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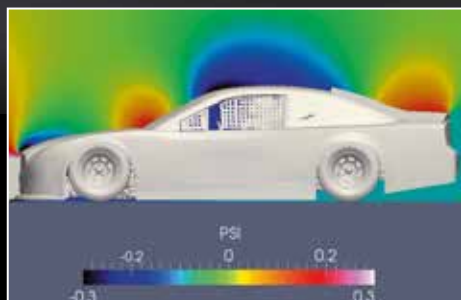
IndyCar

New aero kits
signal end of
spec formula



Nissan GT-R LM NISMO

Debate rages as team delays
debut to address its issues



NASCAR flow study

Focus on R&D centre and its
quest for better aerodynamics



Toyota TS040

Faster and lighter prototype
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25 years and counting

This year, Racecar Engineering is celebrating its 25th anniversary. Started in 1990 as a magazine (it existed earlier in book form), in this edition we mark the occasion with a publication that reflects our broad range of coverage, and provide links to significant features run in the last quarter of a century. Coming soon to our new member's area on the website, www.racecar-engineering.com, will be a download of our favourite IndyCar features, alongside the latest news, blogs and information about our sport.

Since 1990, the emphasis in racing has changed firmly from technical exploration to cost control. Whereas it was possible for a revolutionary idea to be introduced into top flight racing, now it is much harder. It is still possible, however, as DeltaWing proved in 2012, a relatively inexpensive programme introduced into the world of Le Mans can reap huge rewards, much to the chagrin of the manufacturers that invest tens of millions of pounds.

This month, we celebrate the fact that IndyCar has taken the first, welcome step, away from spec racing in a top-level racing series. IndyCar officials say that

the spec period was necessary, and make a compelling case for maintaining the relationship with Dallara in the future.

We also start our Le Mans coverage, and feature the Toyota which continues the trend of developing hybrid technology, while DOME is also part of a developing story. Just as IndyCar departs from its spec formula, the ACO and FIA have started the process of taking LMP2 down that same route, again citing cost control. The small manufacturers of both chassis and engines will lose another market, and the plan further robs engineers of a place to learn their trade. Cost control and spec formula have been a blight on our racing landscape for a long time now. A more open rule book that leaves room for innovation, a clever idea to challenge conventional thinking, can be just as effective. The Nissan GT-R LM may not work yet, but it offers just that challenge that the sport needs.

Follow our coverage of the last 25 years through our back issues, held on Zinio and on our app, and visit the website to take advantage of our latest free downloads.

ANDREW COTTON Editor



Jaguar's XJR-12 graced the cover of the first ever edition of Racecar Engineering with the headline 'Jaguar's Fighter Bomber'. Today the English marque looks set to return to racing

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'He who can, does'

Can the motoring press learn from its past to secure its future?

On average we sneeze 125 times a year. This is not to be sneezed at. This is "the uselessly precise fact" — it's what you doodle when you need to fill a page but have nothing important to say if you are writing for the press with an impending deadline.

This in turn reminds me of Shaw, George Bernard of that ilk, who said: "He who can, does. He who cannot, teaches," in *Man and Superman* (1903). When one uses this quotation, one usually adds "And those who know fuck-all write about it."

Stating this credo over the years has not endeared me to the motoring hacks either, especially when I mention that, as their tools are knowledge and a good working proficiency with the English language, some of them fell somewhat short of the mark.

Finding myself in the awkward position now of being a visiting professor at Cranfield University and writing about racing, I stand self-incriminated despite plaintive negation. So let's cast a look on what is on offer in the motoring press.

Racecar Engineering has given me a bully pulpit so I can rant about my pet themes, but now, on the 25th anniversary of its existence, I can shower it with plaudits, for on the general motoring horizon it is one of few dedicated engineering magazines which focuses on the race engineering side.

Shifting emphasis

In the last century, and I am talking about the middle of it, I learnt an awful lot about the design and technicalities of racing cars by reading the American stalwarts; "Road and Track", "Sports Car Graphic", "Car and Driver", "Motor Trend" and interestingly enough "Hot Rod Magazine". On the European side it was "Auto Italiana", "QuattroRuote" and "L'Automobile", but best of all was the English press — most of the racing cars were built there, so I read with interest "Autosport" and the indefectible "Motoring News". Reading the situations vacant pages in both titles provided a valuable insight into what was going on in the racing world, but for about a decade now it seems to be mostly about wind tunnel technicians, wind tunnel model makers and CFD specialists.

They all had lavishly-illustrated articles on the technical side of racing, with cutaway drawings of

the cars and in-depth coverage of most systems and equipment. And the racing correspondents gave an awful lot of coverage to what these cars were doing on track. Presumably other engineers also had their appetite whetted for competition engineering also. The general drift of the world being what it is, the fourth estate now seems to focus on celebrity and motor-racing coverage is no different, with too many pages dedicated to what drivers are up to, and team politics.

The yellow page journalism that has taken over print has obviously left its paw marks on the

Reading the situations vacant pages provided a valuable insight into what was going on in the racing world



Racecar Engineering's editorial team hard at work, yesterday

racing press. The formula could be one designed to generate more stories and some of them, if they were published on a website, would be considered click-bait. The traditional staid motor press just goes on and on about the current crop of offerings from the manufacturers, which could conceivably be of interest to a prospective buyer sizing up the market, but with a truncated coverage of racing. Different demographics have different needs I guess, but I digress.

The content is obviously geared to a new public, but is it really working? There was a captive market for F1 fans who were not necessarily entertained by the technical nitty-gritty, but looking at the websites online there is good technical coverage,

maybe more than before, but the internet has made access to the information that much easier.

The demise of print has been decried for more than two decades now, but new ways of financing publications still seems to be in a state of flux — presumably in the long-term everything will be accessible in the cloud and a universal system will evolve eventually.

So a resounding cheer to a publication that covers most forms of motor racing with articles that are specifically geared to the technical side. There is a big demand out there and the lack of information

coming out of the racing teams is understandable — nobody wants to give away any clues that would give an inch to their competitors, thus making it very difficult to find out what is current.

Chequered history

Mind you, we are not looking at the past with rose-tinted glasses either. The bane of most correspondents at magazines is eking out their monthly stipend through doing driver PR and management. I can remember one case of a scribe writing press releases working for a major tobacco company and I found that his work would detract a bit from the race report. It got to the point where, having been at the race myself but having trouble recognising the description of it, I began to lose my trust in the reporting.

The old cliché of "Never let the truth stand in the way of a good story" was further skewed in the blatant pushing of the drivers employing the hack along the lines of "so and so had a brilliant race, displaying amazing car control and press-on qualities to a brilliant fourth place. John Doe won the race."

File that one under conflict of interest.

Rant over, one can just hope that racing does not get dragged down by the current festering in F1 and continues to garner a new audience, some of whom can be captured to come to work in it.

We need new technologies and working methods so that the sport ends up being the ultimate engineering challenge, producing a well engineered missile with tight schedules that is used in direct combat with other people doing the same.

No marketing, no perception skewing and with only a stopwatch (er, timing beam and transponders) to judge the performance.

Happy 25th Racecar Engineering, long may you continue to fly the flag.





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M E P C



Power to the people

Why F1's flawed power unit policy is badly hurting the sport

Isn't the recently-released Ferrari F1 concept stunning – surely this is what a 2015 F1 car should look like? Beautiful, breathtaking, a speed icon that shouts 'racing car'. Back to reality and the first (rather dull) grand prix of 2015 is over – and further indicates that the whole energy recovery philosophy as applied to F1 is failing. Miserably.

The aim of introducing environmentally-friendly power units was to preserve Formula 1 (or why else?). But the twin strategies of (a) publicising how such technology is beneficial to future passenger vehicles and (b) simultaneously drawing in more automotive manufacturers on the back of this green technology is simply not working.

So far there has been no evidence of the world at large being particularly impressed by (or even being aware of) the claimed main benefit of a 30 percent reduction in fuel consumption. Only one manufacturer (Honda) has been attracted to date, with no signs of any other major manufacturers joining. With this famed company's rather ignominious re-entry, it may well have already put off possible newcomers. Largely due to the crippling increase in power unit costs, the grid at Australia was down to only 16 cars. Of these, four could disappear if just one man, Red Bull's Dietrich Mateschitz, should decide that he has had enough of F1. The media coverage regarding matters such as Caterham's undignified exit, Sauber's three drivers/two cars contract farce, Marussia turning up but not even managing to run, rumours of other teams dropping out has provided embarrassment for F1 and is surely a turn-off for sponsors as well as for TV broadcasting companies and fans. Public denigration of the new power unit regulations by F1's promoter and several key figures throughout the past 18 months has also hardly helped. I suspect that any consideration by sponsors to invest in F1 as a result of its greener credentials has been more than offset by these unhappy scenarios. So tell me; in what way is the strategy succeeding?

The blame cannot lie wholly with the FIA. They rely on input from F1 team principals and engineers. Why is it, though, that these intelligent and capable people appear to sometimes park their brains when attending meetings concerning future regulations? So often they agree to obviously flawed proposals

then complain about them afterwards, when reality sets in. For example, the decision not to go with engines based on the GRE inline four cylinder concept. The subsequent change to V6 configuration when Ferrari, among others, thought a bit more about it afterwards wasted much time and money and reputedly cancelled any interest that Audi might have then had in F1 participation. Quick-degrading tyres were a good idea, then they were not such a great plan. Blown diffusers were banned, but not quite.

Mismanagement?

Now the whole concept of hybrid power units, after hundreds of millions of pounds invested, is being questioned by those who previously meekly accepted, or even welcomed, their introduction. Could they not see the irony at the time in voting to

Constructors' or Drivers' World Championship and also compromises new suppliers on a steep learning curve, such as Honda. Red Bull's Daniel Ricciardo has already used a quarter of his season allocation in Australia, even before qualifying. With 19 races yet to go. Why ever was this agreed by those whose massive efforts to win could be derailed by circumstances outside of their control, but which are easily foreseeable?

The formation and composition of the Strategy Group that took over the F1 regulations decision-making has drastically reduced FIA president Jean Todt's ability to push through the changes the sport so badly needs. He is, after all, the much-respected leader who masterminded world championship successes for Peugeot and for Ferrari with all the political nous that this must have required, but nevertheless has been unable to get the agreement (surprised?) of the chosen teams which make up one third of the Strategy Group.

I am not against energy recovery in F1, far from it as I detest waste and admire ingenuity – it's just the means that have been chosen. I pointed out in a previous column that there are less complicated and expensive ways of achieving similar, better, results.

A further step might be to replace heavy, expensive and potentially dangerous battery storage systems with mechanical flywheels, as used in Audi's formidable LMP1 cars. How much less would it have cost, I wonder, to have gone down such less complex routes? Enough probably, and for the FIA, the manufacturers and the teams to

use some of the cash left over to contribute to a full-page advert and online equivalents in the worlds' major news media, to put right the misconceptions about F1's environmental issues and extolling the benefits of its focus on relevant technology development? A bit of lateral thinking doesn't go amiss occasionally.

F1 should never be a technical exercise at the expense of the racing. Instead it should run as competition between teams and drivers hand-in-hand with properly thought-through, simpler and less politically-inspired regulations which can still promote advanced engineering and real energy-saving. All features that are sadly absent from the sport at present.



Ferrari wants to provoke its rivals into action with its concept design for a future Formula 1 car

Ricciardo has already used a quarter of his engine allocation for 2015

accept a huge budget increase when concurrently there were endless ongoing unsuccessful debates regarding the urgent necessity for cost-saving?

Power units can take four hours to change instead of the previous 90 minutes, even to access minor problems such as a fluid leak, and drivers can miss out whole practice sessions or qualifying as a result. Didn't teams and engine suppliers see this situation occurring?

Take also the decision to reduce power unit allocation per car even further during this season, from five in 2014 to just four. This decision makes no sense, especially with the new technologies still remaining fragile. The actual cost-saving is almost irrelevant, yet has real risks of spoiling a



Going with the flow

**IndyCar finally embraces new aero kit regulations
with the hope of giving the series a greater
technical edge in years to come**

By ANDREW COTTON

**‘With almost 200 adjustments that are
possible on the cars, the ability to tailor
the set up is going to be key to success’**

The introduction of new aero kits for 2015 is the first technical breakthrough from organisers of the Verizon IndyCar Series, a move designed to give the competing manufacturers, Honda and Chevrolet, a strong visual identity and one that is also designed to be the first step in creating a more open technical platform in the future.

The new aero kits were announced in 2010, and were planned initially for introduction in 2012, at the same time as the new 2.2-litre V6 engines. However, the introduction was delayed and it is only now, three years later, that the new kits have been seen in public.

Both competing manufacturers have taken completely different approaches to designing the new kits. Since the introduction of the DW12, the teams have run Dallara's

aero components and IndyCar expected that the manufacturers would be able to increase downforce considerably with their vast resources. What they achieved caught suppliers by surprise and changes were made at the last minute to mitigate the gains made.

While Chevrolet created a whole new aero division, which now serves not only IndyCar and the TUSCC programmes but also the production car department, HPD turned to its trusted supplier Wirth Research and conducted most of its studies in CFD before wind tunnel and track validation.

The result is two wildly different solutions. HPD has used Formula 1 as the inspiration for its creation no doubt inspired by Wirth's background, with an aggressive front wing and winglets all over the car's rear. Chevrolet took a more conservative approach, with a

dual-element front wing and fewer elements at the rear. Initial testing put the entire field within a second of each other, although at the early tests, the Chevrolet appeared to have the upper hand.

'Our background is a combination of sportscars and Formula 1, perhaps our competitors background is different,' says Stephen Eriksen, vice president and COO of Honda Performance Development Inc. 'That is at why the solutions look so different. We have come at it from a different direction and it will be really exciting given the broad range of tracks to see how those solutions pan out.'

For Chevrolet, they also say that their solution derives from F1 experience. 'We are pretty happy with how our kit is performing,' says Chris Berube, Chevrolet Racing program manager. 'That involves some learning curve.'





Comparison between the two aero kits demonstrates the different approaches. Chevrolet opted for a more traditional dual-element front wing while HPD went for multiple elements. The covers ahead of the rear wheels carry significance for the super speedway kits that were not yet released as *Racecar Engineering* went to press



Chassis supplier Dallara was part of the reason for the maximum increase in downforce as any more would require a redesign of the suspension system

The Honda kit certainly has more components to it, it is familiar looking relative to the modern F1 cars, but some of our components are F1-esque, maybe of a different era. The louvred rear wing end plates are very current. When it comes to philosophy I wouldn't critique theirs, but we have one that we went with our front wing, and it works. The philosophy they have chosen is clearly different and we will see when we race who has ended up picking a better path.'

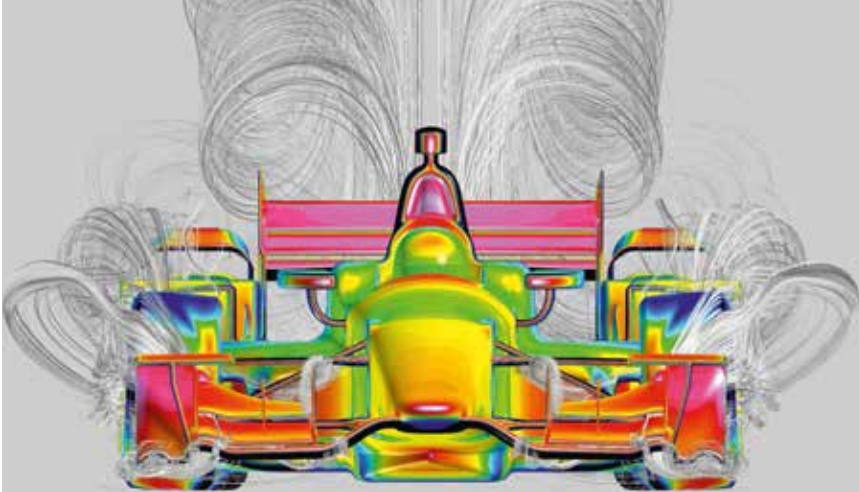
With almost 200 adjustments that are possible on the cars, the ability to tailor the set up to circuits, drivers, altitudes and temperatures is going to be key to success.

Gale force

While the manufacturers played their cards close to their chest, Dallara and Firestone were almost caught off-guard by the increase in performance.

'Once we laid the ground rules for aero kits, and the manufacturers started working on it, they didn't want to share too much with Dallara because they were flat out reinventing the wheel,' says IndyCar's president of operations, Derrick Walker. 'We were trying to see how good it would be and what would be the issues. Finally we said that we wanted their data, their numbers and they gave them. Once we saw the data that they provided we could see that there was going to be a significant increase. That was where we got with our partners, with Dallara and Firestone. We worked out the right percentage of increase, which we thought was worthy of an aero kit rather than out in the stratosphere and have to redesign the car. The idea of taking the strakes and sidewalls out of the tunnel took some downforce, and we are where we think we need to be for the first iteration.'

After discussion with its partners concerning maximum load limits for existing components, IndyCar eventually set a target of a maximum increase of 25 per cent downforce over the Dallara aero kit. 'We estimate that the standard Dallara downforce was 2155kg, which was the maximum you could get out of it with the 14 floor and the DW kit,' says Will Phillips, vice president, technical at IndyCar. 'At the start of this season we think they'll be around 2480kg, so potentially a 15 per cent increase. We don't think they can get much more increase than that. The drag increase is about two per cent so they have done that very efficiently. At a typical road track that should be 1.25s faster, although that depends on weather, temperature and so on.' Initial examination of the super speedway kits showed a more modest increase in performance, with gains



Above: IndyCar set a maximum of 25 per cent increase over the Dallara DW12 for the new aero kits. Neither HPD nor Chevrolet were willing to say how many hours of development were put into the new kit, but have been working on them on and off since 2010 in the case of HPD, and 2012 for Chevrolet.

Left: Airflow over the front wing is dramatically different for both solutions yet early indications are that performance is similar

‘The new underwing is designed so that if the car goes nose-up there is less chance of a backflip’

between 1-3mph. So concerned was Indycar at the increase in performance that at the Barber test it evaluated longer steering arms and is looking at introducing power steering.

IndyCar had already permitted the manufacturers to create their own brake ducts, rather than adapt Dallara’s as in 2014, outside the \$75,000 aero kit to ensure its competitors did not run out of brakes. Chevrolet homologated new front and rear ducts, Honda just the rears.

The new underwing, a safety initiative from IndyCar, was planned for introduction on the DW12 at the 2014 Indianapolis 500, but initial testing at Fontana in January 2014 demonstrated an instability. That instability was cured at a test in Indianapolis in May, but the handling issue delayed its introduction by one season, and the aero kit manufacturers were then informed that the new underwing would be a requirement for

2015. ‘The new underwing is designed so that if the car goes nose-up there is less chance of a back flip’, says Tino Belli, director, aerodynamic development at IndyCar. ‘For a given nose up configuration, the speed that will cause a back flip is significantly higher. The whole underwing is new and is designed to be equivalent in strength to the previous underwing.’ Another change for the super speedway aero is a mandatory horizontal ‘wicker’ that runs up the nose to the windscreen and is designed to reduce the risk of a car flying in the event of a high-speed spin.

Options

IndyCar gave aero kit manufacturers areas in which they could develop, labelled as ‘volume boxes’. There are 12 ‘boxes’ in total in which the manufacturers were free to develop as they

wished. The Dallara monocoque, or safety cell, and the radiators, are standard across all cars. Manufacturers were allowed to introduce their own components, including items such as the engine covers, and kit ‘options’ according to the condition and nature of the circuit.

Broadly speaking, there are two kits from each manufacturer; a high downforce kit, and a super speedway kit that was not released by the manufacturers as *Racecar* went to press. Teams have the option of running the Dallara kit or their engine manufacturer’s aero kit at each event. A team must commit to a configuration at scrutineering at each event other than the Indy 500, where it may test the Dallara kit against its own in practice, and only finalise what it will use when it qualifies. The potential combinations, with the ‘options’ within the manufacturer bodykits are bewildering, and it would not be

‘The car we have is a dinosaur. It should look like something from the future, not something that has crept out of the past’

a surprise to see many teams experimenting throughout the season with various levels of success for each individual car.

‘When the manufacturers submitted the homologation, they declared mandatory parts,’ says Belli. ‘One of the rules is that you are not allowed to see engine or ancillary components from the top or the side, so that mandates that

you have to have the sidepod. Then they have optional components that the teams can take on and off as they choose. Then you have shutters that you can close off for cooling, you are allowed to trim them to optimise their cooling. As Indycar we don’t differentiate the option components between Speedway, Indy and road course. Teams can run speedway

components on a road course or road course components on a speedway if they think there is some sort of advantage.’

The kits are fixed for two years, but of the 12 ‘boxes’, three can be modified for 2016. ‘We have provisions that are in the manufacturers’ hands to correct any deficit that they have,’ says Walker.

‘Supposing there is a big difference between the manufacturers, and one of them starts to get behind, a manufacturer can come to us and say that they are behind, and then show and prove to us that there is a deficit that justifies a change. Then they apply to change the car. It is a good safeguard to stop half of the field wasting its time turning up.’

What the manufacturers say - HPD

‘We started work on the new aero kits as soon as we knew that was the plan,’ says Stephen Erikson, vice president, COO Honda Performance Development Inc. ‘For a variety of reasons it didn’t happen in 2012 and with hindsight that was possibly better because we had enough to do with new powertrains and a new chassis.

‘There have been a lot of changes along the way. One of the first changes, around 2013, was the need to add the rectangular holes in the underfloor to make a safer IndyCar. IndyCar asked both us, and our competitor, if we wanted to help in developing a solution. Our competitor declined, but we agreed to devote our resources to that because to have a safer race car is important to us.

‘Our solution was reviewed by Dallara, IndyCar and our competitor to ensure they got the same answers as us. We were going down that path, then it was a question of when we

introduced it. And then there were more changes for manufacturing reasons, which changed how the piece worked, so that was another adjustment. Then the discussion was that we had proceeded along the path of making more performance, and they asked for a report. We gave a report, and looking at both our progress, and at what Dallara advised were the loads capable without making changes suspension-wise, they took some action to try to bring the performance into the window, and that is where the strakes and sidewall came in. That was very late in the process, but it is being done for all the right reasons, which is safety.

‘It is very rewarding to see that the two solutions look so different. For two brand new solutions to be within three tenths of each other, that is pretty phenomenal. There will be broad range reaction to anything. You release a new vehicle and people love it, or hate it, that is normal. But it is causing

conversation on IndyCar and that was the point – to get more eyeballs on IndyCar. So far it seems to be doing that.

‘What we need going forward is a stable financial platform for the racing to carry on. The configuration of the car or regulations is less important than ensuring that the foundation on which it is built is a stable one. We want to race, so we need racing to exist and for people to be excited about racing.

‘It is very important to get a third manufacturer in. We are the only OEM involved in open wheel racing in North America since 1994. We have been through periods of multiple manufacturers, and no manufacturers. The economics work better when you have at least three manufacturers. We have 11 or 12 cars to support, and when you make changes you have a big task, and you have to ramp up for the Indy 500 when you have 17 cars, so another manufacturer is very important.’

The future?

The introduction in aero kits has started the conversation about IndyCars once again. ‘We haven’t had that level of interest because we have been technically dead for a little bit because we went through the spec period, which was necessary at the time,’ says Walker. ‘I think we have got great racing, and we need more fans. We want to build some wow factor into the cars and drivers. I don’t care if you are dealing with a car with a battery or a nuclear reactor, the car still has to be driven by a driver.’

All options are on the table for the new cars in 2018, including a change to hybrid technology, the Global Race Engine and a radical new look for the cars. ‘If you look at today’s world, and the technology, the car we have is a dinosaur,’ says Walker. ‘Dallara built the car that we wanted, and it is a good car and even with the different aero kits we have happy campers, but I think that we need something that is futuristic, but looks like an IndyCar. It should look like something from the future, not something that has crept out of the past.’



Chevrolet (left) went for cut openings in the rear wing in the example seen at the Barber Motorsport Park test in March, and a coke bottle shape around the radiator. Honda’s solution (right) shows a closed rear wing but the kit features more adjustable features than Chevrolet’s. It remains to be seen whether or not this will be an advantage.



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The option to use moveable aerodynamic devices seems to be the most likely idea for the manufacturers. But, while it has put attracting a third manufacturer to the party at the top of its priority list, there also needs to be a clearly defined line between where the cars are now, and where the series and its current manufacturers want it to be in two years' time. 'When you look at 2018 you have a clean sheet of paper, do we want to change what we are doing, upgrade it, keep it the same?' asks Walker. 'It offers that challenge on more than one front, and it is not just the car, although that is a big component of it. Manufacturers want to understand where we are going. When you

ask people the question, my feeling is that they come at you with something that is way out, which is good, but you have to bring it to reality, to work out the plan of how you are going to get there. You have to take everyone with you, and keep the teams healthy because change costs money. How do we change to where we want to go rather than dream of a hypothetical race car that we have no way of connecting to this other than manufacturers who want to pay a lot of money to do it?'

Will IndyCar take the final leap and move away from the spec Dallara chassis? While Phillips considers this to be a possibility, Walker has different ideas. 'I don't see a lot of manufacturers

out there ready to build IndyCars,' he says. 'It is a question of how much difference do you want, and how much can you afford. Back in the day when there were different manufacturers, there were a lot of cars sold, and they were sold quite frequently. Manufacturers could get their money back from that kind of investment. With a long shelf life of a car I don't know how that would be commercially viable. What it should be, in my opinion, is that some of the basic components stay the same, so if you develop a safety cell and that has the best technology that you can create for the driver, then it should be the same for every car, and there should be enough of the exterior shape to be technically different that can be based on the chassis of a standard design. What I think is important is that the outward shape looks different and is a lot more open and innovative than it is now. I think we need a more modern racecar, kind of imagine what it would look like in 2020 or 2025, and to me what we have right now is behind the trend.'

Manufacturers may not be queuing up for now, but with the changes mooted in the LMP2 category, and with the loss of LMP1 in the Tudor United Sportsscar Championship, options for a top-level US racing programme are limited.

The new aero kits may be a small step in the right direction for IndyCar, but they have had a big impact on how the outside world views the category. Interest is high – whether that be positive or negative – fan interaction on social media has increased, and the manufacturers certainly have their own identities. It seems that the spec period for IndyCar is over. 



In a bid to improve stability should the nose rise, IndyCar worked with HPD and the solution was an underwing, and a cut out in the floor ahead of the sidepod. Initial instability was a concern, but teams worked on aero balance

What the manufacturers say - Chevrolet

'Chevrolet decided to come back to IndyCar because the engine formula was appealing for us, as was the opportunity to do our own aero kits,' says Chris Berube, Chevrolet racing programme manager for the Verizon IndyCar Series. 'The brand differentiation that we could have, the opportunity to impact on the performance of the car and own it, was important. The process involves assembling a team that has the skill set to do it, so we found a chief aerodynamicist that we trusted, and has done a fantastic job and led a team during this multi-year process. The first task was to establish a baseline with what you have, which was the DW12. Then you set goals, and then you start the creative process. You refine targets as you go along,

but there was a very rigorous target-setting phase, and that was occurring at the same time as the regulations were going from pencil to pen. There were plenty of changes along the way, and we had to react to them.

'Because these are not all-new ground-up cars, they are kits added to the Dallara chassis, there are logical load limits for the suspension. We weren't allowed to change the main planes and the tyres. We did a bit of development without being told what the limit was. Once we started getting to the point where we were sharing information with IndyCar, we passed some limits and a correction was applied.

'You want downforce without adding drag, and in addition to that, IndyCar races on superspeedways and street

courses and our aero targets were in that range. There are different targets depending on the type of racetrack. Things like sidepods and engine covers, which are common across all race venues, have to be optimised for what you choose to be your priority, but that is the skill. We also integrate engine performance into the kit, with the air inlet.

