination. We will also be announcing some new and very exciting technical partnerships.

AUTOSPORT INTERNATIONAL Engineering Show
8 - 9 January 2015 NEC Birmingham, UK
In association with Racecar engineering

International appeal

Autosport International has lived up to its monicker with 120 companies signed up to exhibit at the 2015 Autosport Engineering show. Recently signe-up firms include Advanced Performance Parts from America, Albins Off Road Gear (Australia), Evo Corse (Italy) and Plex Tuning from Greece.

Exhibitors that have already signed up to the 2015 show include returning companies such as AP Racing, Brembo, DC Electronics, Eibach, Xtrac and Zircotec, alongside newcomers to the event, such as Euro CNC, Sandwell UK and Trelleborg Sealing.

Trade registration is now open for the show, which returns to Birmingham's NEC for the 25th consecutive year.

Tickets are on sale for the Autosport International Engineering show, held at the Birmingham NEC, on 10-11 January 2015. Advanced Adult tickets cost £32, children £21 (under fives go free). Group tickets are available. Paddock passes cost from £42, VIP passes from £120.

Paddock passes include general admission plus access to the Driver Signing Area, the backstage Paddock Area and a paddock guide.

VIP tickets include: access to the VIP enclosure at the Live Action Arena, complimentary champagne and canapés, a Club Lounge, free parking, access to Driver Signing Area and dedicated VIP signing sessions, fast-track entry to the Live Action Arena and access to the backstage Paddock Area.

For more information call +44 (0)844 581 1420 or visit **www.autosportinternational.com**

Trade stands are available for the Autosport Engineering Show, held in association with *Racecar Engineering*. Don't miss out on your opportunity to exhibit in a trade-dedicated area for two days ahead of the main show. To exhibit, please log on to **www.autosportinternational.com/trade**, or contact Tony Tobias; **tony.tobias@haymarket.com**

A crisis of identity

The Formula E Championship burst into life in Beijing in September and the racing was as good as any other single-seat series. It was a surprise to many that almost everyone finished the race, that the overtaking was genuine and the battle for the win ended in a spectacular crash on the last corner of the last lap, an accident that could be broadcast around the world.

As we all applauded what could have been a disastrous first event, I did wonder whether what Formula E delivered was good enough. Certainly the fact that there was overtaking and reliability silenced a lot of critics, but it was only as good as any other single-seat series and for a new series, albeit with brand new technology, was being as good as any other good enough? Have we too easily accepted mediocre racing and declared it good enough, or should we be pushing for something better?

Racing is going through something of an identity crisis and perhaps now is a good time to take stock and work out a clear direction. We have new technology in Formula 1, endurance racing and Formula E. We have a new audience to attract and an existing audience to keep happy. We have to rebuild the staircase of talent and maintain the pure ethos of racing. This is all possible, if everyone accepts their position in the heirarchy and put money, or cost-capping, ahead of the business of racing.

Have we too easily applauded and accepted mediocre racing?

Tight technical regulations and spec formula racing around the world has robbed us of variety. Chassis development is limited, engine development is curbed, the room to manoeuvre is restricted to the point that we no longer have innovation. We have, instead, stagnation and the sport needs to deliver more.

The rise of LMP2 in the US has led to more companies taking an interest, both on the chassis and tyre front. Yet these chassis are cost-capped, making it difficult for low volume manufacturers to compete on price. In GT racing, balance of performance is the differentiator. This can be argued behind a closed door, the effects only seen on race day and few take the result seriously. Wins are bought, or argued, not earned (that's not true, by the way – any win is earned but the perception is different).

With a focus on technology, endurance racing and Formula 1 have both taken a clear step towards technology over budget. What now needs to happen is that they identify themselves within this new envelope. Money is still a concern. In Formula 1, teams are struggling to agree on anything, while in LMP1, the discussion whether or not to go for much larger hybrid systems in 2017 is tempered by a need to slow the cars down. What sort of an advertisement is that?

The technology bred in endurance racing is feeding into the mainstream. Williams' flywheel system tested in Porsche's 997 GT3 and then in Audi's R18, has found a natural home under company GKN in public transport systems. Racing can push development and that technology is finding relevance which is key to its success. But we also need to keep in mind the quality of the racing and here, I am afraid I cannot applaud Formula E. There was overtaking in the opening round in Beijing, the cars were reliable, Nick Heidfeld's accident didn't result in a catastrophic fire, but the fury, the drama, the *racing*, was lacking.

But that's not what the series is all about. Either a series is pure in form, with open regulations, or it is a technical innovation testbed. Or, in Formula E's case, it is aimed at an entirely new audience and should accept that fact, and not blur the lines.

Formula E cars are not fast, and don't require professional drivers. The series is looking for a younger audience that appreciates electric racing and which will go out and buy electric cars in the future. It is selling to a new fan base. It could have introduced a 'Strictly Come Dancing' style competition ('Dancing with the Stars' in the US) where celebrities are coached and compete for wins. We can dispense with judges and the fake 'you are just what this show needs' rubbish. Lose the race, and you are out.

Leave endurance racing as it is in its new home – a place to prove technology over a long distance. It is working for the sport as manufacturers are looking at it in a different light. No longer is Le Mans the only return on investment. Now, technology can feed back into product, and that's a whole different ball game.

Top-line single-seat series such as IndyCar and Formula 1 need to have more relaxed technical regulations, and encourage innovation in all areas, from chassis design to aerodynamics, suspension to engine. There is no place for a spec chassis in top-flight racing. They should return to their place and be about pure racing. I would, for example, love to see a tyre war in F1 in 2017 (the rumour mill suggests that Michelin is actively working on a product for 2017 and Pirelli clearly needs to establish its endurance credentials as it concentrates on GT racing, and LMP2 for the US market), a relaxation of power unit regulations in 2020, abandonment of the minimum weight restriction to encourage new materials, and an increase of power. To control costs, have a closely monitored bank account. This has been proposed before. Look at Max Mosley's cost-capped F1 plan. It should have happened. It can still. You cannot delete a good idea.

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Subscription rates
UK £66 (12 issues)
USA $162 (12 issues)
ROW £84 (12 issues)

News distribution
Seymour International Ltd, 2 East Poultry Avenue, London EC1A 9PT
Tel +44 (0) 20 7429 4000
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Email info@seymour.co.uk

Printed by Wyndeham Heron
Printed in England

ISSN No 0961-1096
USPS No 007-969

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