'Bandwidth is what we targeted; the number of adjustable parts is probably less than [Honda's] kits, just looking at it. They have more flaps than we do, but I wouldn't limit the aero performance adjustment to the number of physical adjustments. That is one of the things we are quite proud of, the bandwidth, trimming it for qualifying and the race, and it has more bandwidth than the DW12.'

Five years ago



With the collapse of Champ Car the IndyCar series reached a crossroads, and launched a process to find a new car for the series, it resulted ultimately in the DW12 and also the Deltawing. Racecar Engineering explored all of the option in the May 2010 edition

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Seeking perfection

Toyota won the World Endurance Championship title in 2014, but still seeks victory at Le Mans

By ANDREW COTTON



‘We have put huge effort into upgrading the whole car, including the powertrain, where we have made small but significant improvements’



Toyota had a near perfect 2014 season. Five wins from eight World Endurance Championship races, in dominant mood particularly on home turf at Fuji, and with drivers' and manufacturers' titles all won, on paper it was a magnificent performance. Yet, there is still room for improvement and in the 2015 car, Toyota has fine-tuned to the extreme and says that 80 per cent of it is new.

Much improvement is expected from rivals Porsche and Audi, and so Toyota has undertaken some major development work for this season. Work has been undertaken to reduce the weight of the car in order to open up the possibility of going to the 8MJ category

this season, although it has subsequently opted to stay with 6MJ for the 2015 season, to improve serviceability and to improve aerodynamics, which has led to a new nose box and that in turn meant a new crash test. Work has also been done to the suspension to improve how it works its tyres, one of the 2014 car's strongest points during the year.

Rule clarifications have been brought in regarding the amount of bodywork flex following Toyota's controversial wing (and Porsche's controversial bodywork at the pre-test), and the flexible floors that were designed to protect the monocoque. 'The floor flexing to protect the chassis, it is still allowed to a small extent, everyone was doing

it, but some teams were going too far on it, and so after Le Mans the FIA set out the load requirements what flexing there could be but we already fulfilled that point so from that point it had no impact,' said Toyota's project leader, John Litjens. 'We are now going into the details, the general development steps where we find efficiency and downforce, and on the other side we work to optimise the car in small areas, such as weight saving in the hybrid side as that always costs weight, and we work on the suspension kinematics to make it easier to set up to the tyres.'

Toyota has improved the hybrid system, producing more power, which reduced the need to make a leap in MJ category and meant



While the petrol engine feeds the rear wheels, the electric motors deliver drive to all four wheels – the TS040's powerplants combine to make 1000bhp



that the final decision for which MJ class in the car could run in was left right up to the last minute. The team reduced the overall weight of the car, and introduced more cells into the hybrid system to maintain power over the course of a 6-hour or 24-hour race, but did not save enough to be able to accommodate the larger components required for 8MJ.

Hisatake Murata, general manager of the motor sports unit development division, said: 'We have put huge effort into upgrading the whole car, including the powertrain, where we have made improvements in most areas. This means that, even if the total maximum power remains at 1000bhp, the actual

gearbox this season. 'The internals are a carry over from last year, but there is a redesign for the kinematics, the rear suspension,' said Litjens. Michelin has continued its development of the LMP1 tyre, but Toyota does not believe that the development of Nissan and its front-wheel-drive prototype will have much impact on the new tyres, despite the increase in power delivered from the hybrid system. 'I think any work that has been done for that specific car is too late,' said Litjens. 'The Nissan ran at the end of last year and there for sure might be some feedback. The development of the 2015 tyre is based on the experience of the manufacturers from 2014. This was just a natural progression.'

As it has in previous seasons, the team has produced two separate bodywork configurations – high and low downforce. Both have had to be redesigned due to the change in the front crash structure that led to a further crash test. 'It is just for the aerodynamic purposes,' said Litjens. 'For the set up of our car it required a small change on the crash box as well, but for homologation you have to crash test it again. It hasn't had a major impact, because the change was small for the nose box and easily done. The wind tunnel development goes hand in hand so it is a total package.

'We have worked on a lot of small bits and the performance of the car was quite good, and

'Our development means we will achieve the maximum hybrid energy much more consistently than we did last season, and at all tracks'

performance of the powertrain has been considerably enhanced. Our development means we will achieve the maximum hybrid energy much more consistently than last season. Therefore, we fully expect to see a performance improvement from the hybrid system, especially over race distances, and at every circuit. Part of this progress comes from the super capacitor, which now has an improved power to weight ratio.'

Toyota has worked to improve the tyre performance with a change in suspension kinematics and that, in turn, has led to a new gearbox casing for the seven-speed sequential system. Interestingly, the team has stuck with its philosophy of having an aluminium gearbox despite looking to save weight. As with the 2014 car, the team elected to take the safest, least complicated option and not run a carbon

Additionally, to ensure smooth braking performance during regeneration, and to contribute to weight saving, the TS040 HYBRID will employ two ECUs; one to manage the powertrain and the other to handle braking. The brake-by-wire system is unchanged for 2015. 'It was clarified that our system was legal, so there was no need to change from our side. Other people might have done some work on it but we have not had to touch it,' said Litjens.

Development of the 2015 car began directly after last year's Le Mans 24 Hours in June and the updated car was tested for the first time on 13-15 January at Paul Ricard. Further three-day tests at Motorland Aragon (twice) and Portimao, as well as the pre-season test at Paul Ricard has ensured that the car is ready for the opening races of the season at Silverstone and Spa with more than 25,000km of testing under its belt.

we had some small changes to improve the operation of the car for the mechanics in case things are needed. It might not affect directly, but if there is a problem it might help.'

The engine is the same 3.7-litre V8 normally aspirated unit that was used in 2014 with revisions only for reliability and what the team describes as 'normal engine development' ready for the new season. There were engine problems in 2014, notably around the loom that caused the retirement of the lead car at Le Mans on Sunday morning, but they have been addressed.

The fuel flow meter from Gill Sensors was, according to the team, working adequately at the end of last season, and there was no need to make a major change this year. A second sensor, produced by British company Sentronics, has not yet been homologated. 'From our side there is no effect,' said Litjens. 'At the end, the



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The Toyota is the only LMP1 entrant to use a V8, and that powerplant is proven – last season's car took five victories out of a possible eight during the 2014 World Endurance Championship

TECH SPEC

TS040 Hybrid

Type: Le Mans Prototype (LMP1)
Bodywork: Carbon fibre composite
Windscreens: Polycarbonate
Gearbox: Transversal with 7 gears sequential
Gearbox casing: Aluminium
Driveshafts: Constant velocity tripod plunge-joint driveshafts
Clutch: ZF-supplied multidisc
Differential: Viscous mechanical locking differential
Suspension: Independent front and rear double wishbone, pushrod-system
Springs: Torsion bars
Anti roll bars: Front and rear
Steering: Hydraulically assisted
Brakes: Dual circuit hydraulic braking system, mono-block light-alloy brake calipers front and rear
Discs: Ventilated front and rear in carbon
Wheels:
Rims: RAYS magnesium forged wheels
Front rims: 13 x 18 inch
Rear rims: 13 x 18 inch
Tyres: Michelin radial
Front tyres: 31/71-18
Rear tyres: 31/71-18
Dimensions:
Length: 4650mm
Width: 1900mm
Height: 1050mm
Fuel capacity: 68.5 litres
Powertrain:
Toyota Hybrid System - Racing (THS-R)
Engine: 90° V8 normally aspirated engine
Engine capacity: 3.7 litres
Fuel: Petrol
Valves: 4
Overall max. power: Over 1,000PS (engine and hybrid)
Capacitor: NISSHINBO
Front hybrid motor: AISIN AWA
Rear hybrid motor: DENSO
Inverter: DENSO

storm at the start of the season was quite big and there were some issues during the season, but this is for the supplier and they are working on an improvement and I don't expect any big issues. At the end of last year things were going smoothly as well.'

Pascal Vasselon, technical director, said: 'The regulations have been essentially stable so there was no reason to completely review our concept and, considering our performance throughout 2014, it would probably have been a mistake to restart from a clean sheet of paper. So the updated car is definitely no revolution but it's about evolution almost everywhere. It looks like it is from the same family, nevertheless we have redesigned roughly 80 per cent of the parts.'

'Again this season we will have high and low downforce packages, for the usual reason that Le Mans has very different requirements compared to most other tracks. The current regulations favour more subtle changes between these packages to keep the drag reasonably low, such as modifications to the rear wing, engine cover and front end. So far we are satisfied with our progress during the 'one-car race' that is testing. Now we have a few weeks remaining to get ready for the racing.'

There is a tremendous amount of pressure on the team to deliver victory at Le Mans, especially given its performance advantage throughout the entire season in 2014, and early indications are that the overall lap times at all circuits will be around two seconds, including Le Mans. Outgoing Team President Yoshiaki Kinoshita has stated clearly that Le Mans, and retaining the World Championship title, is the team's primary focus in 2015.

The team has done all it can to give itself a chance but, at the great French race, there is still one area in which it is vulnerable. The old adage

of needing three racecars to stand a chance of winning (one to crash, one to break down, and the other to win) still favours Porsche, Audi and Nissan. Budget concerns mean that Toyota will run just two cars this season, including at Le Mans. That means that the Japanese will also need a large share of luck, but there is another adage; you make your own luck and with the improvements to the 2015 TS040, Toyota will hope that it has done enough.

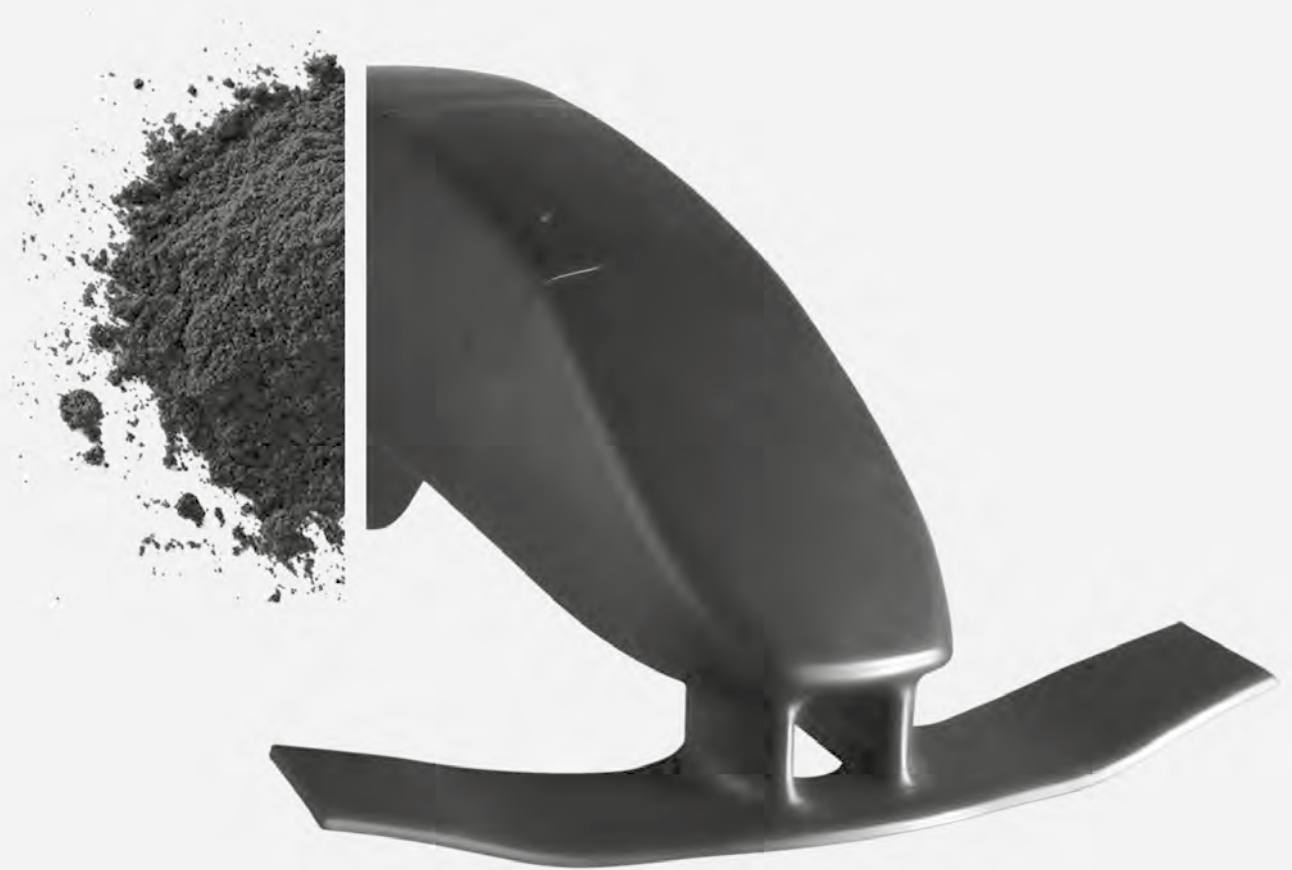


Three years ago



When Toyota returned to Le Mans its new car was a first thought to be an evolution of the Dome S102 but in reality it was one of the most advance hybrid cars ever constructed. We had exclusive access to it before its launch in 2012. Read it now at www.zinio.com

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Latecomer to the party

We look under the skin of the delayed Strakka DOME S103, arguably the most technologically-advanced concept in its class

By GEMMA HATTON



The S103 rolled out of the garage for the first shakedown only six months after the contracts had been signed and although this was an impressive achievement, sadly the inevitable happened. Issues began appearing during initial testing and it became clear that the team were not going to make it to the official test at Paul Ricard, instead deciding to debut the car at the iconic 24 Hours of Le Mans. This was not meant to be either, as a crash during testing at Spa-Francorchamps meant that there would not be enough time for Strakka to source replacement parts and fix the car before the 24-hour race and so the entry was scratched. Strakka's philosophy of only running a reliable and competitive car then meant the debut would have to be postponed until the final round of the WEC in Brazil. However, a homologation issue with the headrest mounting prevented the team from competing – concluding the 2014 season without the S103 ever racing.

'The concept of the original headrest was that it was separate from the door, so when the door is opened, the headrest is still in place to the left of the drivers head,' explains Dan Walmsley, team principal of Strakka Racing. 'To remove the headrest there is a little manoeuvre you have to do and the concern raised by the FIA and ACO was that this manoeuvre was not obvious to a marshal acting in an emergency. There were no safety concerns about the quality or impact safety of the headrest itself. The quick fix of integrating the headrest into the door turned out to be a challenge. The door wasn't structurally designed to take the load of the headrest in an impact and we as a team were not happy to make the headrest potentially unsafe just for a quick fix, so we knew we had to re-design it. The resultant system that will remain on the car for the 2015 season weighs the same as before, remains safe and is actually easier to remove. It's almost played into our favour because we've improved the design.'

This original unique headrest concept was designed for packaging and weight saving reasons, like the majority of the components on the car. 'It is a very aggressively-packaged chassis with the aim of optimising airflow which has given us good aero performance. However, it does mean that the tallest driver that can fit in the car is around 5 foot 8 inches,' highlights Walmsley. 'By attacking with such a tightly-packaged car to give us a competitive advantage, it has actually compromised us in other areas. Although it has challenged us to come up with innovative solutions that you just would not have done otherwise.'

Packaging issues

This push for packaging was the underlying reason behind most of the problems experienced in 2014, particularly where the rear suspension was concerned. 'The difficulty was we originally targeted a very low deck height on the upper body work to try and aid airflow



The Strakka DOME S103 will make its racing debut at the WEC opener at Silverstone



3D printed parts not only accelerated the manufacturing process but also improved reliability – during testing the parts successfully completed the equivalent mileage of two 24 hour Le Mans events

which made a significant compromise to the rear suspension packaging,' explains Walmsley. 'The load paths through the suspension made it very difficult to retain the stiffnesses we wanted, so effectively the load through the contact patch was being amplified by the ratio of the links on the suspension.' The teams tactic of solving this issue was to evaluate the aerodynamic losses of the more conventional double wishbone pushrod arrangement, and once this design was integrated into the car, recover these aerodynamic losses elsewhere. 'It was just a packaging constraint which resulted in unusual link angles that created a stiffness issue.'

One knock-on effect of altering the rear suspension was that the exhaust then had to be re-designed, which is a further evolution of the car during last season. 'The original concept was to have an upper exiting exhaust, but with the suspension redesign we couldn't do that so we started looking at all sorts of other options,' explains Walmsley. 'We completed CFD studies

on where the best place to exit was and at what angle. Engine pulse rates were used to try and figure out the best position, length and curvature required to achieve the right back pressures and waves through the exhaust – it really is a fantastic science.'

Thorough testing

Another exhaust technology used was the famous thermal heat shield coatings from Zircotec. 'Our primary focus is always 24 hours and we need to be working with companies like Zircotec so that after the race the car looks as good as it did when it was sitting on the grid,' says Karl Patman, team manager for Strakka. 'We're going through a case study at the moment where we've been able to test

components in an untreated form and then at the same event in a treated form, and the reductions in engine bay temperatures are around 35 per cent, which when you're looking at racing 24 hours is considerable – that is really going to save a lot of components.'

Proven reliability

Not competing in 2014 gave the Strakka team time to focus on rigorous testing regimes which not only increased the reliability of the car, but also gave rise to some interesting innovations. 'We've actually just put a record number of miles on a Nissan LMP2 engine,' highlights Walsmley. 'They normally go for a re-build around 7000km and I think we have completed just short of 9000km.' The reliability of the S103 has been

“A packaging constraint resulted in unusual link angles that created a stiffness issue”



astonishing, despite its various issues which prevented it from racing. 'There are two reasons for this high reliability,' explains Patman, 'firstly, the expertise that DOME has due to previous projects both in single seater and endurance racing and secondly, we advised them on our historical views of endurance. By putting those two experiences together we have reached this reliable design.'

Arguably the most innovative technology exploited by this project is 3D printing which was used to manufacture certain components on the car. Together with their technical partners Stratasys, the team realised that 3D printing was now no longer just a rapid prototyping technique but was, in actual fact, a manufacturing process. Components such as titanium door hinges, the dash console and the air intake have all been printed, are fully raceable and are fitted to the car. 'What we

have also found, particularly for low volume composite parts, is that we can use 3D printing for the tooling,' explains Walmsley. 'So we can now manufacture from a design on a screen to the finished carbon part within three days in the factory, which for us is unreal because the process used to take six weeks. It has given us massive flexibility, and when you can empower your engineers with the freedom to think because they are not constrained by manufacturing timelines or techniques, suddenly the ideas begin to flow.'

Blossoming partnership

With the LMP2 cost cap of €450,000, there is a trade-off between performance and cost, which inevitably brings weight into the equation as lightweight technologies are usually expensive. 'On a pure like-for-like basis resin infused carbon fibre is lighter and offers a stronger bang for

buck than a 3D printed part at the moment. But there are parts on the car that do not need to be of high strength and high structural integrity of extreme lightweight because we have a figure of 900kg of weight we have to hit,' says Walmsley. 'We have to accept that the material qualities of carbon fibre are in excess of those 3D printed, but it is the capabilities of printing we are keen to exploit – we can now 3D print in titanium cheaper than we can make in steel. That's how quickly the technology is moving forwards.' These printed parts have been on the car during those many testing sessions throughout 2014, which means that those parts have clocked the equivalent mileage of completing the 24 hour Le Mans race twice without failure.

The aerodynamics of the DOME S103 is somewhat different to that of its contenders, however it follows Strakka's inherent concept of a forgiving and driveable car for the gentlemen

S103 utilises a tyre pressure monitoring system on the wheels – this measures air pressure and temperature



Sat in the corner of the workshop, the 3D printer remains in-house. Strakka has discovered that tooling for composite components can also be 3D printed, which now means that composite parts can go from a paper design to the final part in just three days – it used to take up to six weeks

The Strakka and DOME partnership

The idea of a collaboration between Strakka and DOME was born in the Le Mans pit lane back in 2012, with more serious discussions at the 2013 Fuji round and the project officially kicking off in October 2013. Aside from their prestigious history within motorsport, DOME are renowned for their highly optimised aerodynamic concepts and with their own 40 per cent scale Wind Tunnel back at base in Maibara Japan, the S103 could capitalise on this to improve overall performance.

'The whole project was a fairly even collaboration all the way through. DOME certainly led the design work in Japan and we led all

the procurement, manufacture and assembly of the car in Europe,' explains Dan Walmsley, team principal of Strakka Racing. 'However, there were some parts that we just couldn't find suppliers for in Europe at that time so there have been a few components made in Japan, such as the bell housing which was made by one of our technical partners Hashiba, in Japan. I think it gave us massive flexibility to be able to use both European and Japanese suppliers and 'cherry pick' the merits of both.' In terms of manufacture, around 80 per cent of the car was made in Europe and the UK while the remaining 20 per cent was made in Japan.

Having the car designed and manufactured in two different places that are halfway across the world seems like the beginning of a disaster. However, with today's technology, both Strakka and DOME developed a tactic which effectively extended their working day to 24 hours. 'We would have a telephone conference every day first thing UK time and last thing Japanese time to analyse progress,' highlights Walmsley. 'It was not something completely new to us as we had a similar situation with HPD. Now, to have cloud based data sharing, teleconferencing and more we could be looking at designs on a screen in real time both here and in

Japan, which increased the progress phenomenally.' At, at crucial points throughout the project members of Strakka spent time in Japan and vice versa. An interesting aspect is how this time difference actually accelerated the aerodynamic development of the project. 'We took TotalSim engineers to the wind tunnel in Japan and while we were running tests in the wind tunnel during daytime, we had TotalSim running CFD validation runs back in the UK during the day which was overnight Japan time. This meant that when we went to the wind tunnel the next morning we had the results from the CFD runs, so this time lapse has been hugely beneficial.'


racer. 'The aero concept is different because we wanted a stable and forgiving aerodynamic platform and it was that which led the direction that we went with for all the aero development, reveals Walmsley. 'There was one key decision of how the car was going to be and if you understand that, then all the consequential knock-on effects of everything on the car will become clear.'

The WEC forms a credible platform where the innovations and technologies can be shared, unlike the secret world of F1. This makes it the perfect place for teams to develop technical partnerships to gain expertise and also opens up the WEC to a much wider audience. One of the newcomers to this Strakka DOME project was bf1systems who focused on the wiring loom and the electronics of the car. 'This partnership is very exciting because the business plan for bf1 is to grow within the industry and showcase their capabilities,' highlights Patman. 'We are trying to provide good case studies to promote their products, but obviously with the restrictions of LMP2 and cost capping we have to be careful. There is also talk of Strakka utilising bf1 system's composite

facilities as well to reduce manufacturing times and also job sharing between the two companies so that the race team can gain electronic expertise and the electronics engineers from bf1 can gain the practical understanding of their designs; all in all developing everyone's understanding of the challenges of LMP2.

Clear strategy

The immediate aim of the team is clear: to win LMP2 in 2015. With such a reliable and now competitive car this may become a reality. However, the development of Strakka goes far beyond the racecar. The company has expanded over recent years and now includes a World Series by Renault team, a Formula Renault 2.0 team and they have even bought their own karting team in Italy. Their base in Silverstone now includes a simulator, a brake simulator, a neck trainer and they also offer a driver management service. 'Motorsport is such a volatile and aggressive industry and we are trying to build a platform that minimises that turbulence and remains sustainable,' explains Walmsley. 'We want people to see that there is

a clear path they can go on to maximise their career and if they come to Strakka, we can guide them all the way through. Whether that steers someone towards a seat in F1, LMP1, GT or Touring cars, we will unequivocally steer people to the right place for them with no ulterior motive. Our ambition is to see a driver on the top step of the podium at Monaco having come through Strakka and we would love to be part of that transition to world superstar' 

State-of-the-art sensors

One of the safety features of the DOME S103 is that it carries a Tyre Pressure Monitoring System (TPMS) provided by bf1systems. Today's systems work with standard TPMS wheel sensors, capable of measuring air pressure and temperature or IRTPTMS wheel sensors, capable of measuring inner tyre carcass pressure. The sensors have become highly integrated and smaller, meaning they are easier to fit onto existing rims, and now last for up to six years.

Specific systems exist for open wheel race cars, which utilise a combined ECU and antenna, meaning only a single box is required on the car for all the data receiving and processing, and for closed wheel race cars which have a fully automatic learning system,

so it can determine where on the car wheel sensors are fitted, without any user intervention. This means no resource has to be allocated to maintaining the system after initial installation.

In addition to producing systems for use on the car, equipment is produced to support the teams with knowing the condition of the tyres before they even go on the car. The recently launched Garage Monitoring System (GMS) is widely used within the F1, GT3, GTE and LMP categories as it allows teams to monitor the status of the tyre pressures and temperatures while the wheels are being stored and heated, ensuring that every wheel is optimised prior to going onto the car.

The GMS is complemented by the hand-held

Mini Analyser which allows engineers to interrogate specific wheel sensors for data when the wheel is on or off the car, meaning they can quickly and easily receive data on all the tyre pressures when the car enters the box. This removes the need for teams to manually check every tyre pressure individually.

The bf1systems Tyre Pressure Monitoring System was originally introduced in 2002, and has evolved considerably from the original analogue system which utilised coaxial cables to connect components.



bf1systems is a new technical partner for Strakka Racing and has been instrumental in wiring up the S103

TECH SPEC

Chassis make: DOME
Chassis model: Strakka DOME S103
Chassis type & material: Carbon monocoque
Bodywork material: Carbon-fibre composite
Engine type: Nissan NISMO V6 45DE / 4.5L V8 naturally aspirated
Power: 480bhp (estimated)
Engine location / orientation: Mid mounted longitudinally aligned
Engine mounting: Semi stressed
Transmission type: Xtrac 6 speed sequential
Driven wheels: Rear-wheel drive
Clutch material: AP Racing Carbon
Front suspension type: Double wishbone with pushrod actuated dampers
Rear suspension type: Double wishbone, with pushrod actuated dampers
Dampers: Hydraulic, gas pressurised
Springs: Eibach, Coil over damper
Brake disc material: Brembo, Carbon fibre
Calipers: 4 Brembo 6 piston calipers (one on each wheel)
Tyres: Michelin
Wheel dimensions: Front & rear diameter 18" Front width 12.5. Rear width 13"
Regulation weight: 900kg without driver or fuel
Fuel tank capacity: Maximum 75 litres mounted in rear of monocoque

Five years ago



Dome's last Le Mans Prototype, the S102, perhaps never reached its full potential, but its design was certainly influential and turned heads. It was capable of matching the then dominant diesels at Le Mans. We profiled its design in 2008.

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Taming the beasts

GT3 gets new rules for 2016. We look at how the different manufacturers have interpreted them – and what they mean for the sport's future

By SAM COLLINS

When Stephane Ratel came up with the idea of GT3 it was as a catch-all class for otherwise redundant one make trophy cars. Over the years the class has evolved and today it relies on purpose-built machines rather than obsolete cup cars.

In 2016, new rules will come into force in GT3 and a new generation of cars has already started to go into production to comply with them, with BMW, Audi, Mercedes all revealing cars ready to be fully homologated in September. Ferrari, Jaguar, Aston Martin, Porsche, Corvette and others are all expected to reveal new cars soon.

The most advanced of this new generation will actually contest races this year as part of their development programmes, but to develop a car for GT3 is not as straightforward as it may

2016 where the aerodynamic performance of all cars racing in GT3 will be reduced.

But Audi clearly believes that the effort is worthwhile and has equipped its the car with a full floor with rear diffuser and a smaller rear wing, something that the engineers responsible for its development claim give an improvement in overall aerodynamic efficiency. A lot of work has also gone into the wheel arches and wells, which now look more like they belong on a DTM car than a GT machine.

GT3 is a global series that races on every continent and in all conditions. As a result Audi has put in a lot of work into the cooling flows – the cooling area of the radiator at the front has increased by ten per cent to handle maximum outside air temperatures. In order to improve the race drivers' ability to concentrate on their

makes the race result, it is the amateur driver, so you have to give the him the tools to get as close as possible. The car needs to be forgiving and the new car does that.'

It is a sentiment echoed by Giorgio Sanna of Lamborghini Squadra Corse, which recently revealed its new GT3 specification Huracan. 'You cannot go too extreme in terms of aero because GT3 is meant to be for gentleman drivers, and that means you need more mechanical grip rather than more aero grip,' he explains. 'You have to have a car that is easy to drive, and that's a key requirement for us. Everyone says that a Lamborghini must be fast, but it must also be easy and safe to drive. You could spend money and time bringing a car up to F1 standards, but the FIA will peg you back with BoP.'

'The most important thing is to meet the FIA requirements. You can still adjust the front splitter, rear underfloor aerodynamics and rear wing'

seem, possibly because there are not really any technical regulations. The origin of the class, being for a disparate array of designs from little known models from Venturi and Ascari to more widely known cars such as the Lotus Elise and Dodge Viper, meant that a set of technical rules was not especially useful. Instead SRO decided to homologate each individual model and balance their performance. This ethos remains, although for all new cars homologated since 2012 the FIA has defined a set of performance criteria for the cars' rate of acceleration, maximum power, downforce level and drag level. These criteria are displayed as a set of three performance boxes and the cars must remain fully within them at all times. It is these boxes that have been revised for 2016, although there is still a lot of scope for different approaches in the way that a car is engineered.

Audi Sport has decided to introduce a new car for 2016 based on the new for 2015 Audi R8 production car. It is immediately apparent looking at the new R8 LMS GT3, that this car has undergone a serious amount of aerodynamic development, something that seems pointless in a class where all the cars are balanced, and in

tasks, fresh air circulation in the cockpit has also been improved. At a speed of 200 km/h, the airflow rate is 250 litres per second.

Mercedes, which showed off its new AMG GT3 model for the first time at the Geneva Motorshow in March, 2015, has apparently taken a much tamer approach to the cars aerodynamics, and it appears to be far less extreme. It replaces the SLS GT3 model which has been a front runner since its introduction.

Strict regulations

'The FIA defines the aero window for these cars, so it's not worth making a very high downforce car and then going to the BoP test and finding out that you have to change things,' explains Thomas Jaeger of AMG Customer Sports. 'The most important thing is to meet the FIA requirements. You can still adjust the balance with the front splitter, rear underfloor aerodynamics and rear wing. One of the advantages of the SLS was that it was very responsive and predictable and it gave drivers confidence. Many manufacturers have gone out and just looked for the best lap time, but in the end GT3 is a pro-am class. It is not the Pro that

This is exactly what happened to Lamborghini, which after inspection was felt to be too strong aerodynamically. The Italian marque was forced to change the design of its floor and other components, something its designers claim has reduced its overall downforce by some 14 per cent.

There has been some speculation that the Audi's aerodynamic design is in response to the history of its predecessor (helpfully also called the R8 LMS GT3). 'Audi has a different approach, it depends on what strategy you have for the future,' Jaeger adds. 'On the SLS we had no big performance updates during its life. That's very important as with the old car Audi did a lot of major updates and that's expensive for them and for the customer, so maybe they want to avoid that this time, but we are very confident that with our package will be competitive.'

Mechanically the cars are truly production derived, with the Audi's racing chassis and engine coming off of the same production line as the standard production cars. 'In general terms we try to stay as close as possible to the series production cars,' Romolo Liebchen, head of Audi Sport Customer Racing explains, 'so that



Above: The Mercedes will use a naturally-aspirated V8 rather than a turbo from the road car in an effort to keep costs under control

Below: Audi features a rear diffuser for optimum aerodynamic efficiency



Huracan shares much of its underpinnings with the R8





Top: Mercedes has concentrated its efforts on saving weight
Middle: The new R8's rear wing is smaller than its predecessor's
Above: Huracan's floor had to be changed ahead of the rear wheel arch, a move that cost an estimated 14 per cent in downforce

means we have to liaise a lot with the standard production department. It is the same with the engines. We use the same V10 as you find in the series production car and this give us excellent value for money. We have pushed its racing life to 20,000km and that reduces the operating costs. We could make it run at 610bhp, but its performance is limited by the rules.'

Lower running costs

Of course, the engine is not completely standard on the Audi. It is adapted for competition, and those adaptations have gone much further with the new R8 than they did with the old car. 'We have used a new electronic system. In the past we used the series production ECU because when we started in 2008, there were no 10 cylinder direct injection control units available, and while we could have developed one, the purchase price for each unit would have been €35,000. But as time has passed, Bosch has developed a new control unit which meets all of the racing requirements,' Liebchen adds.

'We could run at 610bhp, but the engine performance is limited by the rules'

Mercedes has taken a different approach – instead of using the four-litre twin turbo V8 found in the AMG GT production car, it has carried over its normally-aspirated V8 used in the SLS GT3. 'Many people ask us why we do not use the twin turbo engine, but for customer sports it's far easier to deal with a normally-aspirated engine as you don't have the temperature problems, you don't have electronic issues and you have much lower running costs,' says Jaeger. 'That's one of the targets for the future. We were already strong with the SLS, but with this car we wanted to lower the running costs, so that's why we use a N/A V8. Generally, most of the things on the car are close to the SLS because that was already a

good car in terms of reliability, safety and speed. So we have just made improvements in all the small things with this car.'

In terms of the chassis there are some clear trends across all three of the new cars seen on track in public so far, and the biggest of those is on detail refinement, especially in the area of handling. Mercedes, for example, has adopted a shorter wheelbase on its car while Audi has used bespoke racing wishbones for the first time.

In GT3, minimum weight and a maximum weight is specified, and another trend on these new generation GT3's, which has come from those revised performance boxes, is a quest to reduce weight, suggesting that most of the cars of the previous generation sat high up in the performance box. Audi has shed 25kg from its car while Mercedes is attempting to do the same with its car. 'The SLS was always a little bit heavy, which was noticeable over long race distances, so we focussed on losing weight,' Jaeger admits. 'We have also used a carbon torque tube to lighten the car.'

The transmissions of the cars have also been the target of this weight reduction drive, but the trends here are also impacted by making the cars more user friendly. 'The transmission is all new, so we opted for a new gearbox, a proper racing transmission which gives us the opportunity to run it longer without overhaul. The differential is also adjustable externally, which is helpful at the track. The transmission is also lighter. The gearbox housing and clutch housing is now one part, so we've save a lot of weight with fasteners,' Jaeger continues.

Safety has been a big factor and while the 2016 rules have yet to be finalised, they are certain to feature a number of improvements in terms of driver protection.

'When we started to develop the new car we decided to include elements not required in the rules,' says Liebchen. 'We have fitted the cars with a rear impact structure that meets the Le Mans Prototype safety requirements, and this goes beyond what is required.' Audi has been proactive in investigating accidents in GT racing and has come up with its own conclusions, which could impact the rules across GT racing if adopted. 'We have developed a new safety seat based on GT accident analysis. We developed our own seat because we were not happy with the products available on the market. Our



Lamborghini Huracan

Lamborghini has followed Audi's lead in GT3, not least because despite the very different looks of the two cars they are in fact based on the same model. 'The Audi R8 is same platform as our car,' Sanna admits. 'When we decided to start our GT3 project Audi Sport were already one year into theirs. So we used the power of Audi in the development of this car. There are differences between the cars though – the roll cage is designed by us, the aerodynamics by us with Dallara and the suspension is developed around us, but it uses the same philosophy as Audi does with the R8 LMS. The hardware is very similar and that's important for people to know because everyone is aware of Audi's vast experience in long-distance sportscar racing, and we have benefitted significantly from that. The engine, gearbox and electronics are all the same basically, and we have shared information throughout.'

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investigation showed that the seat mounting sliders are actually quite a big safety risk and we expect it to become part of the rules in future. The forces through the seat are so high it's really hard for the sliders to cope. Our design makes the car safer,' Liebchen explains.

The new seat is a composite part attached directly to the floor of the car and appears to be inspired by the current generation of NASCAR Sprint Cup seats – the early examples of the Audi designs were produced by Fibreworks Composites in North Carolina, although production has now been shifted to a German

the production Huracan was designed from the outset with a racing version in mind. The strategy of different manufacturers is also very important. We only have customer racing, so for us it's an important marketing tool and we deliberately avoid high running costs. We have no intention of a factory programme at races like Spa. There is a risk that GT3 becomes too expensive, but that is in the hands of the manufacturers and the FIA.'

Mercedes has suggested that the costs are already on the verge of being too high. 'In the development of this car we looked at both costs

'With all the steps to protect the customers physically, some want to protect their wallets too'

firm. With the seat being attached directly to the chassis it is not adjustable so other elements have to change instead. The pedal position is hydraulically adjustable and the steering column is adjustable like the road car,' Liebchen explains. 'We have also included a roof hole, which allows the driver's helmet to be removed, and his spine and neck to be stabilised before extrication from the car in an accident. We hope this becomes mandatory.'

The roof openings, which stem from DTM cars, are present on the Mercedes, Lamborghini, Audi and BMW, but it is not yet clear if they feature on the Lexus.

Time for reform?

With all of these steps to protect their customers physically it should perhaps come as no great shock that some are calling for more steps to be taken to protect their wallets too. Twelve months ago the future of GT racing around the world was uncertain, unification of the GT3 and GTE classes looked likely but nobody seemed to be quite sure how to do it, and cost was something of a sticking point. 'The GTE and GT3 discussion had been going on for two years. We had hoped for a compromise in time for this car and at one point it looked like we would get it, but going forwards it was clear that the GTE manufacturers wanted to protect their business,' Jaeger reveals. 'It is unfortunate, but it looks like things will stay as they are. Ultimately I think that the market will decide, and GTE prices are not competitive.'

Indeed, there seems to be a concern across sportscar racing that GT3 is on the verge of spiralling out of control with bespoke racing cars being created and costs becoming unsustainable. 'I think it depends on the philosophy of each manufacturer a lot,' Sanna explains, 'but our road car is not all that far away from a pure racing car in terms of engineering. So it's not so difficult for us to develop a racecar from the production car. In my opinion GT3 cars must not be too far from the production model. But it's important to point out that

and performance, and we decided that this car has to be cheaper. The car purchase price is one thing but the running costs are higher over time. If you do lots of 24-hour races, within one year the running costs can go higher than the purchase price. Building a car for racing is always about performance, so with a GT3 you build a car to meet the performance windows, then you think about how to do that at the lowest cost without compromising quality.'

GT3 racing looks to be facing a very strong future, particularly with integration into the TUSCC in 2016, and with so many new cars being unveiled, strong grids seem certain. However, there is much talk in the paddocks that the whole subject of convergence is not quite dead.



Nine years ago



When Stephane Ratel wanted to put together a new series for redundant cup championship cars from around Europe he called it GT3, Racecar Engineering investigated the concept of the series and its philosophy in an article as relevant today as it was in May 2006. Read it now at www.zinio.com



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Back to basics



Is James Glickenhaus's simple approach to racing the blueprint that will secure the sport's future?

By SAM COLLINS

I find that the very thing that I get criticised for, which is usually being different and just doing my own thing and just being original, is the very thing that's making me successful,' – the words of musician Shania Twain sum up the racing philosophy that one group of Americans and Italians follow. Scuderia Cameron Glickenhaus was put together to contest the 2011 Nürburgring 24 hours with a one-off special, dubbed the SCG P4/5 Competizione, a car based on a Ferrari 430 GT, and styled after Glickenhaus's one off Ferrari P3/4 road car. It proved popular with everyone but Ferrari, and the Italian manufacturer refused to endorse the project.

'If you look on Facebook, our page has 100 time more likes than that of the team that won the N24. There must be something we are doing that people like,' claims Paulo Garella who headed up the Ferrari P3/4 road car project, the P4/5C and the latest SCG project.

'My view is that motor racing around the world is struggling. There is less money and fewer people. The manufacturers are making a lot of money but it is starving as a sport. We

need to look at ways to get more people and more interest. The main thing is to bring cars that are different, cars that connect people to the soul of the cars,' Garella continues. 'I have been in this business for 40 years and I have worked for major manufacturers, small teams and car restorers. What is really strange to me is that the automotive world is an archipelago, a group of islands with nobody talking to each other. If you go to Pebble Beach you will find people who will talk to you for an hour about how original the car is, then you go racing and people there think everyone else is a bunch of idiots and that the only thing that matters is performance and how much money you can make. Then you go to the OEMS and they have no clue about anything but cost and margin – sure there's a bit of performance but basically it's about selling as much product as cheap as possible. For the last 15 years I have been trying to build bridges between these worlds.'

Garella and James Glickenhaus, who owns the team, believe that GT racing has gone wrong in recent years and have been working to try to create their own antidote to the problem. The first part of this antidote was the P4/5C, but the

most recent and perhaps ultimate expression of it is the new SCG 003, a ground-up new design which made its first public appearance at the recent Geneva Motor Show in March, 2015. It was a long awaited project and Glickenhaus openly suggested that SCG may build a Ferrari powered LMP1 or similar, but when he formally announced the project it was clear that he had another plan. He had updated the P4/5C to feature a low-level hybrid system and was hoping that the latest generation of hypercars from the likes of Ferrari and Porsche would be there to take him on. But it quickly became clear that this would not happen.

'We won the FIA Alternate Cup with the P4/5C and I was happy that the next group of hypercar (McLaren P1/La Ferrari/ Porsche 918) would use KERS and be eligible to race us,' Glickenhaus explains. 'Then I realised that none of them were going to. The cost and complexity of KERS and their 1000bhp had turned them into monsters, but not monsters like the 917-30 that were going to see real racing after they set sub seven-minute 'Ring times. I began thinking about my cars. My P 3/4 weighs 816kg and has 430bhp. The Dino Competizione weighs 590kg



Glickenhaus says the SCG 003 will weigh 1350kg with a 49:51 weight distribution. it will be built around SCG's own carbon fibre monocoque

and has 230bhp. They were both so much fun to drive, then I started to think that maybe hypercars were losing their way, especially as they were never going to race in anger. What if I stepped back? Simpler. Lighter. Smaller. Could less really be more?' Glickenhaus contacted Garella to assist in making this concept a reality, and Geralla then enlisted the services of Peugeot 908 designer Paulo Catone.

'The objective of this new car was to take the P4/5 and move it forward. James has this dream of having a competition car that can be used on the road. When you develop a car for the 'Ring you are basically developing a car for the road; the end objectives are quite similar. We became very focussed on the Nürburgring 24 hours and building a car capable of running that race is a big challenge,' Garella explains. 'It has been a clean sheet design. We started by taking the performance of the car and doing a design analysis. We wanted excellent aerodynamics, excellent acceleration and the car had to be easy to service. These were the project guidelines.'

The styling of the new car is dramatic, designed not only to be eye-catching but also

effective in aerodynamic terms, and it hints at another underlying philosophy of the SCG 003. While the P4/5C was really a pure GT car with almost all of its mechanical parts taken off an existing GT2 donor car, the new car is much closer to a Le Mans Prototype both in concept and in construction.

LMP2 inspiration

'The idea of this car is to have a GT car which has the same airflow as a LMP2 car,' Garella explains. 'Today LMP cars represent the closest things to a road car, even if the performance is different. LMP is the most interesting class of racecar development and this is what we have tried to maintain. The aero design has been done jointly between the aerodynamicists and the stylists. For example, the rear of the racecar was sketched by a stylist and the design was then made to work by the aerodynamicists.'

'It's a very interesting car from an engineering perspective. The car has a V-shaped radiator at the front with the airflow going from under the nose of the car, around the cockpit and then to the intercoolers and finally the rear, just like current LMP2 cars do.' Other hints of this

prototype mentality are the fin on the engine cover, the front splitter and the swan neck supported rear wing.

That LMP2 philosophy can be also be found under the skin as the car is powered by a Autotecnica Motori tuned variant of the HPD HR28TT Twin Turbo V6, the same engine found in the back of the Honda-branded LMP2 cars developed by Nick Wirth. 'Our concept was that we wanted a turbo engine, because we need the torque from it, so we chose the HPD. Our concept for the road car is basically the same as the track car with more than 650bhp and massive torque. The whole thing is designed for a lot of torque, to give that kick in the back, that rapid acceleration. On the road version we have 750Nm at 1000rpm and that stays flat

'When you develop a car for the 'Ring you are developing a car for the road'



The suspension has been designed to be firm. It's also very user-friendly and is quick and easy to adjust

up to 5500rpm. You will need to use only two or three gears to get up to a very high speed,' Garella enthuses. Drive to the rear wheels comes via a Hewland sequential transmission with paddle shift. On the road version we are thinking about using the same unit. It will be very sharp or rough, but the drivers of the road car will get that exclusive and true feeling of driving a true racecar on the road. I think in the market today you can get everything you want in terms of supercars, but what has been lost is the connection between the racing cars and the supercars,' Garella adds.

The SCG 003 features a bespoke carbon fibre monocoque chassis built by HP Composites, which Garella claims offers high torsional rigidity and light weight. Additionally, the suspension layout is very much a competition layout rather than a production car solution. 'The suspension is front and rear pushrod with KW dampers and coil springs as the race car is designed to be as stiff as possible. It is also easy to adjust. It's very user-friendly for customers who just want to turn up and go racing.'

Two cars have been built so far, with one already sold to a customer, and SCG intends to enter both in this year's Nürburgring 24 hours, but other races could be on the cards too. 'We have spoken with Stephane Ratel about the Spa 24 hours and he wants us to come, and we have also spoken with Jim France about the Rolex 24 next year – many other races want us to come too,' Garella says.

'We have a very different approach to racing and have designed a supercar specifically to race'

But pitching a new car which is essentially a road going LMP2 against GT3 machinery is not likely to go down well with some competitors or even the manufacturers. 'We are controversial. We have a very different approach and have designed a supercar specifically to race, not designed a road car and adapted it to race. Clearly this means we will be balanced against the other GT cars, but balance of performance is great because you can make a car very slow. To make a car slower is easy, to make it faster is much harder. The SLS Mercedes is very similar in terms of aerodynamic sections to this car, so it should not be difficult to balance the performance of this car. However, it might be difficult to beat us,' Garella continues.

The comparison to GT3 cars goes beyond the world of racing as the creators of the SCG 003 believe that the current format of GT racing spoils the future of each individual car.

Creating a legacy


'At Pebble Beach today, the most valuable cars are the ones that have raced and have a track history but nobody racing GT3 today will have a car with history. Year-on-year they lose value and will eventually end up in the hands of some crazy hillclimber. It will be stripped, reworked or written off, losing its originality and its value. Nobody keeps a proper record, racing people do not care,' Garella adds glumly. 'What we are trying to do here is the opposite and we hope that one day these cars will have a value, a history. We are trying to make the racing just a moment in the life of the car, something that increases its value, not something that someone is using to make money out of it, the way they do in GT3. We want these cars to be at Pebble Beach in the future. There are a lot of questions about the life of carbon fibre chassis, but we all fly on planes made from carbon fibre and they last a long time. It's about how you treat it and



The SCG 003 promises to be a torque monster. Drive to the rear wheels is governed by a Hewland sequential transmission with paddle shift

how you protect it. People don't look at the Ferrari F50 and say now's the time to change all the carbon fibre. At some point with the Ultraviolet there was an issue but that has gone.'

Garella thinks the time has come for race organisers to change the very soul of the racing business. 'I think it's time for the other organisations to look at our cars and others like them, not as something stupid that people want to race for some reason, but as something that has a great advantage for everyone involved, something that is different and something people want to watch race and remember.'

When the SCG 003 makes its race debut, be it at Spa or the Nürburgring, it is certain to turn heads and just as certain is its ability to potentially upset the status quo. 

Four years ago



Some people just want to do things differently and have the resources to do it, Jim Glickenhaus is one of them and Don Panoz is another. While the world contemplates the prospect of a Deltawing GT car, we recall the Panoz Abruzzi GT.

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Let battle commence

Motorsport is its very own battleground – so the new boys in this year's Dunlop MSA BTCC should feel right at home

By GEMMA HATTON



The team's livery was officially unveiled at the Autosport International Show in Birmingham

Two new Infiniti Q50s, which will line up on the 2015 British Touring Car Championship grid, have been built and prepared by a team like no other. Infiniti Support Our Paras Racing includes eight full and part-time crew, all former members of Britain's Parachute Regiment, to maintain and race the two manufacturer-backed cars throughout the entire season.

These former paras have all suffered injuries in the field, and have had to be discharged from the regiment. A total of 26 paras lost their lives in Afghanistan, with more than 130 wounded, yet fundraising for the UK Armed Forces has dropped by 30-40 per cent in the last two years. Supporting the injured and the families of those who have been lost is now even more difficult.

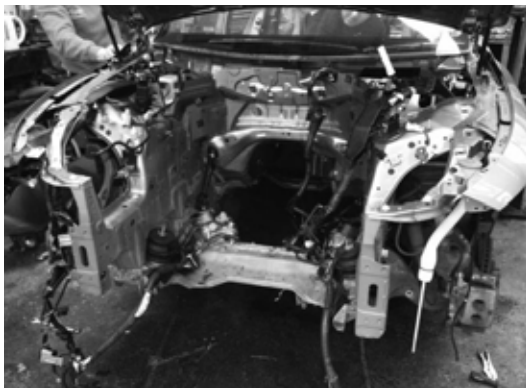
This year, the two main Parachute Regiment charities have merged into one – 'Support Our Paras' – and with the amount of exposure guaranteed from a championship such as the BTCC, it should raise much needed funds and awareness. The team has pledged that all of its profits will be donated to the charity, and as well as employing paras, the long-term aim is to develop Paratrooper graduates to drive one of its racecars. 'My mission will be accomplished when an injured para races a car prepared by other injured paras and steps on the podium,' explains Derek Palmer Snr, team principal. The first targets will be achieved when the team runs a third car as part of a three-year plan.

'This first year we are going to have to work our way up the grid – we're all new to the game

and this is not a simple conundrum. In the second year, I want to give a good account of ourselves and be up there with the best of them, while running paras in a series of club races. At the latest, in our third year, I want to be fighting for the championship and bringing a para through into a potential third car,' continued Palmer. 'We are aware of the challenges ahead of us, but with the united forces of the paras and Infiniti, we are confident we can deliver.'

Infiniti has been increasing its presence throughout Europe and began building its brand in the UK in 2009. 'We are approached around the world by people who want us to go racing with them,' explains Jerry Hardcastle, Infiniti's general manager for performance and innovation. 'Obviously we have the global

'My mission will be accomplished when an injured para races a car prepared by other injured paras and steps on the podium'



Top: Infiniti will supply the body shell and panels but will leave the preparation of the cars to Derek Palmer's Pro Motorsport

Above: The cars will be driven by Derek Palmer Jr and Richard Hawken, who have both been successful in Touring Cars

Top right: The race car produces more than 300bhp from a 2.0-litre turbocharged powerplant

Right: The Parachute Regiment's motto is Ready For Anything. Would you bet against them succeeding?



RWD vs FWD

Last year the West Surrey Racing BMWs shot off the line every race, largely because they were rear-wheel-drive. There are advantages and disadvantages to both set-ups, but with the FWD teams complaining, it was time to review the regulations. 'It's quite an interesting conundrum,' explains Palmer. 'They are intending to limit the boost in first and second gear of the rear-wheel-drive cars to try and stop their initial pace off the line. It is all about trying to make all of the cars equal.'

However, the front-wheel-drive racers have the advantage of generally being easier to drive as they are less liable to spinning due to a greasy track or contact. 'Previously, they have tried raising first gear to ensure the use of the clutch to get off the line along with various other techniques but it remains to be seen whether this is effective,' Palmer continued.

Of course, limiting the boost in the early gears for the RWDs raises the concern of the system cutting in when it's not required. The first round at Brands Hatch on April 4 and 5 will reveal which method the regulations will enforce and whether or not it actually works.

presence of Infiniti Red Bull Racing in F1, but British Touring Cars is really appealing to us now because Infiniti is coming to the UK.'

The premium car brand recently invested £250 million in the award-winning Nissan manufacturing plant in Sunderland to start production of a new model this year. 'It's almost back to race on Sunday, sell on Monday,' Hardcastle explains.

Palmer had previously been working with the Parachute Regiment on various other projects, but with his rich history of touring car success both in the pit lane and out on track, the idea was born. The new team is based at Mallory Park, and the car provides the perfect platform to develop potentially winning NGTC Q50s. 'The car is very good aerodynamically, it is a very clean design,' says Palmer. 'This is mainly because the original road model uses aerodynamics effectively and, with the help of Infiniti and ABS Motorsport, the body design is very good.'

The Q50s will be the same as their road car brothers and will use rear-wheel-drive, which may play into the hands of Paras Racing as it

did for last year's WSR BMWs, or alternatively have minimal effect due to the new proposed regulations for this year (see left).

Common to all the cars is the fact that both a front and rear subframe needs to be accommodated. For a rear-wheel-drive setup this means having the engine mounted in the subframe, with the gearbox behind it and the differential behind that. As the rear subframes are basically the same, all the suspension parts can be carried over from one car to another. The 2.0-litre turbocharged engine produces more than 300bhp and features a six-speed sequential gearbox. The wheelbase is slightly longer than most of the field, but Palmer reckons that this is not an issue.

To add to the challenge, the car had to be built with the limitations of the injured paras in mind, although some of the changes are actually a benefit to the overall car. Paras team leader, Daz Fuller, for example, has a prosthetic lower arm due to a battlefield incident where a mortar shell was jammed inside the firing tube of his weapon – to maintain cover the

'We're set to prove that there's nothing that can't be done if you have the will to do it'



It looks like a conventional racecar from the outside, but under the metal it's been heavily adapted for the Paras working on the car

only option was to remove the blockage and consequently the shell exploded, tearing through his arm. Another para, John Price, was also victim of an equipment failure. 'I was making a jump and I had a container strapped to me. As we approach the ground, we release the container and the theory is that we land safely,' he explained. 'But this time the release mechanism jammed, so I had to land with the container still attached and this crushed my knee. I've had six operations but I've virtually lost all movement in my leg.' Being a race mechanic is a hard enough job without the extra challenges these paratroopers face.

Long-term plan


'The car was designed to make it simple to work on with the idea being to make it easier for the paras to adapt,' says Palmer. 'With the best will in the world, they are not race mechanics at the moment, but I'm certain that this time next year they will be as good as anyone in the pit lane. We have been forced to make various adaptations such as working with GPRM to achieve a subframe that can be detached easily, but it's always better to design a car that is simple to work on anyway.'

Interestingly, the paras may actually have an advantage over other teams. 'We can cross over the obvious skills from our military experience such as working as a team effectively under pressure and working to a chain of command,'

explains Fuller, 'but we also know how to adapt ourselves to overcome any obstacle. In the army you always train one level above your actual job so that you can step up if you need to and we'll be taking this work ethic into the team. This will become an essential tactic for the team's success as different paras will have to be switched in depending on the requirements of that particular job and the limitations of that para.'

'To be a part of this team is not only a great honour, but it also gives us the platform to show we can adapt ourselves to new challenges, regardless of our injuries, while simultaneously raising funds and awareness,' explains Fuller.

'The Parachute Regiment is like one big family and we as a team are just an extended branch of this family. The reality is, we all may need help one day in the future, if not now. Our team is their team and they are as much a part of this as we are. We are just the ones there day-to-day working on the cars.'

Palmer is keen to highlight Infiniti Support Our Paras Racing is here for the long-term. 'Paras Racing is not just a flash in the pan,' Palmer says, 'and this project is not just raising awareness for the paras, but for all injured ex-military and disabled people out there. The advantage these people have is that they regard themselves as having issues which are a slight inconvenience. But that's all. Infiniti Support Our Paras Racing is set to prove that there's nothing that can't be done if you have the will power to do it.' 

11 years ago



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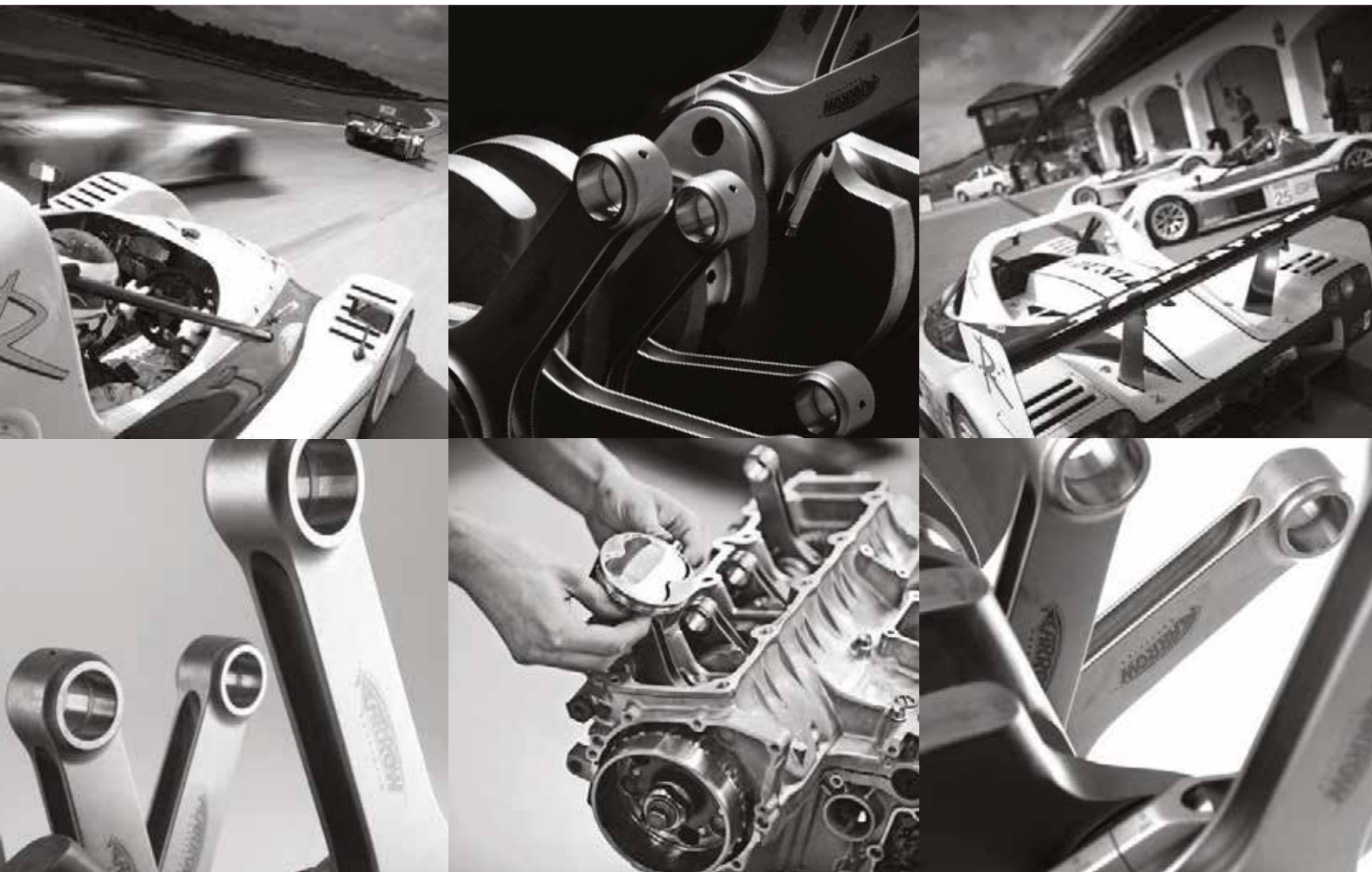
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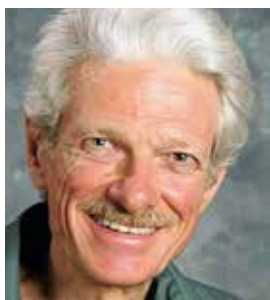
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Unconventional road racer

Investigating the design merits of an offset front engine

Question

I know of one dominant, high-powered, front-engined, live/solid axle GT race car which was built and raced on the roads years ago by a major auto manufacturer that used slight engine offset to the right. The driver was on the left and the racecar featured maximum rearward engine/transmission setback, with the driver as far to rear as possible. If there are relative design merits of this, besides the rearward engine/transmission balancing/offsetting weight of the driver, and getting him some room with maximum engine setback, what would be the A-arm and other suspension geometry design and tuning considerations of such a configuration?

A related obvious question for a solid axle car would be the effects of greater asymmetry at the rear with differing axle/housing lengths as a result of right engine offset?

Do you think all the related and required changes related to the engine side offset would be worth the bother and make the chassis work all that much better?

The consultant says

If the car is in the design phase, there's probably no more bother to have the engine offset than not. Small offsets are actually quite common in production cars. However, if we're talking about an existing car with the engine centred and we're considering modifying it, then that's a lot of bother as it would involve a fairly comprehensive rebuild of the whole car. Therefore offsetting the racecar's powerplant would only make sense if we were already committed to that.

When we wish to have a car that has the ability to turn both ways, we generally want the front suspension symmetrical. However, there may in some cases be an argument for tolerating small asymmetries due to packaging constraints. At the rear, with a beam axle, it's desirable to have asymmetries that cancel torque roll, as discussed in previous issues, but no other asymmetries that affect wheel loads.

However, that doesn't mean the centre section can't be offset as that doesn't affect torque roll, or at least not in and of itself. What

counts for that is the members that transmit axle torque and thrust from the housing to the frame – where the pinion shaft transmits its forces to the housing doesn't matter one iota. Dramatically offset centre sections are the norm on front axles in four-wheel-drive vehicles and those offsets don't have any noticeable effect on suspension behaviour.

In some cases, elements that do transmit torque and/or thrust from the axle to the frame are necessarily offset along with the centre section – for example, in the case of a torque tube. But ordinarily, packaging constraints permitting, we can have any linkage design we want, and equip the car with any centre section offset we want.

Unless the front of the engine is located entirely behind the front wheels, generally the front wheel housings and front suspension will limit how far we can offset the engine. Having no front wheel housings helps somewhat, but the wheels still have to be able to steer. Having a narrow engine helps too, as does having a wide track.

Axle considerations

Explaining the advantages and disadvantages of rotating suspension links

Question

I'm in the process of building a car that uses the A-H Sprite rear axle (no laughing, it's all that I have at my disposal). Back in the day the Lotus 7 used a similar axle with a lower A frame attached to the centre of the axle to replace the lower trailing links and a Panhard bar. I always thought this was pretty slick solution as it allowed transverse location without hanging structure out behind the axle. Of course, it goes without saying that didn't work as the axle didn't like the load and, as a result, leaked its fluid.

My question: If I flipped the A-arm around, so its apex mounted at the centre rear of the chassis floor and with the other ends mounting where the lower trailing arms would normally mount on the axle, would I end up with a workable set-up similar to a dual trailing link and Panhard bar?

The consultant says

Yes, it is possible to turn the layout around like that, and this has the additional advantage of making the roll centre move up and down with the sprung mass rather than the axle. This makes it a more harmonious partner to an independent front suspension.

The most common obstacle to this idea is finding room for it. If the A frame is made short, the driveshaft tends to hit it in droop. If the A frame is made long, it intrudes on seat or footwell space.

These problems are lessened greatly if we don't need a lot of ground clearance or suspension travel, as in a pavement racecar. It may be possible to integrate the mount for the front of the A frame into a driveshaft containment structure. That point will see very large longitudinal loads, so the structure needs to be built to take those.

In the Lotus design, those large longitudinal loads are applied at the middle of the axle housing, and the resulting bending loads are what cause the problems. The A frame is about six inches above the ground. The upper links are about 15 inches above ground. When each tyre exerts a propulsion force of 45kg, the A frame is loaded in compression and applies 15kg rearward to the centre of the housing. The axles each apply 45kg forward at the outer bearings. The upper links each apply 30kg forward. This combination of forces tries to bow the housing back in the middle and forward at the ends. There are also torsional loadings, but it's the bending that's the real problem and causes leaks at the gasket where the diff snout goes in. Other axles, including the Ford 9-in, can have the same problem if they are loaded sufficiently in this manner.



Reversing the layout means the bending loads become smaller

If we go ahead and reverse the layout, the 151kg rearward is applied as 76kg rearward at each end of the axle. There are still big torsional loads on the tubes – bigger in fact – but the bending loads are now very small. And under braking, only the ends of the tubes are loaded in torsion.

Of course, it is possible to reinforce the

housing so that it will take the bending loads. One method of doing this is to add a channel-section brace across the rear of the housing. This adds torsional stiffness as well as bending. Alternatively, it is possible to use angled tubular members on the back of the housing, anchored to a bracket protruding rearward a little behind the diff. This creates a triangulated

structure. It is possible to have opposite-hand threaded clevises or Heims at the ends of the tubes and get limited toe adjustment. It's also possible to add another set above or below the axle and get limited camber adjustment. All of these ideas can be used in conjunction with any linkage layout, it's just that the design of the Lotus 7 makes them unusually desirable.

Coping with tightening turns

Decreasing radius turns and slaloms in autocross

Question

I see that your speciality is oval-track and road racing, but I get the sense that a few cursory minutes of your thoughts on autocross might be as good as some experts in this smaller field of interest.

Do you have any thought on shock absorbers when the driving is to keep control during all quick large steering movements and sharp transitions between off-throttle and/or trail-braking into tightening slaloms and other no-rest decreasing radius turns, and powering out of tight corners?

The consultant says

I'll actually advise on any kind of vehicle. Right now I'm mentoring a team at UNC Charlotte who are designing a human-powered vehicle. US-style autocross is basically road racing (asphalt surface; car turns both ways) in a parking lot, one car at a time, around traffic cones. Usually the turns are tight and the straights are very short. Well maintained

parking lots tend not to be very bumpy, but they can be quite wavy, since they cover a lot of area and are generally intended to be used at very low speeds.

I've driven a few autocrosses, and the turns and gates come at you so fast that the steering wheel is in nearly constant motion and the car spends very little time in steady state.

The event also rewards aggressiveness. You get a time penalty for every cone you knock down, and if you miss a gate your run is not counted, but on the other hand there is usually not much to hit except cones, and you are scored only by your best run.

Because most of the turns are tight and of short duration, the car is generally undergoing large yaw accelerations for a substantial portion of the run. The usual challenge in very tight turns or slaloms is to overcome understeer when initiating the turn and oversteer when concluding the turn. My usual recommendation for this is to use more low-speed damping, both compression and

rebound, at the rear than at the front. That tends to de-wedge the car (unload the inside rear and outside front and load the other two wheels) when it's rolling outward and add wedge when it's de-rolling or rolling inward.

This is not without some disadvantages as the rear wheels will tend to unload more than the fronts over any crests. Using compression damping, not just rebound, at the rear can help calm things down. This may call for more than a simple adjustment on a single-adjustable shock, however.

The questioner asks about decreasing-radius turns and slaloms. The courses I've driven didn't have these, but I can easily imagine course designers including them to add a driving and setup challenge. When we're trying to slow down during sustained cornering, we are most often worried about oversteer rather than understeer. If we've adopted setup tricks that are geared to tossing the car entering tight turns, especially extra rear brake, a steady turn of decreasing radius can catch us out.

Barring elaborate active suspension and braking systems, we can't really expect the car to know whether we're trying to toss it or slow it without spinning it. However, if we use rear low-speed damping to free the car up on entry rather than using rear brake, that will have relatively great pro-oversteer effect entering abrupt turns, and relatively little effect in sustained braking and turning. R

CONTACT

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis setup and handling queries. If you have a question for him, get in touch.

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Autocross places demands on good handling rather than engine power and outright speed. A good setup is crucial

New track for Malta

State-of-the-art motorsport complex to be built for Formula 1 testing and international racing

A new motorsport facility in Malta, the first of its kind in the country, is expected to attract Formula 1 testing and events up to and including GP2. The facility will cater for racing in the summer, and testing and car-launches throughout the year, and the target is to develop the young driver training market. Malta does not have a grass roots racing heritage and this facility, still at the proposal stage, aims to address that problem.

The facility will also help to improve road safety skills in a bid to reduce road accidents and fatalities with driver education courses to a supremely high level.

The facility is to be built to a similar model as Vallelunga in Italy, that is to T1 (Formula 1 testing) and Grade 2 (for series up to GP2). It would be able to host events, with closed circuit high definition television cameras around the complex and significant spectator facilities. Currently there are no motor sport racing circuits that reach international standards and safety measures required to groom existing and new talent.

There would be more than one circuit within the facility, including a track designated for cars and motorcycles, and another for go karts, Mini Moto and scooters that would be constructed in accordance with FIA, CIK

FIA and FIM specifications and designed to accommodate motorsport events up to Formula 3 level. However, the government is open to considering other options.

One of the project's main aims is to develop an international multi-purpose educational motor sport complex, which can host a wide variety of events, from amateur and recreational level to national as well as international-level motor sport events. The operation of the circuit is proposed to be year-round, with racing in the summer months, and testing and car launches in the winter to help to generate income for the circuit.

Better driving skills

However, the aim for the facility will be to improve road safety in line with the calls from UNESCO and the FIA (Action for Road Safety). The facility would aim to educate and train drivers to improve their driving skills and to control their vehicles when faced with emergencies initially away from busy traffic.

The state-of-the-art complex will have a specific area dedicated for road safety with a driving academy offering courses for defensive driving and driving improvement technique courses to individuals, government personnel, civil protection, police and security forces in collaboration with government agencies.

A motoring and transport museum, exhibition and conference facilities, club member facilities, race engineering facilities and function facilities should also be considered to be feasible. The Educational Motorsport Complex would itself be unique, introducing a range of educational and interactive projects as part of the service to the community, including engineering and safety workshops for children, high-tech courses in mechanical engineering, a collaboration with the University and MCAST in areas of engineering, sports management, event and tourism and vocational training.

Land has been earmarked for the facility, with 110 hectares deemed appropriate for the full facility, which would include a medium sized hotel of not less than three stars, including a restaurant, a café and banqueting all. On the basis of what has happened in similar facilities outside Malta, it is estimated that the entire complex will create a significant number of jobs in addition to more jobs in other businesses as a flow-on effect.

It is expected that such a project would contribute to the growth for the local economy and could generate millions of euros into the Maltese economy. ♦



The proposed facility will be a starting point to develop Malta's racing heritage, providing a circuit that will satisfy the country's large number of racing enthusiasts



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Gasoline Direct Injection, or GDI, is steadily making its way into racing from the top level down with added emphasis on fuel efficiency. GDI technology can reduce the fuel consumption of race cars significantly and is therefore high on the hit list of engine developers wanting to improve their performance.

One key element of GDI technology is the extremely high pressure at which the fuel is fed to the injectors. This is often in the region of 150 bar, which is significantly higher than traditional port fuel injection. This extremely high pressure allows very precise injection of fuel, multiple times in one power stroke, which in turn makes for much a more efficient burn. Such high pressure means that high pressure fuel pumps must be used to feed the fuel rail. Normally there is low pressure fuel fed all the way up to the actual fuel rail and there sits a high pressure pump that feeds the rail. As the fuel pressure is integral to the calibration of the engine, making sure the high pressure fuel pump is correctly calibrated is a very important task.

The GDI pump unit consists of one or more cam lobes rotating at the same speed as the camshafts – once per engine cycle. The cam lobes are used to pressurise fuel and deliver it to the fuel rail in order to maintain the target fuel rail pressure. The pump contains two valves – an

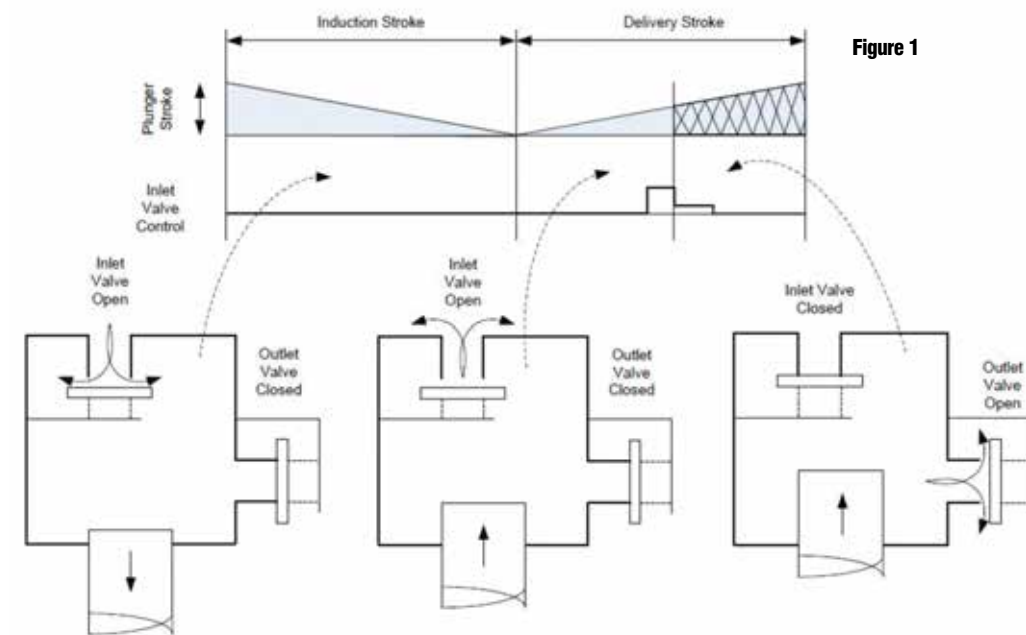


Figure 1

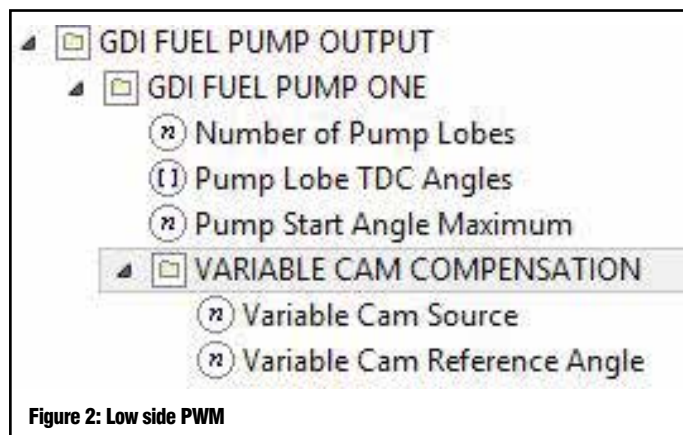


Figure 2: Low side PWM

inlet valve and a control valve. The inlet valve controls low pressure fuel into the pump chamber, and also allows unrequired fuel back out from the chamber into the low pressure fuel circuit. The control valve is a “normally closed” configuration with the ECU controlling the opening time and duration.

The pump operates by generating pressure which is

“normally” returned to the low pressure system unless the control valve is actuated by the ECU. This means the valve opens towards the end of the pump’s delivery stroke. For this reason, calibration of fuel mass flow is required so that the correct start angle can be determined as per **Figure 1**.

Before any calibration is done it is important to configure the

engine dataset or map for the type of pump in use. Parameters such as the number of pump lobes, the location of top dead centre of the lobes with respect to crank angle and the maximum start angle for the pump. It is important to verify the true location of the cam lobes of any pump as they may not be uniformly distributed. This also adds a complication when calibrating the flow rate of the engine as there can be varying pressure due to the non-uniform cam. In order to compensate for this it is useful to set an averaging function for the pump events, and this should then be turned off once the flow rate is calibrated. Additionally, if there is a variable valve timing system on the engine, there needs to be a compensation for any movement of the camshafts, as shown in **Figure 2**.

Before starting the calibration of the pump the base angle map that allows the compensation for the efficiency of the pump

Extremely high pressure allows very precise injection of fuel



should be set to zero. This map is particularly useful at high engine speeds or after the engine volumetric efficiency has peaked, but should also be the last thing to be properly calibrated.

The flow rate can now be calibrated in the

pump flow rate map. This map references the current fuel rail pressure and the volume of fuel used during each cylinders injection sequence.

This should be calibrated at steady state on a dyno, with the D and I terms of the PID controller

for the demand valve control set to zero. Then set the target fuel rail pressure map to the minimum pressure in the Pump Flow Rate map, as demonstrated in **Figures 3 and 4**.

Now run the engine at the speed where the volumetric efficiency is maximum and adjust the engine load so the volume of fuel used is at the minimum value in the pump flow rate matrix. This value should also be the lowest value of the fuel rail pressure axis. A typical value for the pump flow rate angle in a large bore V8 engine is 90, although this base value will differ based on the expected fuel usage of the engine – see **Figure 5**.

It is now necessary to tune the flow rate based on the P control term for the angle and the observed flow rate duration angle. Subtract the P term value from the flow rate angle until the P term is as near to zero as possible. An error of +/- 5 degrees is usually acceptable. Now return to the target fuel rail pressure map and set it to the next breakpoint in the pump flow rate map (60) and adjust the engine load to maintain the lowest volume of fuel used. Repeat the procedure for zeroing the P term and continue to work this way across the fuel rail pressure axis at the set volume of fuel used point. Then return the target fuel rail pressure map to the minimum value in the pump flow matrix and repeat the procedure for the next value of volume of fuel used. An experienced calibrator often extrapolates values to speed up the process. Once the calibration is complete it's possible to work on the base angle map, which is used to compensate for any inconsistencies in the pump flow at high engine RPM. This is generally based on observing the pressure and smoothing out any inconsistencies.

FRP Axis (bar)	30.0	45.0	60.0	70.0	80.0	90.0	110.0	120.0	130.0	140.0	150.0	160.0	170.0	180.0	200.0	250.0
200.0	39.75	45.75	46.50	48.50	49.25	50.25	50.75	51.25	51.50	52.00	52.50	51.75	51.25	50.75	49.50	33.00
191.0	39.75	45.75	46.50	48.50	49.25	50.25	50.75	51.25	51.50	52.00	52.50	51.75	51.25	50.75	49.50	33.00
181.9	39.00	45.75	46.50	48.50	49.25	50.25	50.75	51.25	51.50	52.00	52.50	51.75	51.25	50.75	49.50	33.00
172.9	39.25	45.75	46.50	48.50	49.25	50.25	50.75	51.25	51.50	52.00	52.50	51.75	51.25	50.75	49.50	33.00
163.9	39.25	45.75	46.50	48.50	49.25	50.25	50.75	51.25	51.50	52.00	52.50	51.75	51.25	50.75	49.50	33.00

Figure 3: Matrix pump flow rate

RPM (crpm)	2000	2500	3000	3500	4000	4250	4500	4750	5000	5250	5500	5750	6000	6250	6500	6750	7000	7250	7500	7750	8000	
3000	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
1000	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
1800	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

Figure 4: Target fuel rail pressure

FRP Axis (bar)	30.0	60.0	90.0	100.0	110.0	120.0	140.0	160.0	180.0	190.0	200.0	210.0	220.0	230.0	240.0	250.0
350.0	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
300.0	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
250.0	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00

Figure 5: Pump Flow rate

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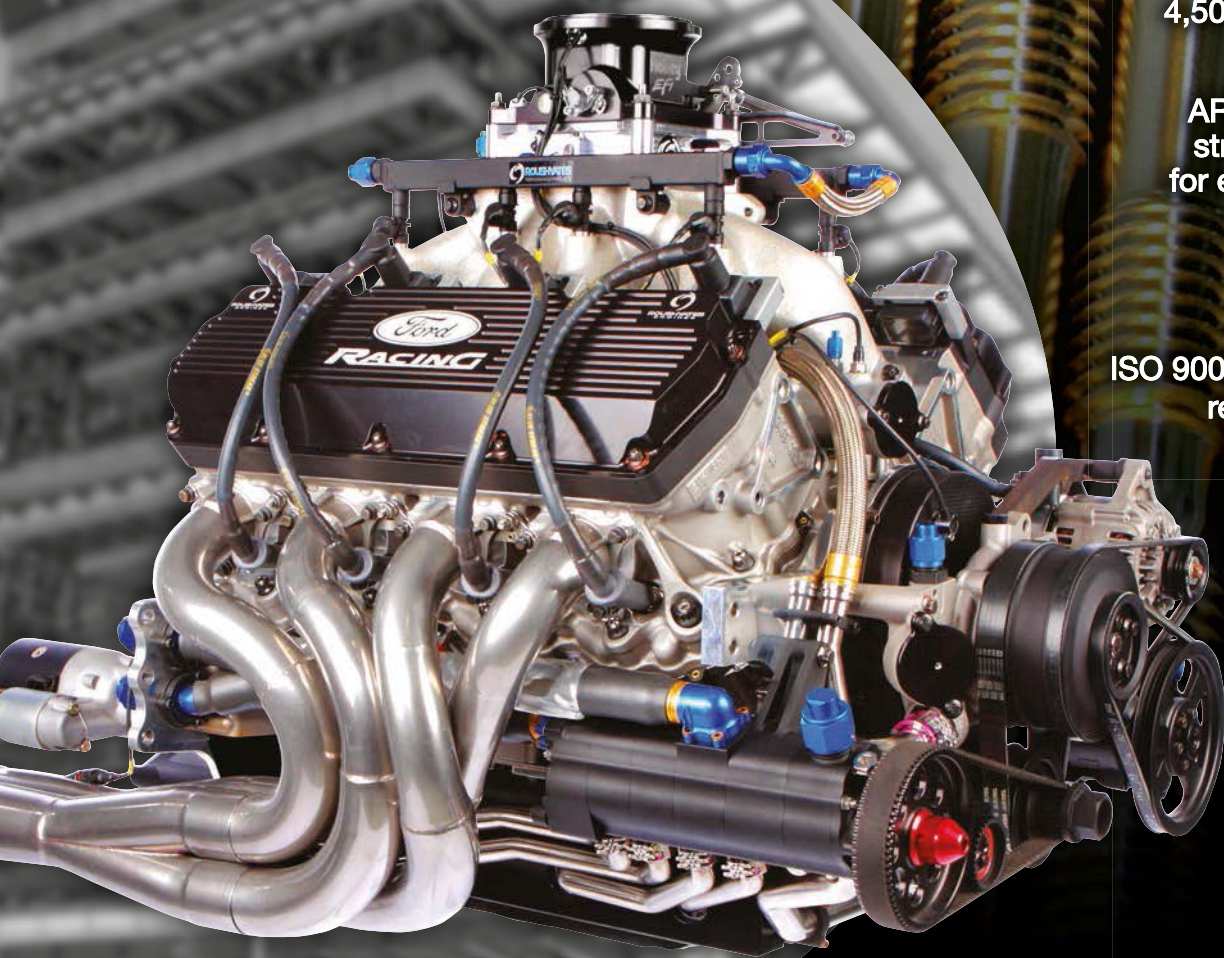
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Lifting the lid on aero balance

A new project begins; a lightweight sportscar from Mexico

Launched in the UK in 2013, the VUHL 05 apparently impressed Mexican former F1 driver Esteban Gutiérrez when he drove it at the Goodwood Festival of Speed that year. This sportscar fits the genre of road-cum-track car already populated by such as the Lotus 2-11, the Ariel Atom, and the BAC Mono and perhaps the Caterham AeroSeven concept. However, the prime movers behind the car, the Echeverría Brothers, Iker and Guillermo, have said they think of it like a Lotus Elise; a car anyone can drive quickly. With the prototype in the UK undergoing development by Collins Advanced Engineering (another fraternal partnership run by antipodean engineers Jenner and Jilbruke Collins) it was a timely coincidence that brought the VUHL 05 into the MIRA full-scale wind tunnel with *Racecar Engineering* to share some of the findings on a car that will surely find its way onto the racetrack of the world very soon.

The VUHL (Vehicles of Ultra Lightweight and High performance) featured the expected aerodynamic aids aimed at creating modest downforce, namely; a small front splitter; side splitters or running boards; a flat underside; a short, curving rear diffuser; and a small, low-mounted rear wing. The car's cooling package comprised a front mounted water radiator plus an intercooler mounted at the rear of the right hand side duct. All of these aspects would come under the spotlight during the session. Collins Advanced Engineering also fitted a 46-port pressure tapping loom on

the car prior to our session, with ports along the centreline of the car and at other points of interest in the hope of being able to correlate measured pressures with CFD data derived from the digital model of the car. We'll visit that aspect in a future issue. Meantime, let's take a look at the baseline coefficient data on the car as delivered to the wind tunnel. **Table 1** shows the coefficients and aerodynamic balance of the car at 16.2m/s (58km/h or 36mph), 26.2m/s (94km/h or 59mph) and the wind tunnel's maximum of 35.3m/s (127km/h or 79mph).



Table 1 – baseline coefficients on the VUHL 05 as delivered to the wind tunnel

Speed	CD	-CL	-CLfront	-CLrear	%front	-L/D
16.2m/s	0.539	0.108	0.071	0.036	65.7	0.200
26.2m/s	0.535	0.119	0.083	0.036	69.7	0.222
35.3m/s	0.533	0.135	0.102	0.032	75.6	0.253



Picture 1: The VUHL 05 open two-seater sportscar from Mexico



Picture 2: Compact and lightweight, but was it efficient?



Picture 3: Front splitter and cutaway airdam in front of the front wheels



Picture 4: Low-mounted rear wing





Picture 5: Twin short rear diffusers at the termination of the flat floor



Picture 6: This motorsport-modified Lotus Exige produced comparable CD but greater CL from a more aggressive aerodynamic package

Table 2 – the effects of yaw angle on the aerodynamic coefficients and balance

Yaw angle	ΔCD	$\Delta -CL$	$\Delta -CL$ front	$\Delta -CL$ rear	$\Delta\%$ front	$\Delta -L/D$
+5.0deg	-	-34	-6	-27	+19.5%	-64
+2.5deg	-5	-12	+1	-12	+8.1%	-20
-2.5deg	+3	-23	-1	-21	+14.6%	-44
-5.0deg	+3	-45	-12	-31	+23.3%	-83

So let's examine the key facts from this initial data set. First, the car generated modest drag and downforce. The CD value was very similar to the motorsport-modified Lotus Exige that we tested back in 2007, but the $-CL$ or 'downforce coefficient' value, was somewhat lower. However, given that the VUHL's primary downforce inducing devices, the front splitter and the rear wing, were more modest than this should be expected.

Second, the aerodynamic balance in the baseline configuration was front biased. The car's static weight distribution was around 37-39 per cent on the front, so in that sense the baseline aerodynamic configuration was too forward-biased. With sufficient downforce at the rear to get the aerodynamic balance closer to the static weight balance, the car would have significantly higher total downforce. We shall examine various changes that bear out this assertion in the next issue.

Third, the changes in the data with test speed were interesting. With increasing speed:

- CD decreased very slightly
- CL increased
- CL front increased
- CL rear barely altered
- Balance shifted forwards

As to the cause of these changes, it is most likely that a front-located downforce producer started working better as speed increased. This could really only be attributed to the front splitter. However, the extent of the change in $-CL$ front seemed to be relatively large. We have seen slight increases in $-CL$ front as speed has

increased on cars with splitters previously but, relatively speaking, these are not as big as those witnessed on the VUHL. However, the VUHL was not producing very much rear downforce in this configuration, and there was very little change in CL rear as speed increased, so any front end speed sensitivity would probably be more evident as a result.

In terms of the actual mechanisms that produced lower $-CL$ front values at lower speeds, the splitter was seen to be roughly 10mm closer to the floor at 35m/s than at rest, which would certainly contribute to the data trend. It might also be that the airflow was separating at the splitter's leading edge, but as speed increased this separation was suppressed by the increased mass flow under the splitter. If this was the case then a thicker splitter with a more generous leading edge radius to the lower face might perhaps be less speed sensitive.

To round off this opening instalment on the VUHL we'll look at how the data changed with yaw angle. The car was rotated on the tunnel's balance turntable, first 'nose to the right' (positive yaw), then to the left (negative yaw) to 2.5deg and 5.0deg. For clarity the data are shown in **Table 2** as changes (deltas or Δ values) in counts (1 count = a coefficient change of 0.001) from the highest baseline speed values in **Table 1**, all subsequent tests having been run at approximately 35m/s.

Clearly the most significant change to the data was the reduction in downforce, the majority of which was at the rear, where downforce was already quite small in the

baseline configuration. The other most striking aspect was the asymmetry in the data, negative yaw (nose to the left) producing greater effects than positive yaw. It doesn't take a leap of imagination to think that the off-centre location of the dummy driver had much to do with the asymmetry in the changes, although this was not the only non-symmetric characteristic of the car; as previously mentioned the intercooler was located on the right side while the duct on the car's left side was empty. Nevertheless, at 5deg yaw either way the small amount of rear downforce had all but disappeared in this configuration, while front downforce reduced by just 12 per cent of the straight ahead value at -5deg yaw.

Next month: We'll look at the effects of blanking off the various cooling ducts to get an idea of total cooling drag, and further explore the characteristics of the VUHL. *Racecar Engineering's thanks to Iker Echeverria at VUHL, and Jenner and Jilbruke Collins at Collins Advanced Engineering.*

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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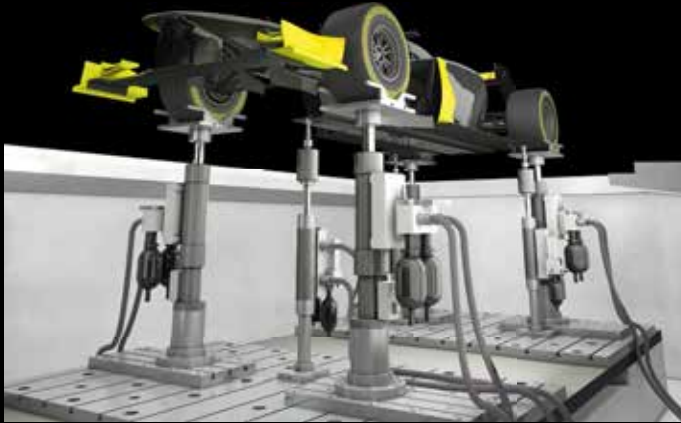
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Probing times

A look at the high-tech probes, sensors and electronics gadgets that are essential items in the aero team's arsenal

By ERIC JACUZZI

As an aerodynamics engineer with the majority of my background in Computational Fluid Dynamics (CFD), I am often able to know the answer to most aerodynamic questions before anyone else thanks to the magic of CFD. Intricate flow structures, velocities and pressures are all readily available in post-processing, painting a complete aerodynamic picture. However, there comes a time when we must validate the insights CFD gives us in terms of this detailed flow structure, aside from simply learning force levels in a wind tunnel. As part of NASCAR R&D's continued investment in its own capabilities, leadership at the R&D Centre in Concord, North Carolina, gave the aero team the green-light to invest in the technology needed to take our aero programme to the next level.

The following article chronicles the technologies we decided to purchase, and more importantly, their function and the testing objective they fulfil. It has been a great learning opportunity for the team to delve into the black art of physical aerodynamics testing beyond the usual full-size wind tunnel testing. It takes the work of many separate specialist

companies to produce all of the probes, sensors and electronics that work together to create a functioning system. The dearth of published material on this topic inspired us to share our learning experiences, and I hope this insight is valuable to both engineers and fans alike. Hopefully the form and function of the mysterious appendages mounted to test cars will be a little clearer in the future.

Brains

The first decision to be made is how many channels to measure – or how many can you afford to measure? Since each channel corresponds to a probe or pressure tap location, we reviewed the available market options before settling on a 128 channel system from Scanivalve (Washington, USA). To determine the number of channels we truly needed, TotalSim USA (Dublin, Ohio) plotted the effect of discrete spacing on a CFD planar slice of the wake behind a car. **Figure 1** shows the CFD resolution compared with a 2inch spacing for C_p Total, representing a 2inch spacing between Kiel probes in a rectangular array. The wake profile is easily observable at this level of separation,

but much greater than 2inch proved to be too coarse of an image to be of much use. A 128 Kiel probe array allows us the opportunity to span the entire car or to choose a smaller horizontal distance and expand vertically. Of course, this limitation can be overcome with a moving rake, but there is substantial added complexity involved that we chose to avoid at this time.

The measurement units themselves are twin Scanivalve ZOC-33 modules, each capable of recording 64 channels. The supporting electronics to run the modules include a solenoid bank to control the pneumatic valves, a power supply, and an ERAD control module that communicates via Ethernet with an in-car laptop. Additional equipment includes a nitrogen supply of 65 PSI to give the solenoid bank the ability to open and close its pneumatic circuits, and a substantial 24-volt battery that provides a full day's running.

The ZOC-33 modules are capable of sampling each channel at 500 Hz, although there are considerations beyond simply the amount of data generated. Each sensor has its own time constant, usually on the order of 0.1-0.5 seconds, which is the delay between a



NASCAR's aero programme has taken a step with the purchase of key equipment for accurate measurement in the wind tunnel

pressure change at the tip of the sensor and when it could realistically be measured at the takeoff. Additionally, there is latency associated with the pneumatic line lengths – the longer the pneumatic tube, the longer the delay. This makes sense intuitively, as pressure changes on one side of a tube should be felt more rapidly on a shorter tube compared to a longer one. For this reason, we chose to use a 5Hz sampling rate.

The packaging solution was much easier in a stockcar than with other racecars because of the very open cabin area. It was decided to package all of the equipment into one case for ease of use and to avoid exposing any part of the system to the heat and vibration of the in-car environment. The waterproof case features two 64 port pneumatic connector exits, a rugged ethernet connection and a reference port inlet for the pitot-static line.

We discovered an improvement in a recent wind tunnel test to make life easier so that we don't need to open the case to re-zero the system. In order to correctly zero each sensor, the calibration line must be pneumatically shorted to the reference line so that the diaphragms inside each sensor see the same pressure condition on each side. We determined that rather than having this occur inside the case, it would be easier to have the ability to shorten the lines outside of the case, particularly when the system is nestled into its running position on the car, as shown in **Figure 3**.

Designing the pitot foil

The most noticeable appendage on the car is the hood-mounted carbon foil that contains the pitot-static probe and the five-hole probe. The question is; why such an elaborate mounting solution for these probes when something closer to the car would do? **Figure 4** reveals the impact on the flow field that the sedan-style body has. While a roof mounted solution gives an easy and seemingly clean mounting location, there is a large low pressure region created by the air accelerating over the greenhouse. If we were only concerned with determining speed, this could be offset out of data by comparing the pitot-static measurements of the car to that of the wind tunnel itself and correcting appropriately. However, our pitot-static has a more important role to play.

The next best options for mounting are forward of the top of the windshield, or mounted on the nose. As the hood is a stiffer carbon structure and can be braced underneath, it was decided to pursue this route due to simpler mounting of the assembly and more interchangeability between different manufacturer's vehicles. CFD runs were made to determine both fore-aft positioning on the nose as well as the incoming flow direction. The final positioning is shown in **Figure 5** with a wind tunnel smoke run to demonstrate the incoming flow angle and why the probes are mounted with a 10 degree nose down orientation.

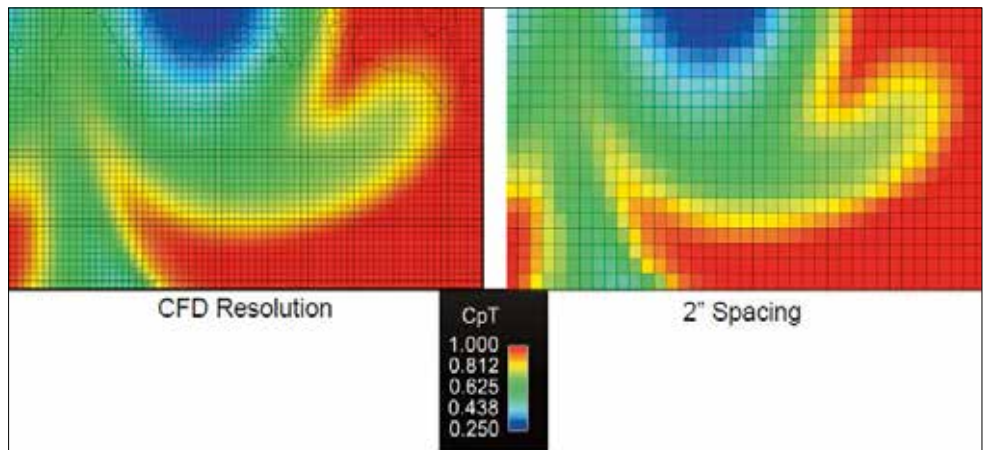


Figure 1. CFD probe spacing visualization estimate



Figure 2: Scanivalve system in its enclosure



Figure 3: Scanivalve system mounted inside the test car

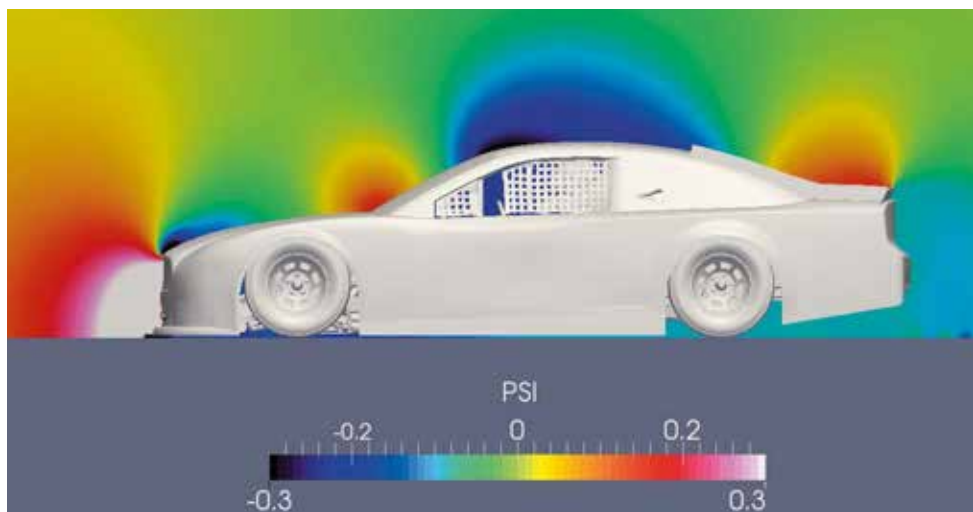


Figure 4: Flow field disturbance of the car body



Figure 5: Final mounting position of the Pitot foil with smoke verification of the flow angle

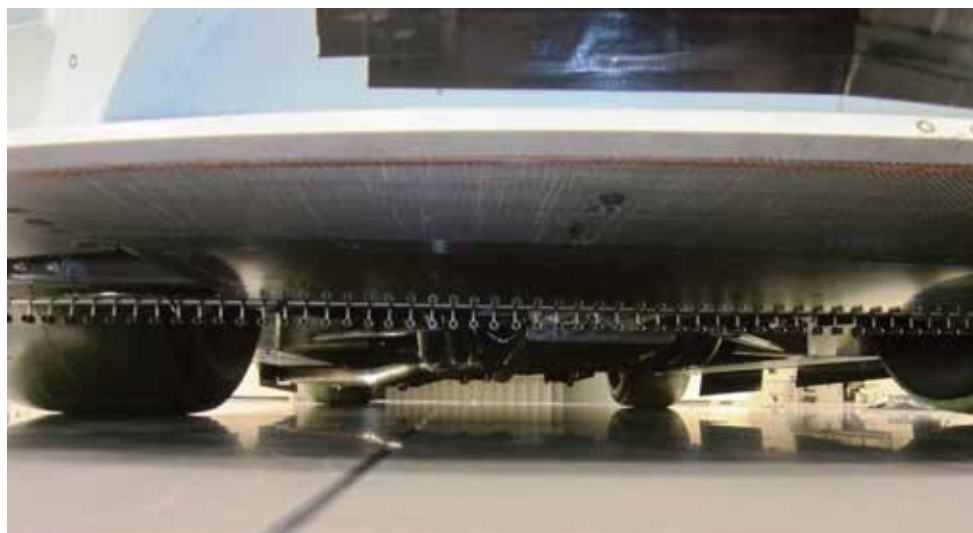


Figure 6: Kiel probe undercar rake, located just behind the splitter and radiator pan

“The Kiel probe returns only a single pressure line and measures total pressure, similar to the nose port on the pitot-static ”

The design of the foil itself is relatively simple, with an aluminium mounting base and carbon aero shroud. Due to the location of the pressure tap exits it was decided to keep the mounting hardware on the exterior of the hood and cover it, rather than have it under the hood. Underhood temperatures can regularly exceed 300degF, making it a rather unfriendly environment for our nylon pneumatic tubing. Our designers are already working on a second version of the housing to make it easier to install and remove, and make it less likely the pneumatic tubing can be pinched inadvertently.

Explaining the probes:

United Sensor 22in pitot-static probe

The tallest probe on the aero sensing foil is the pitot-static probe designed by United Sensor (New Hampshire, USA). Many people who are less familiar with aerodynamic test devices often equate any probe on the car to being a pitot-static probe, but there are some important limitations to a pitot-static probe that must be kept in mind. Pitot probes are fairly sensitive to pitch and yaw, and generally start to become inaccurate over five to 10 degrees of misalignment with the flow. This means that prior knowledge of the flow direction is necessary in order to accurately position the probe without needing any offsets for the pressure measurement recorded. Another factor is the local flow conditions – putting the pitot-static probe on the roof of a NASCAR Sprint Cup car may be convenient, but it is the worst possible area for the measurement to be taken because it is deeply within the low pressure region caused by the greenhouse as air accelerates over the roof. Again, this can be offset out of the data by comparing the car’s pitot-static measurements to a full-scale wind tunnel pitot-static channel, but it is less than ideal for all of our needs.

Getting back to the probe itself, there are two pressure takeoffs from the probe – one from the total pressure port on the nose, and one from the static ports on the side. This is nearly enough information to calculate flow velocity. Since we know from Bernoulli’s relationship that total pressure is equal to the sum of static pressure and dynamic pressure, we can rearrange this as follows for the flow velocity (assuming there’s a constant density):

$$V = \sqrt{\frac{2(P_{total} - P_{static})}{\rho}}$$

But aside from simply calculating flow velocity, the static port of the probe fulfils a much bigger purpose to our overall system – this line is plumbed into the reference side of our Scanivalve pressure scanning system. So having an accurate static side measurement is crucial to the accuracy of the data from our pressure ports, Kiel probes, and any other





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Figure 7: Front Kiel probe rake at ride height

Table 1

Probe type	Measurement	Aerodynamic benefit
Pitot-static probe	Static +total pressure	Air speed calculation, reference pressure for pressure scanner
Kiel probe	Total pressure	Total pressure measurement in turbulent/unknown flow conditions
Five-hole probe	Directional total pressure	Air speed and direction calculation
Pressure taps	Local static pressure	Pressure magnitude at a discrete location

Eight years ago



The world of NASCAR never really stops, but one of the biggest changes came in 2007 with the arrival of Toyota. As outsiders they brought in a lot of new thinking and new ways of working, but also had to learn a lot of lessons themselves.

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‘Pitot probes are fairly sensitive to pitch and yaw’

sensors we may use since the ZOC-33 modules measure differential pressure between the sensor input and the reference input.

Kiel probe

The Kiel probe is certainly one of the most visible, particularly in Formula 1 testing, and is the probe most likely to be erroneously referred to as a pitot probe. The two are definitely siblings: the Kiel probe returns only a single pressure line and measures total pressure, similar to the nose port on the pitot-static. However, where it differs dramatically is its ability to handle flows coming into the probe at high degrees of yaw or pitch. This is due to the venturi shroud that surrounds the measurement tube, also known as an impact tube.

For our probe design, a customised version of a standard United Sensor Kiel probe, we are able to accurately measure up to 63 degrees of pitch and yaw misalignment. The benefits of this are obvious in motorsports where there is an abundance of turbulent flows.

The Kiel probe design itself is a “probe on a stick” version rather than an inline probe design. This was simply done for cost reasons, as the cost of manufacture is much lower than an inline probe. The design also lends itself to a simple mounting solution, consisting of a 1/8in hole to insert the probe stem into and some type of clamping solution. CFD runs were performed to validate that the probe design and mounting did not adversely affect the flow near the probe heads.

The Kiel probes are crucial to validating CFD, particularly in flow regions that drive the overall car aerodynamic performance such as the

underbody jet. As mentioned previously, the discrete spacing of the probes is crucial. For outerbody measurements, we utilize a 2.25inch spacing. Under the car, we use a closer 1inch spacing to more accurately capture the high speed splitter jet and undercar structures, shown in **Figures 6** and **Figure 7**. Since there is little flow of consequence above the splitter, we are able to use a simple rake design made of round tubing rather than a complex airfoil shape.

The Aeroprobe (Virginia, USA) five-hole motorsports probe is mounted below the taller pitot-static probe in our sensing foil. The five-hole probe features as expected, five holes on the nose of the probe with a static ring further back. Once the probe is correctly calibrated, it is able to determine incoming flow direction and velocity to within one per cent, with a yaw and pitch range of 20 per cent. This is suitable for our on track testing as the car will rarely exceed four degrees of yaw. Generally, large crosswinds are not an issue due to the large grandstands shielding the track surface. The probe allows us to have both a secondary speed measurement to compare with our pitot-static calculated speed, as well as a true yaw measurement of the car relative to the oncoming air and not just a mechanical yaw measurement, as demonstrated in **Table 1**.

Correlation

Now that we have all of our probes and equipment up and running, the next question is; what to do with it?

The aerodynamics group at the R&D centre has been developing an experimental car design potentially for the 2016 season that features a reduction in downforce, drag, and sideforce while still maintaining a favourable aerodynamic yaw moment. The aerodynamic yaw moment is a critical component to driver feel on the long, relatively steady-state corners that feature heavily on NASCAR ovals. The new package has shown itself to be superior to other aerodynamics packages so far when put through our battery of CFD and lap simulation programs, resulting in a car that loses less time in traffic due to aerodynamic deficiencies.

The design does feature some new elements that have been refined in CFD but will no doubt require extensive experimentation in the wind tunnel. Having the capability to verify flow structure locations and ‘see the unseen’ will reduce those head scratching moments where by all accounts something should have worked, but didn’t. Or in the more positive instance, where something is more effective than CFD predicted.

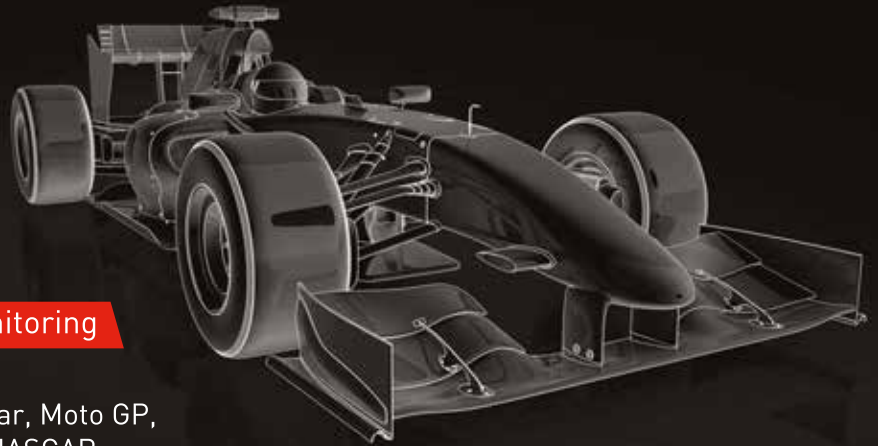
At the end of the day, aerodynamic testing tools provide additional insight, but race teams still rely on their aerodynamics team to know what to measure, how to do it, and more importantly – what to make of it all. Some things will never change...





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Material world

Advanced composites have dominated racecar construction for slightly longer than Racecar Engineering has been around; we talk to one of the engineers involved from the beginning

By SIMON McBEATH



As in nature, evolution in the usually fast-moving world of motorsport technology can actually be quite a slow, steady process. This perhaps is especially so with ever greater pressures to produce racecars that meet increasingly complex technical regulations, some of which are expressly written to limit design freedoms. Such a framework almost necessitates sticking with what is proven. Yet there has been steady progression in many aspects of composites manufacturing in motorsport. *Racecar Engineering* has been privileged to talk with Brian O'Rourke, recruited from the aerospace composites industry more than 32 years ago by Formula 1 team Williams – and he's been there ever since in the role of chief composites engineer. This is his review of the state of the art and possible future directions.

O'Rourke represents the MIA on the UK government's Department of Business, Innovation and Skills (BIS) 'Composites Leadership Forum', set up as a cross-sector panel to develop a better UK composites industry through knowledge transfer. With typical modesty O'Rourke quips: 'Quite what I am doing there, I am not sure, but it is an opportunity to talk to all of the other users – aerospace, automotive, rail, renewables, marine, suppliers etc – and find out at what stage everyone is; there are quite some differences!'

Clearly, then, there can be very few people with a better perspective on the general state of the art in motorsport, and his 'opening summary' is certainly thought-provoking: 'We are still processing things in the same way as ever but parts have become much more complicated. Actually, we are buying only

50 per cent of the quantity of pre-preg that we did 10 years ago (because of things such as testing bans, no spare cars and so on) but making probably more iterations of things. We have discovered a few tricks, of course, soluble mandrels being one of them (and there are four versions of that, more of which follows later) and matched-moulding is more prevalent (compression moulding via autoclave). The actual materials themselves are not that much different but Zylon does figure in certain FIA-specified parts alongside carbon fibres. I have become very aware of how rapidly moulding processes are evolving for high-volume composite road car manufacture, with the BMW i3 being the trend-setter. Meanwhile we carry on in the same way because it is still appropriate for us while they are doing lots of clever stuff..'

‘Much work has gone into reducing the manufacturing costs to enable higher volume production with CFRPs’

The Audi R18 monocoque is a state of the art single piece structure typical of modern competition car design



Clearly there are different incentives and different targets in the automotive world, and at the moment it is only really the niche hybrid and supercar sectors that are embracing composites. Much work has gone into reducing manufacturing costs to enable higher volume production with carbon fibre reinforced composites (CFRPs), and as such the knowledge transfer direction in some applications may be the opposite of what motorsport people might like to think. Hopefully we’re all open-minded enough to embrace that change.

Resins

‘You can rank resins in terms of their usefulness (properties, temperature capability etc) and, working from the bottom upwards, for all-round capability, they would be ranked as shown in **Table 1**,’ says O’Rourke.

S. McBEATH



Picture 1: Brian O’Rourke, chief composites engineer at Williams F1 for over 30 years

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Picture 2: ‘Traditional’ twill weave carbon fabric can be seen in the wing elements of the Empire Wraith, with ‘trendy’ spread tow fabric featuring in the diffuser

Table 1: resin systems

- Polyesters: not often used in pre-preg form but still a wet lay-up staple.
 - Vinyl-esters: as above, but more temperature-capable.
 - Epoxies: moderate to high mechanical properties, from low temperature to about 200C for the best; well-understood processing.
 - Phenolics: temperature duty overlapping with epoxies at the bottom end but way above most other types at the top (450C); not recommended for structural duties, some processing issues.
 - Cyanate-esters: low moisture absorption (not a big deal on a racecar but a lot on a spacecraft); structural performance equal to some epoxies but good for 250C, harder to process.
 - Bismaleimides (‘BMI’): very good mechanical properties and good retention at temperature, performance towards 300C (the choice for military aircraft like the Lockheed Martin F-35 ‘Lightning II’ JSF; processing complicated).
 - Polysiloxanes: ‘ceramic blends’ – quite new but offer the possibility of duty up to 650C although they are not rated structurally (i.e. heat-shielding duties best).
 - Polycarbosilanes: similar to the above but capable of >1000C. They require high-temperature treatment (silica infusion) before use so are only processable by specialists (PyroSic® from Pyromerall is an example). Pyromerall have claimed conventional CFRP processing methods can be used, so discussion with the supplier is advised.
- In the case of the last two resin systems, carbon fibres start to oxidise at about 650C so different reinforcements will become necessary (e.g. S2-glass, quartz, aluminium-oxide).

Table 2: reinforcement fibres

- ‘Standard Modulus’ carbon fibres: $E = 230$ GPa (typical trade names would be Toray). T300 and T700, Hexcel HexTow AS4, Toho Tenax HTA, Grafil 34-700, plus others).
- ‘Intermediate Modulus’ carbon fibres: $E = 280$ GPa (Toray T800, T1000, Hexcel IM7 & IM9, Toho Tenax IMS).
- ‘High Modulus’ and ‘Ultra-High Modulus’ carbon fibres $E > 350 < 550$ GPa (Toray M46J & M55J).
- ‘E’ glass fibres: $E = 70$ GPa
- ‘S2’ glass fibres: $E = 85$ GPa
- Aramid fibres: $E = 120$ GPa (DuPont Kevlar 49®, Teijin Aramid Twaron).
- Ultra High Molecular Weight Polyethylene (UHMWPE) fibres: 110 GPa (Royal DMS Dyneema®, Honeywell Spectra®).
- PBO fibres: $E = 280$ GPa (Toyobo Zylon®).

‘Zylon is poor in compression, is difficult to cut and suffers profound strength reductions over time through exposure to ultra-violet radiation’

‘Looking back, epoxies as used in pre-preg systems used to be very much split into two groups: those that cured at 120C and others at 175C (‘250F’ and ‘350F’ types). If you needed the properties to hang on at temperature, though, you had to use the latter; the former would only let you work to about 85C and cure cycles were long – three-hour dwell times were common). Over the last 15 years, however, newer types started to appear which would cure at, say, 135C for one hour and they would provide working strengths at close to that; higher with an optional post-cure. In F1, that made our lives much easier as one system was then able to cover 90 per cent of our needs with niche products for the remainder, meaning that autoclave use became more efficient and much simpler to manage.’

One potentially exciting development (see RE, May 2013 (V23N5) is nanoparticle reinforcement of resins. The high surface-to-volume ratio of nanoparticle reinforcement could offer significant increases in structural properties (and other possibilities too) but,



Picture 4: Non-impregnated twill weave Kevlar® fabric



Picture 3: Non-impregnated ‘dry’ twill weave carbon fabric

says O’Rourke: ‘These haven’t arrived yet – at least applied to pre-preg matrices – but the work is being done. There is an issue with what the nanoparticles might be as carbon nanotubes, for example, are prohibited by the regulations.’

This is in reference to F1’s Permitted Materials List, the existence of which effectively prevents the development of new materials. An F1 team can develop any new material it likes, but it must be added to the Permitted Materials List before it can be used. This involves making a submission to the FIA, who will add it to the agenda for the next Technical Working Group meeting. Present at these are the technical directors of the other teams, so two possible outcomes arise: (i) objections are raised to its use (say, if it was thought to offer the applicant an advantage or (ii) the material is allowed but the other teams then source their own equivalent, thus negating the advantage of the new development. So the Permitted Materials List seems very unlikely to grow as it’s a very effective brake on new materials technology.

‘There is still the dilemma that resin formulators can produce tough systems and temperature-capable systems, but ones that provide both are still the Holy Grail,’ says O’Rourke. ‘In the late 1980s, third-generation toughened epoxies started to appear and these formed the main submissions for the military and civil airframe programmes that came along thereafter; probably still the biggest volumes sold today, globally. Since then resins have continued to develop, but the improvements have been in small increments.’

Fibres

There haven’t been many fibre developments, and what materials we have in total are shown in **Table 2**. ‘In F1 we are prevented from using anything more exotic, so things like boron and aluminium oxide are off-limits. Curiously, silicon carbide fibres are allowed in that they are used – in woven form – in the ‘PyroSic’ high temperature material mentioned in **Table 1** with a silicon carbide matrix. Heat shields are exempt from the restrictions on structural materials.



Picture 5: Chassis pattern made from epoxy tooling board and surface finished ready for mould manufacture



Picture 6: Additive Digital Manufacturing (ADM) is now used in many intricate tooling applications in F1. This one is soluble in high pH (alkaline) liquid



Picture 7: 'Aquacore' is a thermally stable, water soluble tooling medium

'Zylon may look an obvious competitor for IM carbon as it matches on modulus and vastly exceeds it on elongation but, in common with the other 'man-made' fibres, it is poor in compression. It is also difficult to cut and suffers profound strength reductions over time through exposure to ultra-violet radiation – web searches will reveal cases of litigation in the US where body armour hasn't worked, and it is put down to this. It's worth noting that Zylon is mandated in the anti-penetration side panels of F1 chassis and is also the fibre used in wheel tethers – see REV11 N2. In both of these applications it is encased and shielded from ambient UV radiation.

Fabrics

'On the fabric front quite a lot has happened over the last few years, mostly due to the increasing capability of new machinery, which in turn comes from the development of ever more sophisticated control software – although again some of these materials are not permitted in F1. As well as the considerable number of conventional fabrics available, **Table 3** lists some interesting variations.

'The excitement around spread tow fabrics – to my mind – doesn't truly explain why they might be useful. These fabrics are very difficult to characterise in terms of their properties, which means it's difficult to know how to incorporate them into a design. However, newer

suppliers have got something really useful in the form of 'slit spread-tow'. In these examples, after spreading a high-count fibre tow, it is then slit down into, say, 5mm widths, which makes the resulting woven material more useful. The products that show a large checker-board pattern in the final fabric don't drape so well – the slit versions have much more scope.'

Japanese company Saikai-Ovex offers a range of ultra-light carbon fabrics comprised of slit tows between 2mm and 5mm width, with areal weights of around 61-65gsm, which the company says are suitable for moulding into complex shapes because they are very thin. For its part Oxeon states that Textreme offers a reinforcement with the mechanical performance of a cross plied UD (unidirectional) and the ease of handling of a fabric. Vice president of sales and marketing, Andreas Martsman, says: 'Extensive testing and FEA modelling of TeXtreme in aerospace and F1, as well as the widespread use in F1 and other racing, proves the theories of the wide tapes work. The initial doubt about drape ability is often there, but this has been proven not to be an issue in the wide

Table 3: developments in reinforcement fabrics

- 'Multi-axial' or 'non-crimped fabrics' to differentiate them from woven fabrics: whilst it was always possible to obtain non-crimped fabrics (NCF) – particularly popular for wet-infusion and resin transfer moulding (RTM) processes – more variations on these are now readily available including biaxial fabrics at 0/90 and +/-45, 'triaxials' and 'quadaxials'. This can allow a complete laminate to be supplied for infusion and is aimed squarely at the automotive industry. Formax UK is one company that manufactures these materials. They are still a 2D material though.
- 3D or 'structured' textiles: a few years ago there were only 3 companies that did this work, all in the USA (Bally Ribbon Mills, 3-Text and Albany Techniweave); there are now others in Europe (Sigmatex in the UK being one). This material has fibres arranged in all 3 directions and so can provide the full reinforcement for a metal-replacement part ready for RTM.
- Braids: these have been around for ages in carbon and other fibres but, again, the process has now developed to enable bespoke 3D reinforcements to be made. Eurocarbon has long been a leader in this field.
- 'Spread-tow' fabrics: these are quite new and are developing rapidly. One example is Textreme® from Swedish company Oxeon

range of complex shapes where TeXtreme is currently being used. It undoubtedly offers a particular aesthetic appeal too.

Bulk moulding compounds, the term to include sheet moulding compounds and forged carbon – which have been around for ages – will find more of an uptake for pressed 3D parts, albeit in thermoset form. HexMC® is a newer variant from Hexcel, analogous to 'OSB' or Sterling board in the timber industry, and made up of carbon chips cut from conventional pre-impregnated unidirectional (UD) fabric, which are then pressed into roll form. Processing involves heat and pressure and cure times are quite short. However, Hexcel told RE there are no current plans to market this to motorsport

Thermoplastics

We looked briefly at thermoplastic composites in REV18 N4, specifically focussing on the co-mingling of structural fibres (glass, carbon etc) with thermoplastic fibres such as polypropylene or polyester by Carr Reinforcements, the specialists which began weaving carbon fabrics in 1969. The structural reinforcement came from

'The high surface-to-volume ratio of nanoparticle reinforcement could offer significant increases in structural characteristics, and other possibilities'

Table 4: soluble moulding materials

- Thermally polymer-stabilised mineral 'sands' can be simply pressed to shape, baked, laminated on and then washed away in water. Advanced Ceramic Manufacturing's Aquacore™ is a good example of this.
- ADM polymers can be dissolved out using a high-pH liquid, but these require specialist equipment.
- Casting waxes can be moulded to form mandrels and then melted out after pre-preg curing.
- Low-melting-point – frequently bismuth based – alloys can be cast, as above, and melted away from a pre-preg part by the use of hot oil.

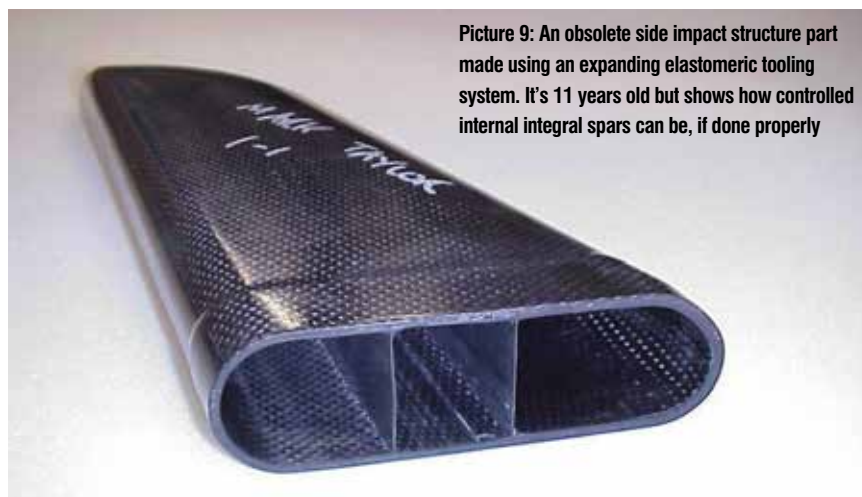
'When considering composite materials you aren't just thinking thickness of elements, but ply count and ply orientation as well – there are a lot of variables'

the glass or carbon fibres and the thermoplastic fibres melted as heat and vacuum pressure was applied to create the matrix to bind the fibres. At about the same time as this article appeared, F1 was investigating the use of thermoplastic fabrics in conventional epoxy pre-preg systems for use in components like front wing end plates with the specific objective of containing debris in the event of impacts and collisions. An interesting paper entitled 'Evaluation of Polypropylene Fibre Reinforced Composites for use in Accident Debris Retention', written by Dr Gary Savage when at the Honda Racing F1 team, can now be found on the internet, and although it would appear that the findings were not put to use in F1, other categories seem to be exploiting polypropylene in specific areas.

O'Rourke continues: 'In F1 nowadays, thermoplastic matrices are banned but one thermoplastic fibre type is allowed: polypropylene. It has had very little application as its mechanical properties – other than its prodigious elongation – are not great. Two trade-names that crop up are Innegra Technology's Innegra™, a fibre that is capable of being conventionally impregnated with epoxy



Picture 8: This small carbon pipe was made using carbon epoxy for the exterior tooling and a low-melting point alloy for the internal tooling



Picture 9: An obsolete side impact structure part made using an expanding elastomeric tooling system. It's 11 years old but shows how controlled internal integral spars can be, if done properly

– although not very easily – and which formed the basis of the reinforcement in Gary Savage's study mentioned previously, and Milliken & Co.'s Tegril®, which is a ready-supplied composite of polypropylene fibres in a polypropylene matrix. The idea is to heat it until the matrix flows but not the fibre – they have subtly different temperature behaviour and melt 10C apart, and so form components. Again, the matrix precludes its use in F1 but it has found use in NASCAR for rubbing strips on bibs. In the automotive industry, thermoplastic-matrix composites are finding uses alongside wet-infused fabrics and hot-pressed pre-pregs. My belief is that, although each of the three camps are saying that their approach is the way it will all go, all of them will find uses.'

Tooling

There have been some very interesting developments on the tooling front, that is, the manufacture of patterns and moulds in recent years, and although 'traditional' methods are still the mainstay there have been two noteworthy developments in particular, as O'Rourke explains: 'In F1 we are still very reliant

on carbon/epoxy mould-tools, most likely laid up on machined and surface finished pattern board, as they give the required accuracy and are manageable in the size that we require. Solid metal will always have its place and is still the default for some (McLaren started with that in the early days) but it's not popular here. Pattern board – in some forms – is a perfectly good material for use directly as a mould if the number-off isn't too many and you can cope with the mass; it's probably best on smaller things where a 'try-out' is needed.

'A major growth area is in 'Additive Digital Manufacturing'. This takes several forms: Stereolithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Modelling (FDM) and Polyjet (photopolymer printing). All these forms are lumped under 3D Printing but can be split into thermoplastics or thermoset plastics. These are extensively used for small tooling in F1 either as full moulds (some of the plastics used in FDM are good for 150C+) or dissolve-out mandrels.

'Soluble moulding materials can take several forms, as shown in Table 4. All are used in F1. The trick is not to believe that any one is a panacea – they all have their place.'

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Table 5: parameters to fully exploit the benefits of composites

- Shape definition – quality surface definition.
- Understand the science of composite materials.
- Structural analysis (FEA, primarily, and how best to idealise complex structures).
- The best configuration of master patterns and mould splits (visualise the component but then think inside-out and back to the pattern shape).
- How to predict the behaviour of the materials in ‘pre-preg’ form – draping to the preferred shape and undraping to give flat ply patterns for automated cutting.
- How to describe laminates in drawing form so that the laminators know precisely how to reproduce the design intent.
- Optimise how to build the laminate, use the necessary consumables and understand resin cure behaviour.

Design and manufacturing

So the materials side has seen some interesting developments take place, but what about design and manufacturing? ‘I would say that, in general, the process is more detailed nowadays than it used to be. For structural parts it is very much an interactive process between stress engineers, designers and manufacturing people. I would emphasise the word ‘interactive’ because it is, I think, the key. At Williams I have always tried very hard to keep all the interested parties in constant dialogue and avoid ‘over the wall’ engineering (ie the ‘silo mentality’ of one group doing their job – or so they think – and lobbing the result over the wall to the next group). Software comes into this a lot because in an ideal world one suite of software could cover all the jobs that need doing and, as long as the different modules representing those activities are well integrated, that should be plain sailing. The reality, however, is different so compromises have to be made,’ says O’Rourke.

Going ‘back to basics,’ what is involved in designing with composite materials? Fundamentally, as we all know, they offer advantages with, i) material properties (some, anyway) and, ii) the ability to produce parts by moulding, the latter facilitating greater potential for geometry optimisation. The things you need



Picture 10: An obsolete wing mould in carbon epoxy

BRIAN O’ROURKE

to be able to do well in order to really exploit what they have to offer are shown in **Table 5**.

That has all been appreciated by people working with composites since day one (as loose principles if not in precise definition terms) but, perhaps understandably, not many people have a complete overall view of the process as it does mean being clued-up on a lot of different subject matter, and in some depth. Nevertheless, it has long been my belief that you shouldn’t be allowed to do any one of those jobs without an appreciation of the rest; you have to see the whole process and understand everyone’s interests and concerns.

‘Originally, some of those tasks were rather hit and miss. There was always a limit to what could be done with pencils and calculators. The advent of CAD helped a lot with shape definition and producing paper templates from which to make a laminate pattern. CAM then allowed us to realise screen shapes in 3D by direct cutting on a CNC machine. That happened more than 20 years ago but some of the other functions took a lot longer to evolve and others still haven’t got there.

‘For example, the approach to FEA of the monocoque is something that has developed quite a bit in recent years. Anisotropic materials are more complicated than isotropic (ie metallic) ones and so a pre-processor is provided that will allow you to build a laminate stack – each ply of which has its own individual orthotropic properties – and which calculates the overall properties for the laminate. These are then applied to the elements where those plies exist. In the case of a sandwich panel, you can build a stack in exactly the same way but have one ‘ply’ which represents the core material; honeycomb or foam. So it will use 2D elements but they will – because of the thickness of the core – be 3D in scale (sometimes referred to as 2½D). That is the way most people will have traditionally modelled monocoque structures,

but nowadays it really doesn’t represent their true nature accurately enough. The approach now is to model the skin laminates as shell elements independent of each other and connect them with a layer of solid elements representing the core; these have appropriate properties assigned to them. This method really has to be followed if what you have (and tubs are much more this way now) is an assembly of sandwich panels with internal laminated stiffeners and complex solid inserts. That way the different materials are all connected as in real life and modelled properly. It all means that the modelling job is substantial (full-time for someone in a company of our size), and if you imagine that other structural parts – wings, noses – are treated similarly, it explains why stress groups in F1 have enlarged in recent times.’

A subject that the author has quizzed O’Rourke on in the recent past is computer aided optimisation of composite structures, examined in our December 2012 issue (V22 N12). Once again our man has words of wisdom: ‘Optimisers tend to divide opinions among stress engineers. Basically, an FE optimiser – in the isotropic material case – will take the mechanical properties assigned to a spread of elements and, when given a target for the structure’s overall stiffness (or strength), calculate the optimum thickness distribution to achieve that for the minimum mass. Considering a composite material, though, you aren’t just thinking thickness of elements but ply count and ply orientation as well – a lot of variables.

‘Engineers of one generation are prepared to put faith in such software to fully determine the laminate for a structure. The result, however, can be very complex, particularly if strict constraints are not imposed on orientation and laminate balance freedom. I could have said a complete mess may result but that might have given the appearance that I was taking sides. Those who have grown up working with composites

‘An FE optimiser will take the mechanical properties assigned to a spread of elements and calculate the optimum thickness distribution for that mass’





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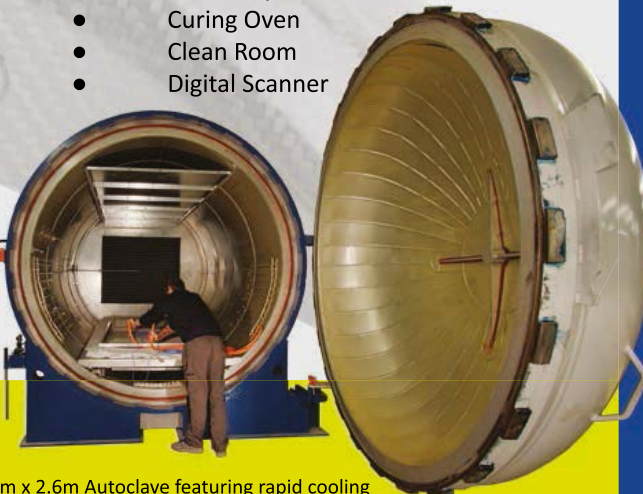
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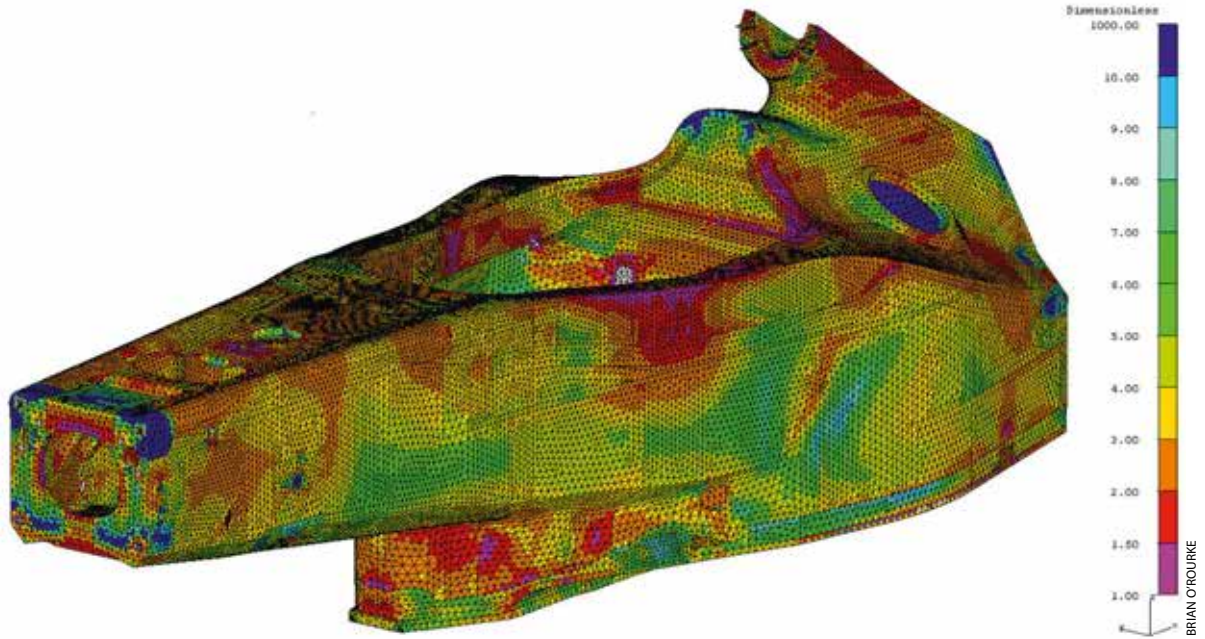


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Picture 11: FEA is an integral part of chassis design in F1, as this non-current image shows

through the more traditional routes prefer to keep the approach simple with a 0/45/90 orientation system and with both symmetry and balance rules respected, thus maintaining some sense of intuition in the design.

'It is important, too, to remember that the part has actually to be built so a sanity check has to be done to ensure that the result is logical from a manufacturing sense. Bits of plies stopping and starting at short distances from one another will give rise to a patchwork quilt of a laminate, which will be difficult to mould accurately, and provide a laminate that is a long way from being

intuitive enough to have a mental picture of what the structure is actually doing at any point.

'Remember, too, that loading on an F1 tub is very complex with multiple cases to cover so one preferred ply distribution will conflict with another; all of them must be satisfied. It is not simply a case of thinking 'torsional stiffness' as some people naively imagined in olden days, which was wrong, even then. Simultaneous torsion, bending, inertial, vibration and aerodynamic loading must all be superimposed – and then there are crash cases!

'So looking at an area of structure and asking "Why is the laminate like that, right there?" is not likely to produce a quick answer from anyone; things are complicated anyway, and the trick is to not let them become too much so. Optimisers are a great idea, but make them work for you and don't let them dictate things to you – that, perhaps, is the best summary.'

A computational tool that Williams has been exploiting is dynamic FEA. 'We have been using that technique for more than 15 years for nose box crush simulation' continues O'Rourke. 'Oasis LS-Dyna (from Arup Associates) has been an integral part of our design process for energy absorbers and has cut a huge amount of time and cost from the process of getting to FIA approval. Getting a short nose like the Williams design working to this year's criteria is extremely difficult as, I read, other people are now finding (when trying to make one like ours). We wouldn't have got our solution working by early January without it.'

On the manufacturing front, the relatively low volumes in motorsport mean that traditional drawing- or lay-up book-led processes still prevail, whereas in aerospace for example lamination is frequently automated, hand lay-up being impractical on mouldings the size of aircraft wings or fuselages. In areas where hand lay-up is still used, laser

projectors display ply outlines onto the mould surface guide where the pre-cut plies should be placed, and at least one F1 team has used this technique. Another product called PlyMatch™ from Anaglyph Ltd uses a CCTV camera to superimpose ply outlines onto the camera view on a PC screen to provide similar assistance. However, O'Rourke considers that, while they are useful for the right application, these techniques are too elaborate or impractical for much of what Williams do.

One software product – Fibersim developed by Vistagy, who were acquired by Siemens in 2011 – that can define laminates, draping, flat patterns and drive laser projectors and so forth, as well as exchanging files with FEA solvers like MSC's NASTRAN and those from ANSYS, has had attractions for many years but its cost-effectiveness has always been brought into question. 'Irrespective of what may appear to be the case from the outside, those of us working at the coal-face in F1 are very restricted when it comes spending, in our company's case, at least! Proof, for those who need it, that there really are budgetary limits in F1! Williams have a longer-term aspiration to see a full integration of FiberSim with Siemens NX because 'the potential is enormous'.

In conclusion

Brian O'Rourke's profound familiarity with composites in motorsport enables him to joke, somewhat self-deprecatingly, that it is something of a cottage industry. However, that is wide of the mark as the reality is that motorsport is a niche industry where composite materials and techniques are applied in particularly specialised ways. Just examine the front wing of a current Formula 1 car to realise that things have come a long way in the past quarter of a century or so.



The use of composite materials in lightweight structures is today a known science but there are still some questions about the longevity of such solutions. A few years ago Racecar asked the difficult question of 'How long is a composite chassis safe for?'

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Head on the block

How Nissan's Ben Bowlby is turning conventional design on its head

By PETER WRIGHT



Throughout the history of motorsport car designers have occasionally stuck their necks out and produced a racecar that bucks all the trends of the day, redefining what a racing car could be. Notable examples include:

- Jim Hall – high wings and fans
- Colin Chapman – skirted ground effect; twin chassis; active suspension
- Derek Gardiner – four front wheels; to be followed by Williams and March with four rear wheels

There are two factors all these have in common: they all originated before the early 1980s, and they all ended up banned by new

regulations because they had the potential to obsolete all existing racing cars. Powertrains have fared somewhat better, with turbocharging and diesel engines being accepted, albeit with their performance regulated. Maybe this is because their development is “relevant”, while virtually all racing car chassis innovations are not.

And then nearly 30 years later, along comes Ben Bowlby and sticks his neck right out, not once, but twice in five years: ‘I think I might be slightly addicted to the thrill of laying my head on the block,’ he explains.

Ben's first attempt, the IRL DeltaWing, conceived as the basis of the IRL's new for 2012 regulations, tore up the existing rulebook. When,

almost inevitably, this wasn't accepted, he was so committed to the concept of halving the energy needed to go racing competitively that he found the one motorsport niche to showcase the car's performance: a small garage, Number 56, at the far end of the pit lane at Le Mans.

Having proved his point in 2012, he helped Nissan use the advantages of such a concept to perform the first all electric lap of Le Mans with the Nissan ZEOD RC. Part of the deal between Nissan and the ACO was that they would come back to Le Mans with an LMP1-H car in 2015, and in doing so Ben gained another opportunity to feel the thrill. Nissan isn't in this for the thrill of course, yet it too has put its head alongside



‘I doubt that Nissan would have built the car if the simulations didn't show its potential to be competitive at Le Mans’



Nissan has chosen to cram much of the engine and through-airflow ducting into such a small space at the front – the engine, gearbox and radiators are all ahead of the windscreen



Engine is an even-firing, smooth-running, low vibration V6 and has been designed specifically to allow Nissan to compete at Le Mans

Ben's and it has done so based on what it learnt in their two Garage 56 sojourns.

Where, before the 1980s, normal racecar concepts often ended up being built because they could not be simulated accurately with the technology of the day, more recently many an idea that may have looked good on paper fell-over in the computer. In 1991 at Team Lotus, we looked at a diamond wheel layout, with three-wheel drive (yes, it was perfectly legal), lots of tyre, and active suspension. Put to the test in simulations, it didn't work out, mainly due to aerodynamic reasons.

Ben has all the best simulation and CFD tools at his disposal to allow him to prove his concepts prior to cutting metal. Many people who should have known better rubbished the DeltaWing and were then proved wrong once the car ran. Many of these same people are sceptical about Nissan's GT-R LM NISMO, with its front engine, FWD and narrow rear tyres, but I doubt that Nissan would have built the car if the simulations didn't show its potential at Le Mans. Ben says: 'As with most things in motorsport, the car is an artefact of the regulations. We studied Le Mans and believe that we need a car with high top speed and exceptional stability and drivability. It needs a huge operating envelope so that the drivers can drive the car without errors in all weather conditions.'

'A car that is quick in the corners leads to frustrated drivers who make risky moves to overtake, because they have too much cornerspeed. A car that is fast on the straights makes overtaking and driving far easier.'

Le Mans has few low speed corners (three first gear, four second gear); several high-speed corners (one third gear, three fourth gear) and the rest of its 8.5 miles are straights. The key question is whether what it gains on the straights outweighs what it loses in the corners and accelerating out of them. And that is all down to the tyres and aerodynamics, both of which can be simulated.

Superior stability

The artefact in the regulations that led Ben to put the engine and primary drive at the front of the car is that the relatively unlimited diffuser allowed at the front has a better L/D than the highly regulated rear diffuser and rear wing. By designing the car to gain everything it can at the front – hence the large through ducts that exhaust the front diffuser to the back of the car, utilising the low base pressure there that is normally employed by the rear diffuser – the car's overall L/D is maximised. This leads to a forward aerodynamic distribution, and the weight distribution of 65 per cent front and 35 per cent rear, follows. It becomes logical to

'As with most things in motorsport, the car is an artefact of the rules'

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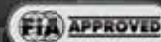
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Top: The bottom half of carbon fibre tub has a distinct V shape to increase the volume of air passing through the car
Above: The GT-R LM Nismo's engine is based on Cosworth's unraced direct injection 1.6-litre unit originally designed for F1

When power is removed from the driven front wheels their cornering power increases, which destabilises the car on entry to a corner

deploy the majority of the power through the heavily loaded front tyres, and the tyre sizes can then be determined: 14inch front and nine-inch rears (although at Sebring in March the team tested more traditional 18 inch wheels to accommodate larger brakes). The total tyre tread/tonne is around 17 per cent less than if the maximum width 14inch tyres had been used all around (it is much more complicated than this simple parameter), and Ben acknowledges: 'This is not necessarily a good thing as we will stress the tyres more. We are about where we want to be for Le Mans; it is a compromise. We expect big developments from Michelin; for instance, so far we have not had any wet tyres, so we have run on slicks in the wet, without major problems, thanks to the stability.'

The configurations should certainly work once the speed and aerodynamic downforce

is high enough for the car not to be traction limited, and this is the reason why it is a Le Mans car and may not work elsewhere. The team withdrew from the opening races of the WEC so we won't see their potential until Le Mans in June. The simulations indicate that this trade-off works at Le Mans and provided they are validated, the success of the car is likely to centre on the question of stability and control. Ben has made it clear why he has put so much emphasis on stability, a quality that the drivers of the Le Mans DeltaWing remarked upon. A stable car by definition returns to its trimmed state when disturbed. The problem with this is the high control forces and moments needed to move it from one trim state to another, such as getting the car to turn in. With cars, because the control force generators – the tyres – are also the main force generators, once they are generating maximum cornering force there is nothing left to generate control forces. This leads to mid-corner understeer and so the driver must resort to using the throttle to change the attitude of the car.

It's all about balance

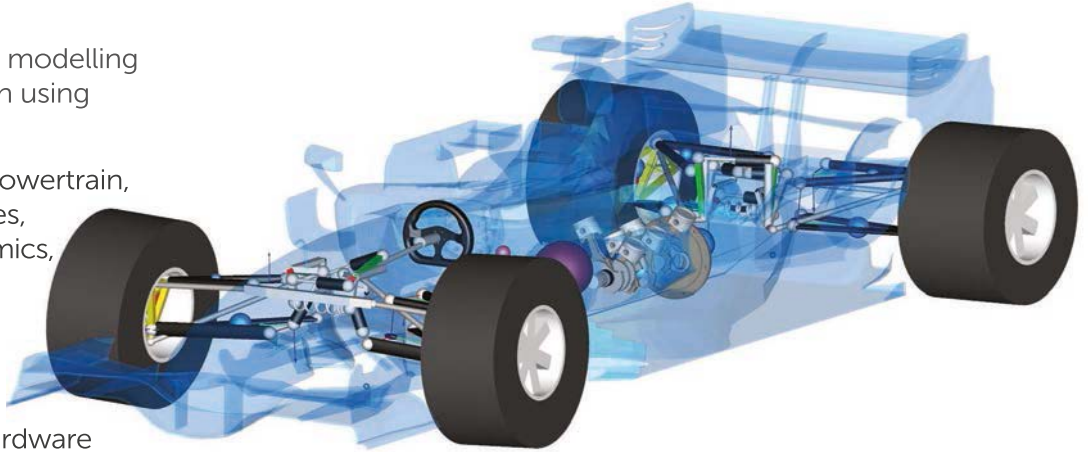
That wonderful pilot's aircraft the Spitfire – an F1 aeroplane if ever there was one – exhibited very high pitch and yaw stability, but also had very large and powerful controls. Because the elevators, which generate the pitch forces and moments used in turning, were separate from the main force-generating wing, the pilot could put in powerful control forces that changed the trim of the aircraft, and the stability prevented overshoot. This is what made it such a pilot's aircraft and a superb gun platform.

Nowadays, fighter aircraft gain their manoeuvrability by being unstable, but are



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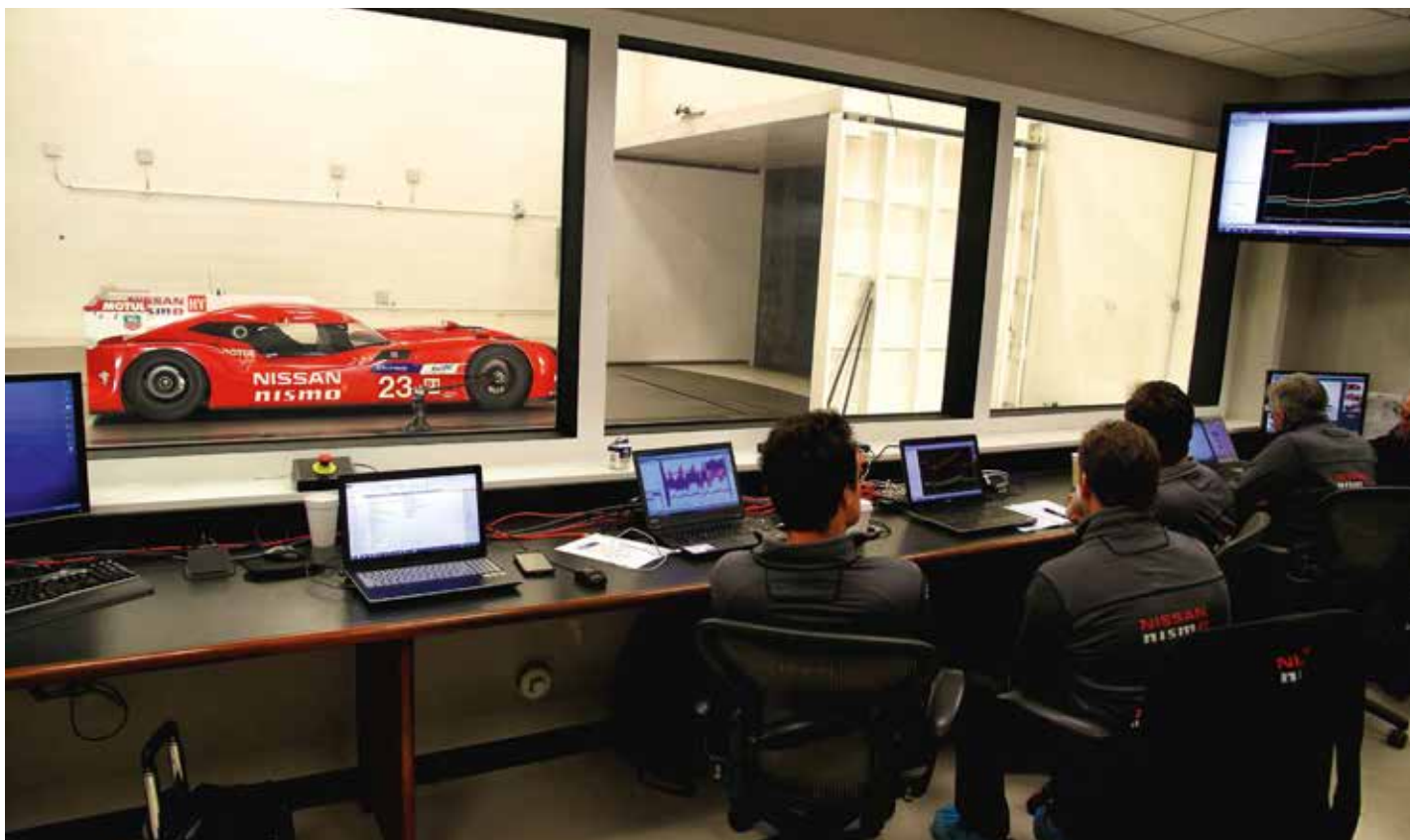
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Extensive testing has shown that the GT-R LM NISMO is quick, although Nissan still has to decide on the car's final configuration ahead of its debut, pushed back to Le Mans in June

Three years ago



The collaboration between Ben Bowlby and NISMO is not a new one, though it started relatively recently. The Deltawing was first conceived as an IndyCar but it went on to become a Le Mans Prototype using the Aston Martin AMR-ONE chassis. Read it now at www.zinio.com

unflyable without artificial stability built into the fly-by-wire system. Such solutions are no longer permitted on racing cars, although they are now widely employed in road cars.

A precisely manoeuvrable racecar demands low stability and a highly skilled driver. This is why the greats such as Michael Schumacher desired cars with powerful front ends, while they would look after what the rear end did.

Whether Nissan has the right stability/control balance throughout the operating envelope (low/high speed, turn-in, mid-corner, exit) is, I would guess, a major part of the development testing, and there is not much experience with such a high-powered FWD car.

Safety first

While much of the problem centres on the front axle, suspension, tyres and the likes, the rear is just as important. With so much mass at the front, lateral load transfer could easily overload the hard working outside tyre. This can be relieved by high rear axle roll stiffness, normally undrivable for traction. Ben explains: 'We have seen the car performing Touring Car antics with its inside rear wheel.' Torque connection between the rear wheels will also stabilise the car, potentially during drop- and trailing-throttle. When power is removed from the driven front wheels their cornering power

increases, which destabilises the car on entry to a corner. Rear wheels locked together, as with a spool, provides yaw damping. Quite what arrangement of rear drive, differential and so on ends up on the car in 2015 is unclear. Ben says: 'The KERS Torotrak-Flybrid system is late and not yet developed, therefore in 2015 we will probably run as FWD only, in an energy class lower than the maximum 8MJ.'

One or two comments have been made about aerodynamic lift-off safety of the GT-R LM NISMO in the event it spins at high speed. Ben is confident that his design has good primary safety. 'The car has a huge aerodynamic stability margin based on its basic layout, which helps prevent spins. We have even tested it! We had a front suspension problem at 300kph at COTA while testing. The car collapsed onto the plank at the front, equivalent to a tyre blowout. No problem, the driver was able to bring it to a halt without losing control. In this respect I would take on our car in a tyre blowout contest,' he says.

So far the team has achieved reasonable reliability and is keen to see how it races at Le Mans. Others have described the design as: "Brave, but risky". The last word goes to a driver of another LMP1-H car: 'If the car wins, all the other LMP1 designers will have to resign for not having thought of it first.'



'The success of the car centres on stability. The key question is whether what it gains on the straights outweighs what it loses in the corners'

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Back to front

The first in a two-part series examines why Nissan's LMP1 GTR makes perfect engineering sense

By DANNY NOWLAN



With the engine at the front, and the centre of gravity further forward than normal, it is possible to generate a huge amount of downforce

One of the great things about what I do is that I am surrounded by high quality people who won't hesitate in telling me I am wrong. When the Nissan GT-R LM NISMO was released in February I took one look at it and thought to myself; you have to be kidding me. Part of that comes from race engineering a high downforce front-wheel-drive time attack car, so I know up close and personal what limitations a front-wheel-drive car faces. Then I had a 30-minute chat with a good friend of mine who has been involved in the peripheries of this project, and this is what we'll be exploring in this article.

While they may seem counter-intuitive at first, there are sound engineering reasons in the configuration that Nissan has selected for the LMP1 car, so we'll start by comparing a standard LMP1 car with it's Nissan LMP1 equivalent. We'll

then run some simulations with ChassisSim to fill in the details. This won't be an in-depth analysis, but the numbers will speak for themselves.

The first stroke of genius of this car comes as a direct result of the layout and what you can do at the rear of the car. To illustrate this clearly let's take a look at this rough schematic of the car that is presented in **Figure 1**.

Yes, they have given themselves some righteous mechanical and packaging headaches by choosing to run a lot of power and steer through the front wheels. Additionally, they then have to package a driver, which also generates a greater yaw inertia. However, the true genius of this thing is at the rear. Ordinarily for a mid-engined rear-wheel-drive car you have to pack an engine with a bell housing, powertrain and double wishbones, and then all of a sudden you have some major packaging headaches because

you also need to fit things like a diffuser and KERS system inside. Here is where the Nissan has two trump cards to play.

Firstly, as it is front-wheel-drive you have considerable wiggle room at the back of the car which will help the aero. What this means is that you are not hamstrung the way you are with a conventional mid-engined car. Consequently, you have a lot of flexibility in fashioning the rear of the car to help the aero, which is going to help in generating downforce.

The other thing this brings to the party is it allows you to fit a rear-wheel-drive KERS system in the car which you can position anywhere you want. Nissan has disconnected this element for now, but my simulations are for when the car works as designed. If you will recall my articles on electric powertrains (RCE V24 N10), the beauty about electric engines is that they package up

really nicely. You have much greater freedom to locate the battery pack where you want. While batteries are heavy, the upside is that you have a great ballast tool. This, when combined with energy recovery strategies, means you have a lot of tools to dial in when it comes to deciding what you want the chassis to do.

Let's now use ChassisSim to flesh this out. We will run simulations of a standard LMP1 rear-wheel-drive car with KERS and a Nissan GT-R LM equivalent. The highlights of the car configuration are presented in **Table 1**.

Apples versus apples

For the purposes of this article the downforce will be the same as I want to get a like-for-like comparison. In terms of the KERS, this will discharge every straight and our simulations will be based on the full Le Mans circuit.

Our initial lap time comparison shows the conventional LMP1 car is quicker. At Le Mans the standard LMP1 car had a lap time of 3:31.85s and the Nissan GT-R LM had a lap time of 3:35.8s. A lot of this is due to the fact I don't have front-wheel-drive KERS hooked up in ChassisSim in basic analysis mode, although at this point I'm not too worried because there are some base comparisons we need to make first. The first thing to observe is cornering – see **Figure 2**.

The standard LMP1 car is coloured while the Nissan GT-R LM is black. Looking at the first trace the speed carried into the corner and the mid-corner is very similar. However, the Nissan LMP1 suffers a bit more understeer meaning it can't get into the corner as fast. Where the Nissan loses is turn exit where it simply can't get the power down. A comparison of the time analysis shows this is costing about 0.15-0.2s a corner. Again, there are no huge surprises here.

However, the devil is in the detail. One of the channels that ChassisSim returns is the maximum available longitudinal force available from all four wheels. **Figure 3** shows what happening at the rear wheels.

I would draw the readers attention to the bottom traces which show the available longitudinal force at turn exit. At a speed of 157km/h we have an available longitudinal force of 710kg per rear tyre. **Equation 1** shows what effect this is having on the available power.

What this means is that we have a potential 606kW on tap at the rear. In reality the figure will be much less than this because the rear tyres have to corner as well. Let's just say, for the sake of the argument, that you can use 300kW of power from the rear tyres. If KERS is used in the right way it will effectively act as a turbo boost. It's worth pointing out that 300kW is effectively 75 per cent of your engine's power – this is money for nothing and effectively cancels out the current losses we viewed in **Figure 1**.

When this was implemented in the simulation it significantly improved matters. The revised lap time was a 3:32.1s lap and a corner snippet is shown in **Figure 4**.

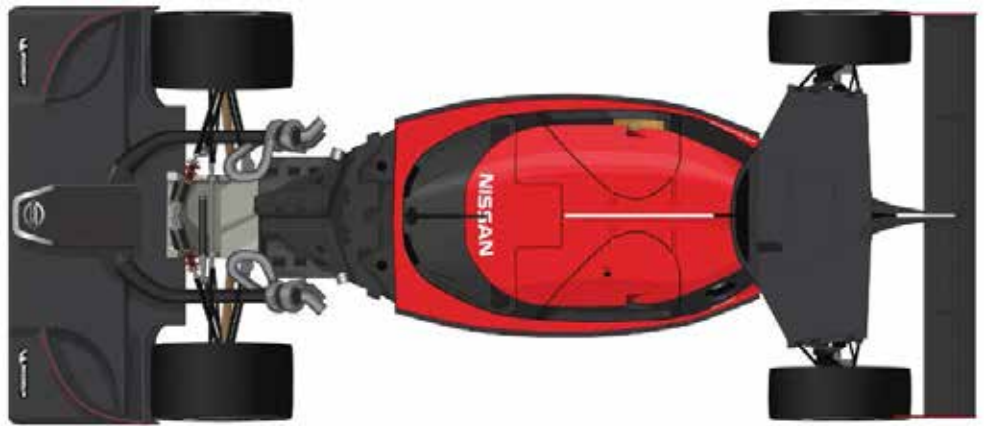


Figure 1: A rough schematic of the Nissan GT-R LM

Table 1 – Comparisons of a standard LMP1 car to the Nissan GT-R LM equivalent

Parameter	Standard LMP1	Nissan LMP1 GTR
Drive	RWD	FWD
Weight distribution	47%	55%
KERS	RWD	RWD
KERS discharge limit	200 kW	200 kW
Engine power	400 kW	400 kW

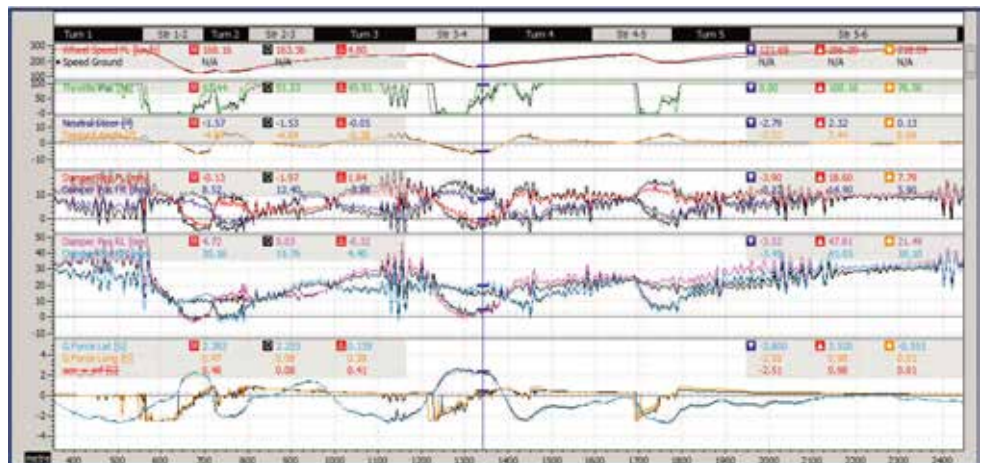


Figure 2: A comparison of medium and low speed corners

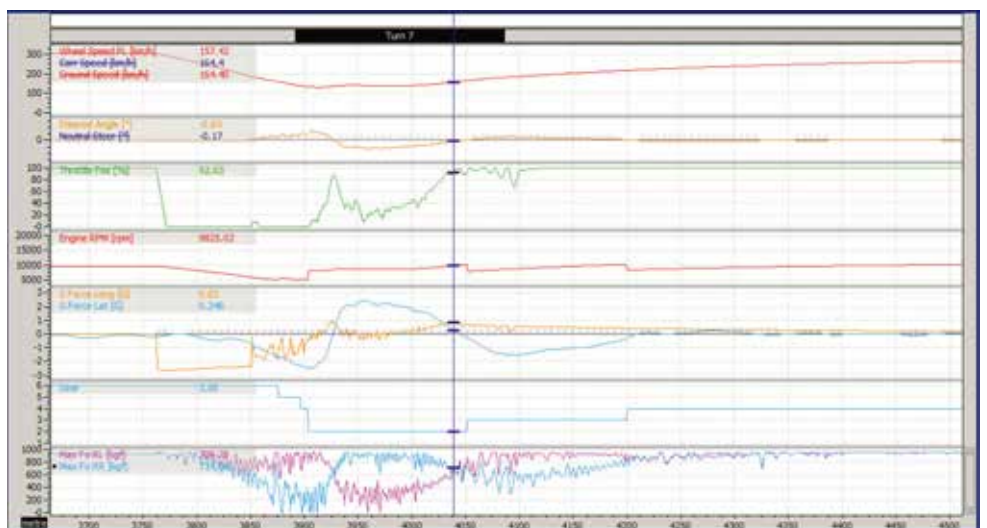


Figure 3: Plot of maximum available longitudinal force at the rear of the Nissan GT-R LM

EQUATIONS

Equation 1

$$P_A = (157/3.6) \cdot (710 + 710) \cdot 9.8 = 606kW$$

Equation 2

$$x_{cg} = \frac{\sum m_i \cdot x_i}{\sum m_i}$$

$$= \frac{850 \cdot 1.2 + 150 \cdot 3}{850 + 150}$$

$$= 1.47m$$

$$\therefore wdf = \frac{3 - 1.47}{3} = 0.51 = 51\%$$

Again, the coloured trace is the standard LMP1 car and the black trace is the Nissan LMP1. Looking at the first trace we are paying a little bit for front-wheel-drive due to the increased weight distribution. This means we suffer a little bit getting the car into the corner. However, the longitudinal G traces are very interesting. We have now recovered most of the longitudinal acceleration and in some cases we are better. When looking at the returned longitudinal forces during the simulation it is clear that the limiting factor is our discharge rate.

To explore this further, the simulation for the Nissan GT-R LM was run with the discharge set at 300kW. Before a lot of you say this is rather arbitrary just remember that for a rear-wheel-drive car we already need to transmit 400kW of engine torque. Even assuming the KERS is split 50/50 we are now asking the rear tyres and drivetrain to take 500kW. This is right on the traction limit of the tyres, but more importantly we are subjecting the gearbox and rear axles to an extra load of 20 per cent. Running this simulation we are now looking at a 3:31.8s lap time and the plot is shown in **Figure 5**.

Head-to-head

The trace for the standard car is coloured and the Nissan LMP1's is the black. Look at both the speed and longitudinal G trace (the first and fifth trace) – it can clearly be seen that both the speed and the longitudinal G of the LMP1 GTR is significantly higher than the baseline, particularly at turn exit. In acceleration we are talking 1.3g versus 1.0g for the standard LMP1 car. This is really promising. We are now head-to-head with the standard LMP1 car.

To complete this analysis let's now reset the KERS limit on the Nissan GT-R LM to 200kW and move the aero balance forward five per cent to bring the aero balance into line with the weight distribution. Running this results in revised lap time of 3:30.7s, meaning we are now quicker than the standard LMP1 car. An example of the simulation is shown in **Figure 6**.

Again, the trace for the standard LMP1 is coloured and the black trace is the Nissan. As can be seen from the speed and steering traces (first and second traces) any semblance of understeer has well and truly been tidied up, allowing the Nissan to make good use of the KERS at the rear to get the jump out of the corners.

As a final sanity check it would be prudent to cross reference how far back we can put the racecar's centre of gravity. We are doing this to make sure the numbers are obtainable, so let's calculate a limit centre of gravity based on the assumptions as outlined in **Table 2**.

The xlocation is measured from the front axle and we are assuming a weight distribution of 60 per cent on the front axle without a battery pack. Calculating the centre of gravity location longitudinally we see **Equation 2**. As shown in the table, the centre of gravity limit is 51, which is comfortably within our limits.

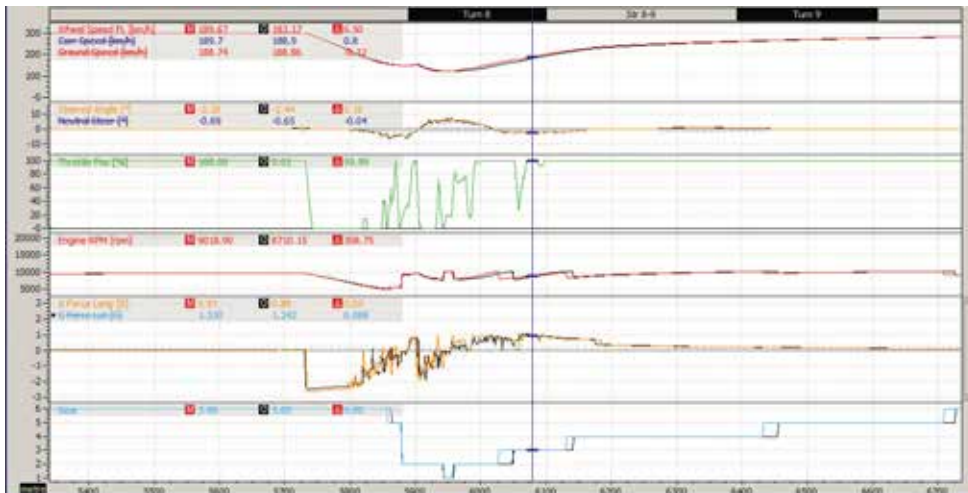


Figure 4: Revised corner snippet For KERS being applied at the rear of the Nissan GT-R LM versus the standard LMP1 car

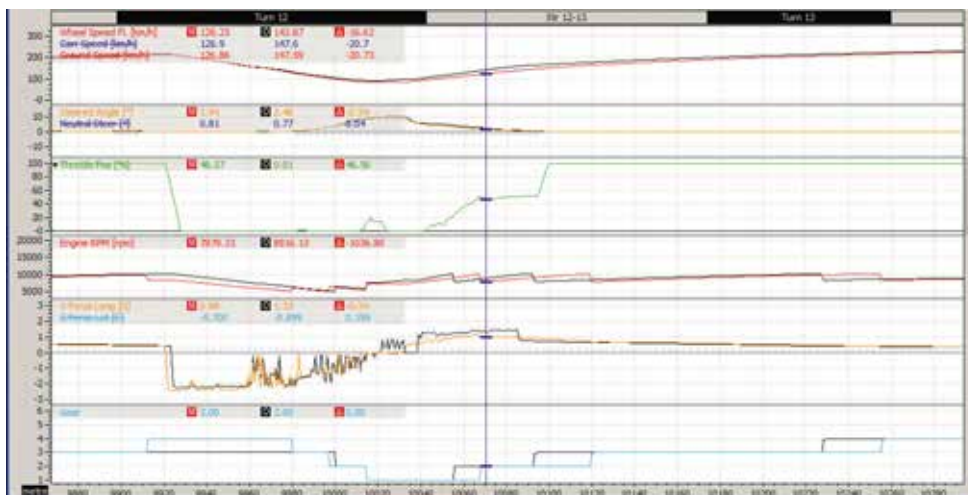


Figure 5: Nissan GT-R LM with 300kW discharge compared to a standard LMP1 car

Table 2 – Limit calculation numbers		
Paramater	Mass	xlocation
Car without battery	850kg	1.2m
Battery pack	150kg	3m

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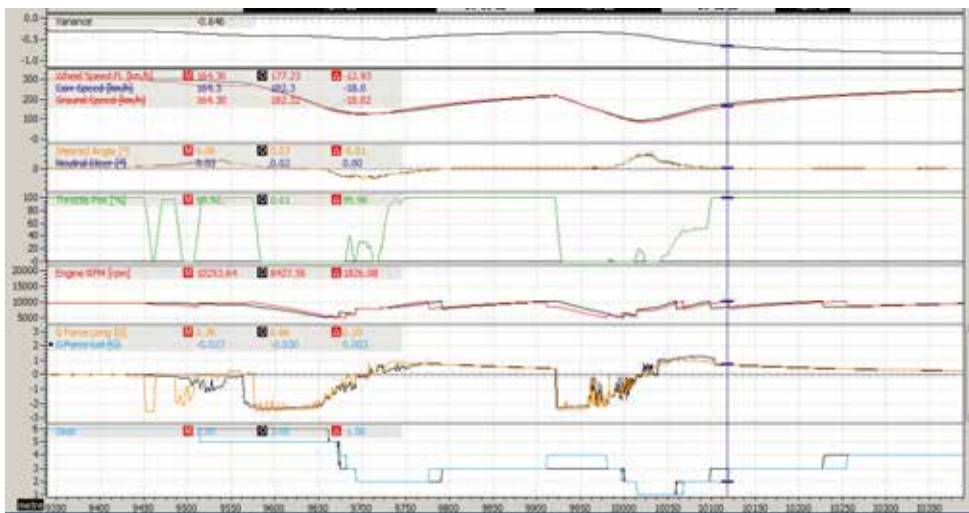


Figure 6: Nissan GT-R LM with an aero balance of plus five per cent versus the standard LMP1 car



Figure 7: A comparison of the standard LMP1 to the Nissan GT-R LM with a weight distribution of 60 per cent

As the rear tyres on a front-wheel-drive car typically don't do very much, we can utilise this for improved power out

Update

It was announced in March that the Nissan GT-R LM will not take part in the WEC pre-season test, called the Prologue, or either of the opening two races at Silverstone and Spa due to ongoing development issues.

Reports claim that it is due to issues with interaction between the hybrid system on the car and its brakes.

Larger wheel sizes have been trialled at a test in Sebring, in order to accommodate larger brake discs but insiders suggest that the car just needs development time to work.

Rather than make the trip to France for the 'Prologue', the Nissan team returned to North America to continue its testing programme ahead of the car's scheduled debut at the Le Mans test at the end of May.

The reason the Nissan is quicker than the standard LMP1 car is a combination of two factors. Firstly, as the rear tyres on a front-wheel-drive car typically don't do very much, we can utilise this for improved power out. This, when combined with moving the aero balance forward, dialled out the understeer that we would experience with a front-wheel-drive car. Effectively what Nissan has done here is to package an all-wheel-drive car, and this is the true genius of this layout. This, when combined with the aero advantages we discussed earlier, should make the car a serious contender at this year's Le Mans. At the time of writing there are reliability issues that need to be sorted out with the Nissan GT-R LM, but with something as ambitious as this it is to be expected.

However, as a final bit of this analysis let's consider the case where the Nissan GT-R LM weight distribution is at 60 per cent. When the analysis was done the predicted lap time was a 3:34.0s lap, and a segment of the lap comparison is shown in **Figure 7**.

An important disclaimer

Looking at the speed trace the big thing we are paying for here is understeer. As can be seen this is effecting our cornering and turn in speeds, however I must point out that these results come with an important disclaimer – we have effectively taken an existing LMP1 model and added a front-wheel-drive model, so the front tyre model isn't optimised for this weight distribution. Consequently, this simulation result has to be taken with a pinch of salt. However, it is a risk that must be mitigated for.

In my opinion the weight distribution for the Nissan GT-R LM will head to 55 per cent on the front axle. The first key reason is that once you head north of a weight distribution of 60 per cent you are asking the front tyres to do way too much. This includes steering and power down. This can be mitigated by tyre design but it is an inherent limitation I've seen time and again. Also, anything north of 55 per cent and you start to press the mechanical and structural limits of the car. I've been up close and personal with both of these factors. Also, as we have seen from our simulation results, it didn't take terribly much to get our LMP1 GTR at 55 per cent weight distribution to be quicker than its standard LMP1 counterpart. That in itself is telling you something, but again it's just my opinion.

The Nissan GT-R LM could present a serious challenge at this year's Le Mans if they get the rear-wheel-drive working. As the simulation work shows, the combination of front-wheel-drive and rear drive KERS has key advantages. This, combined with the aero and weight distribution packaging, mean that Audi and Toyota will have serious company. The 2015 Le Mans will be worth watching as both a driver and an engineering contest. This is something our business has lacked for a long time.

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Marussia:

To the Manor reborn

Manor F1 rises from the ashes of the Marussia collapse but still faces an uphill battle to race again

By **SAM COLLINS**

In the cold weeks leading up to Christmas last year auctions and private sales were held in Banbury, England. The content of these sales were the assets of the Marussia Formula 1 team which had folded following the Russian Grand Prix, and the aim was to raise as much money as possible to repay the teams substantial outstanding debts. A rescue attempt ahead of the final race in Abu Dhabi collapsed at the last minute, meaning the end of the team.

One sale remained, although it had to wait until the new year because it included the team's pair of 2014 MR03 chassis, and they had

to be shipped to Ferrari in Maranello to have their power units and transmissions, which are owned by the Italian firm, removed. But after the cars had returned to the UK the auctions were suddenly cancelled, and it looked like the team was not dead after all.

Indeed, not with a small amount of controversy the Marussia team has returned, under the name of its parent company, Manor F1 Team. The exact details and financial dealings of the team's resurrection have yet to become fully clear and will likely be covered in great depth elsewhere, but notable funding has

come from the boss of a minor British energy company as well as the former boss of one of the UK's biggest grocery store chains.

Of more interest are the cars that the Manor team arrived with in Australia for the opening race of the 2015 season. Based on the 2014 MR03, their specification was something of a surprise, as in early January Manor had been granted a special dispensation not to run with the 2015 specification front impact structure and nose shape.

It would of course be possible to modify the chassis to meet the 2015 chassis height



The team shipped all of its equipment to Melbourne for the race, but didn't make it out on track, sitting out the practice sessions on Friday, the qualifying sessions on Saturday and Sunday's race

'There are a lot of issues, none of which are a big surprise when you consider the amount of work that's been required to get the team here'

and front impact structure regulations by making adjustments to the chassis moulds and reshaping the tubs.

However, the MR03 chassis moulds were sold off at auction and now reside in the collection of an enthusiast somewhere in England. This means that the above modifications would be virtually impossible without making new moulds, something that the team simply did not have time for between coming out of administration in February and shipping the cars to Melbourne for the opening race in the middle of March.

Instead, a very pragmatic approach was taken to the chassis – the 2014 specification bulkhead was left untouched, with the front suspension layout remaining unaltered from the late 2014 design. But a structural composite spacer, similar in concept to that of the front of the Deltawing LMP or the Nissan ZEOD, was employed. At approximately 200mm in length, the spacer allowed the team to fit a new nose to the car which appears to fully comply with the 2015 regulations. This, in addition to the required installation of larger anti-intrusion panels on the side of the tub, led to the car undergoing a series of new crash tests, which it passed with flying colours.

But it is worth noting that the team is still in some difficulty with the chassis as it only has

two available instead of the more conventional three or more. Marussia had built three chassis but one of them was destroyed in Jules Bianchi's accident at the Japanese Grand Prix at Suzuka in October, 2014.

The additional length of the car, with an unchanged wheelbase, will likely have an impact on the car's aerodynamic package which has probably not been fully evaluated, not least due to a significant lack of time – the team's 2014 wind tunnel model was dismantled to allow work on its 2015 design to get underway. The model, less its spine (owned by McLaren) now resides with private individual in the UK. More on the evolution of that model and its current state can be found on the *Racecar Engineering* website and social media sites.

Challenging times

Compounding the lack of wind tunnel model, the team may also lack data for both its 2014 and 2015 designs. When the Haas F1 team acquired the Marussia facility in Banbury, England, it is reported to have acquired some of the team's data and IT assets, and that may include the team's CAD Data.

What the team has also seemingly lost is access to some of the software required to run the cars. The modified MR03's are fitted with 2014 specification power units as the team did

not have time to develop an installation for the heavily updated 2015 Ferrari V6 hybrid.

'It's not simply a software issue,' the team's president Graham Lowdon explained. 'There's a lot of issues, none of which are a big surprise really when you consider the amount of work that's been required to get the team here in a very, very short space of time. I would say that the problems we're dealing with are not unusual for the task that we're doing, which is effectively setting up both trackside and on-car infrastructure for these cars to run.'

This led to the cars being marooned in the garage for the duration of the Australian Grand Prix meeting, but as Racecar closed for press the team stated it would get on track in Malaysia.

The next big hurdles that Manor has to navigate is a shortage of staff, as many key personnel left last year to work in other teams, and in some cases other industries. The other problem the team has will be to qualify its cars within 107 per cent using its outdated power unit and sub optimal aero package. However, one thing that it will have in its favour is reliability, as its components are proven.

Eventually it will have to introduce a new 2015 specification car, possibly based on the stillborn but innovative MNR1 design profiled in RCE V25N2 or an even more substantial update of the MR03.



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Power struggle

As the F1 season begins we examine the power unit arms race and ask whether anybody can stop the all-conquering Mercedes team?

By **SAM COLLINS**

As the Formula 1 teams prepared to head out for the first competitive session of the 2015 Formula 1 season, the level of year-on-year development on the power units was revealed – all but two of the cars on the grid were fitted either with completely new or substantially updated V6 engines and hybrid systems.

Mercedes appears to have done the most development on its power unit, spending 25 of its 32 'tokens', and has gone as far as saying that its PU106B is a completely new design.

All change

The most noticeable change to the German car is the very large plenum, a by-product of the introduction of variable intake trumpets. It is so big that it causes a noticeable bulge on the engine covers of all the cars using it – Lotus, Williams, Force India and the works team. Another major change is the apparent abandonment of the Birmann-style gas dynamic rectifiers in favour of a more conventional set of exhaust headers, likely using the Sulzer type rectifiers instead. Mercedes remains tight lipped on the reasons for this change. Looking at the air ducting arrangement and filter location, it appears that the V6 engine has retained its split turbocharger concept with the compressor mounted at the front of the block, the MGU-H nestled in the V of the engine and the turbine mounted at the rear. Once again the Mercedes appears to be the class of the field and the brand still has enough tokens to make another significant step during the season, probably around the time of the Japanese Grand Prix. These seven tokens could, in essence, be combined with the 25 allocated for use ahead of the 2016 season to give Mercedes the capability to make another significant step forward.

Ferrari has also made major changes to its power unit. The 2014 design was deliberately compromised in order to help the aerodynamic department get the best out of the car but the potential benefits of reducing the overall volume of the power unit were never quite realised. It was apparent that the Ferrari unit was overweight and underpowered, and most of the updates have been to rectify this.

Early on in the 2014 season the power delivery was not particularly sophisticated



Renault's 2015 power unit has a new combustion chamber, exhaust system concept and variable trumpets



Ferrari's development programme has seen the Italian manufacturer close the gap to Mercedes

and quite tough for the drivers to get the type of throttle response that they wanted. It was improved a lot during the season and we take that a step further for the SF15-T, technical director James Allison explains. 'A definite weakness of last year's car was that the amount of electrical energy that we were able to recover from the turbo was not really good enough for producing competitive power levels during the race. It was one of the reasons Ferrari's qualifying performance was relatively better than race performance last year. As a result we have tried to change the architecture of the engine to make it a better compromise between

adopted a totally different exhaust concept – in 2014 it ran its three-into-one exhaust header up the side of the V6 engine and over the top of the bell housing to the turbine. On the 2015 design its headers appear to be larger in diameter and run much lower in the car routing to the turbine via holes in the side of the bell housing. Curiously the plenum on the Ferrari V6 appears no larger than that of the old power unit found in the Marussia, raising the possibility that it is yet to feature a variable inlet.

Following the Australian Grand Prix, Renault looked to be facing another tough F1 season. However, having used the least tokens of any of

F1. The FIA has an equalisation mechanism in its rules and I think perhaps it's something that needs to be looked at,' the Red Bull boss urged. 'The FIA has a torque sensor on every engine, a power output that they can see, that every engine is producing. They have the facts and they could quite easily come up with a way of finding some form of equalisation.'

Bernie Ecclestone later supported Horner's claims and pointed out that indeed there is a mechanism which could be used to blunt the three pointed star somewhat. 'There is a rule that in the event that a particular team or engine supplier did something magic – which

'Mercedes has a good car, a good engine and very two good drivers, but the problem is that the gap is so big that you end up with three-tier racing'

qualifying and racing performance. In this fuel-limited formula an enormous amount of work has gone into all aspects of our combustion efficiency to try to make sure that every single stroke of the engine is extracting the maximum amount of horsepower on the road.'

To achieve these goals, Ferrari has used 22 tokens, with the remainder likely to be deployed ahead of the Belgian or Italian Grand Prix. It is clear to see that the Italian power unit has

the manufacturers, 20, it appears that there are still significant upgrades in the pipeline. Renault claimed at the start of the season that it had introduced a new combustion chamber, compressor, energy store, water pump and variable inlet trumpets. But the teams using the Renault, Red Bull and Toro Rosso, have both complained that the updated power unit is still bugged by both reliability and usability issues, stating that the power is not evenly distributed and reduces the cars overall drivability.

'The main difficulty is the operating modes of the engine and the new power unit is more difficult to configure than last year. However, when it comes to power, we have made a step forward compared to 2014, Renault's head of operations, Remi Taffin, admits. 'We are still behind in terms of performance and reliability, but Renault has won championships before without having the most powerful engine.'

Finally Honda, which returned to Formula 1 in Australia, had a torrid time with its RA615H power unit proving to be a long way off the pace. Indeed, it has been suggested that the Japanese marque detuned the unit just to be able to finish the race, yet one of its V6 engine's still suffered a catastrophic failure on the way to the grid, leaving only a single McLaren in the race. As a result little can be revealed about its performance potential other than that it appears to be very compact.

Honda has been given nine tokens to use during the season, but it is likely to make a substantial number of reliability upgrades before they come into play.

Mind the gap

The clear different performance levels of the power units have led to some, notably Christian Horner of Red Bull, to call for some kind of performance balancing to be employed. 'Mercedes has a good car, a good engine and they've got two very good drivers, but the problem is that the gap is so big that you end up with three-tier racing and that's not healthy for

Mercedes have done – the FIA can level up things,' the FOM boss explains. 'Mercedes has done a first class job but we need to change things a little bit now and try and level things up somewhat. What we should have done was frozen the Mercedes engine and leave everybody else to do what they want so they could have caught up, he says. 'We should support the FIA to make changes.'

But Mercedes motorsport boss Toto Wolff dismissed the calls for equalisation, telling Horner and Red Bull to 'get your head down, work hard and try to sort it out.' With Ferrari siding with Mercedes it seems that equalisation is unlikely to happen.



Honda suffered a troublesome return to F1 – the power unit was plagued with reliability issues and was five seconds off the pace



Mercedes has already used more engine tokens than anybody else, leaving it with the least scope to develop its power unit

Eight years ago



There seems to be a lot of shock and consternation about the new Formula 1 power unit regulations but really nothing should have taken the teams by surprise. Racecar Engineering profiled the current power units back in May 2007. Got the year wrong though.

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F1 team bosses say cost cuts must not change hi-tech image of sport



F1 team principals are concerned that cost cutting could strip the sport of its technological essence

Formula 1 team principals have urged for caution when it comes to cost cuts in the midst of fears that the sport could lose much of its hi-tech character.

F1 has been examining ways of reducing team spending over the winter and an FIA cost cutting body has been set up, which includes all the teams, Formula One Management (FOM), the FIA itself, and the management consultancy company McKinsey.

However, some team bosses have warned that F1 needs to be careful not to lose sight of the sport's technology-driven DNA.

Maurizio Arrivabene, who took over as team principal at Ferrari in November last year, said: 'We are all working together to try to somehow solve the [cost] situation, but it's also important to remember that we are talking about Formula 1, [which] is considered the pinnacle of motorsport competition. So we need to keep up that concept.'

'I think the [FIA cost cutting] group is working very well in this direction and it's not an easy compromise because somehow you have to work on saving certain costs, but on the other hand you want to preserve the development,

the technology, the novelty etc. I think we need to work on the show, as much as the show is growing and growing, and [then] have financial income for everybody.'

But it's not just the richer teams like Ferrari that have urged F1 to be careful to preserve its character, and its value as a product, while it implements cost cuts. Graham Lowden, CEO at Manor (formerly Marussia), which was rescued from administration just before the start of the season (see separate story), said: 'I think the overall thing is not just looking at cutting costs but looking at increasing value and that's really the most important thing, that if everything that we do increases the value of our sport, then that can bring sustainability. Ultimately, the objective of this is to increase the sustainability within the industry.'

Sauber CEO Monisha Kaltenborn agreed. She said: 'I think what we have to do is just make sure that costs come down to a sensible level which allows teams to be sustainable without compromising the show itself. We also need to ensure the competition is not compromised and that it remains very challenging technically.'

Formula E secures new investors and frees up motors

FIA-backed electric racing championship Formula E (FE) has secured investment from a pair of companies owned by American media mogul John Malone, while it has also announced that eight companies are to produce bespoke powertrains from next season onwards.

Formula E Holdings, the company behind FE, has said that Liberty Global, an international telecommunications and television company which raked in a staggering \$18.2bn last year, and Discovery Communications, which chalked up a revenue of \$1.2bn in 2013, are now shareholders.

John Malone, said to be worth some \$6.7bn, owns the Liberty Global Group and also has a controlling interest in Discovery Communications. Liberty was previously in negotiations to buy a stake in F1, but talks with the sport's ultimate owner, CVC, broke down last year.

Formula E has denied speculation that the new investment is actually an acquisition of the stake in FE owned by Spanish businessman Enrique Banuelos, one of its founding investors. Neither the percentages of the shareholding the new investors have taken, nor the amount paid out, have been made public.

Alejandro Agag, CEO at Formula E, said: 'It is a significant step forward for Formula E to receive the backing of two major global media companies when we are barely halfway through our first season. The experience and knowhow they bring will provide a significant boost to Formula E.'

Meanwhile, FE has named the eight manufacturers which

have been accredited to produce powertrains from the 2015/16 season onwards – FE's second season marks the start of a move away from the current spec unit.

Among the companies are Renault Sport, plus current FE teams ABT Sportsline, Andretti Autosport, Venturi Automobiles, Mahindra and Virgin Racing Engineering. They are joined by FE newcomers NEXTEV TCR and Motomatica.

The manufacturers will be allowed to develop a bespoke e-motor, plus inverters, the gearbox and the cooling system. The batteries are scheduled to become the next stage of development during FE's third season.

Agag said: 'One of our objectives from the beginning was to promote technology competition, but we cannot do that as organisers of the championship. We need 'actors' to join and to develop technologies to fight against each other in the races. Through this fight we improve the technology, and then with this improved technology we can improve electric cars in general.'



Formula E boss Alejandro Agag says new investment is significant step

Race team woes blamed for Ferrari brand value dip

XPB

Ferrari's on-track struggles last year have had a knock on effect on the power of its brand, according to a respected study by an asset valuation company.

The study was published by Brand Finance – which describes itself as the world's leading brand valuation company – and it shows that the fabled sportscar maker is no longer the world's most powerful brand, having been bumped from the top of the rankings by toy building block company Lego.

Brand Finance puts Ferrari's fall from grace down to its struggles on the track, particularly in 2014, when the Scuderia failed to win a race for the first time in 21 years. It goes on to say Ferrari's talk of abolishing the cap in the amount of cars it sells has also affected its brand power, as consumers no longer see the prancing horse as quite such an exclusive motif.

Brand Finance explained: 'Ferrari remains a very strong brand but its power is slowly diminishing. It has now gone several years without an F1 title and last season struggled even to mount a challenge. The sheen of glory from its 1990s [sic] golden era is beginning to wear thin. Meanwhile, the departure of Luca di Montezemolo heralds a slight change in strategy at Ferrari's road car division. Montezemolo kept a strict cap on production to maintain the exclusivity of the brand. Since his departure, chairman Sergio Marchionne has suggested that



Three years ago some said the Ferrari F2012 looked like it had been made out of Lego – ironically the building brick has now replaced the marque at the top of the brand value pile

this policy will be relaxed to boost revenues.' It added: 'Many Ferrari owners and aspiring owners are extremely brand-conscious, making the loss of the 'world's most powerful brand' accolade, which Ferrari has held for several years, a particularly heavy blow.'

Brand Finance CEO David Haigh said:

'[Ferrari's] new strategy to capitalise on the brand will certainly drive short term value but over-exploitation risks lasting damage.'

Ironically, at the tail end of 2014 Lego was rumoured to be seriously considering sponsoring Ferrari's F1 rival McLaren, but this ultimately came to nothing.

5.11 Tactical scoops top NASCAR business award

Sports apparel and specialist uniform supplier 5.11 Tactical has won a prestigious award for its business activities within the NASCAR industry.

5.11 Tactical, which has been NASCAR's official apparel supplier for just a year, has been presented with the Driving Business Award, an annual prize given to the official NASCAR partner which has demonstrated 'extraordinary leadership and results through its participation in the NFFB [NASCAR Fuel for Business] Council'.

NASCAR tells us that 5.11's participation in its NFFB initiative generated \$12m in business-to-business revenues in 2014.

The NFFB Council is a business-to-business platform that brings together an exclusive group of more than 50 official NASCAR partners to buy and sell products and services. NASCAR says that since its inception in 2004 its quarterly get-togethers have facilitated more than 1000 'speed meeting' sessions where

official NASCAR partners meet and do business with one another.

Steve Phelps, NASCAR's executive vice president and chief marketing officer, said: 'Our sport is steeped in history and tradition, which is why it's so impressive to see one of our newest council members capture the award through a bold commitment to engage our partners. 5.11 Tactical embraced its role as a member of the [NFFB] Council and delivered tangible business-to-business results that are worthy of this prestigious honour.'

Bob Neapole, 5.11 Tactical chief revenue officer, said: 'When we entered into our partnership with NASCAR last year, we expected to benefit from the sport's massive reach and brand loyal fan base. We also fully intended to leverage the business-to-business opportunities provided by the NFFB Council and we were pleasantly surprised by how quickly these partnership opportunities took shape.'

SEEN: BTCC Civic Type R



Based on the production version of the new Civic Type R which is due to hit showrooms in July, the race version will develop 350bhp with 400Nm of torque. By building on the existing road car, which was sourced direct from the Honda UK factory in Swindon, the team has produced a car with increased downforce compared to last year's Tourer, less drag and a more effective airflow management.

The team has high hopes for 2015 as Barry Plowman, technical director at Honda Yuasa Racing, explains: 'We cannot wait for the new season to start. 2015 is widely being billed as the year

Honda is back and we are continuing that in to BTCC. We've worked hard over the winter to ensure we have a winning car for 2015.'

The announcement comes as the team confirmed an unchanged driver line-up of Gordon Shedden and Matt Neal for the sixth consecutive season.

'This is a car that not just us, but the entire automotive industry has been waiting for,' added Matt Neal. 'We are as excited as anybody to start running the Civic Type R, which is a massive step forward from last year's Tourer – from the engine to the handling and aerodynamics.'

IndyCar boss wants 20-race season from 2016

IndyCar is looking at a winter start rather than returning to its once traditional autumn finish – pictured here at Fontana in 2013



XPB

The boss of Hulman & Co, the company that owns both the Indianapolis Motor Speedway and the IndyCar Series, has said he's aiming for a 20-race calendar from next year, while the season could kick off as early as February.

This comes on the back of worries expressed by some teams that the season was short in relation to other sports and even other motorsports. This year IndyCar starts in March and finishes in August, while NASCAR starts in February and finishes in late November, for example. IndyCar switched to a late August final race in 2014. Teams have said the resultant shortening of the season has given them less exposure throughout the year and therefore less leverage when it comes to attracting sponsorship.

However, Mark Miles, CEO at Hulman & Co, said: 'We're not trying to shorten the season. We are actually planning to lengthen the season. What we're trying to do is slide the season [in] earlier.'

'We've shared with the drivers, with the team owners [and] with the promoters, the vision, the plan, which we'll get closer to in 2016, where we hope we begin the weekend after the Super Bowl, early February. That gets us a little over seven months of racing. Our objective is about 20 races [it's currently 16].'

Miles added: 'So, yes, we started by ending earlier [in 2014]. You haven't yet seen us start earlier. But I want you to understand that's where we're going. We want to race in a very full schedule, about 20 races. That will feel very

different than it did last year and this year. You will see the expansion.' The scheduling was hurt by the cancellation of the Brazilian round in March, 2015.

IndyCar is also looking at incorporating more international races from 2016, particularly during the new early start of the season when the USA can be hit by severe weather. 'We think there's an important market opportunity for us on a limited basis at the very beginning of the championship' Miles said. 'We could fill that early part of the series, February, with additional North American races. But there aren't too many places where we can race climate-wise.'

The IndyCar season kicked off at St Petersburg, Florida, on March 29, and the schedule runs through to Sonoma, California, on August 30.

SPONSORSHIP

Craft-Bamboo Racing has attracted sponsorship from former WTCC Lada backer **Lukoil** for its 2015 campaign in the all-new TCR International touring car series. The Russian oil company's name will appear on the team's three **SEAT Leon Cup Racers**.

Apex Brasil, a trade and investment promotion agency based in the South American country, has ended its sponsorship deal with the IndyCar series, a partnership that had been in place since 2008.

V8 Supercars outfit **DJR Team Penske** has linked up with assembly and fastening material company **Wurth Australia** in a title sponsorship deal. In a neat display of global synergy the No.2 Penske-run Ford Fusion in the NASCAR Sprint Cup sported a Wurth livery while racing at Fontana on the same weekend that Wurth debuted with Penske at Melbourne's round of the V8S championship.

Infinite possibilities for student engineers

Red Bull F1 sponsor Infiniti is expanding its search for race engineering talent in the shape of the 2015 Infiniti Performance Engineering Academy.

Now in its second year, the Academy gives university students the chance to land an engineering job with Red Bull Racing in F1, and with Infiniti itself. This year there will be five posts to aim for, as opposed to just three in 2014.

After a comprehensive assessment to identify the best applicants, a series of regional finals will recruit winners from Europe, Russia, China, Saudi Arabia and the



Fancy working on this? Then Infiniti's Performance Engineering Academy could be just the ticket

XPB

United States, with each receiving a 12-month internship complete with full salary, split between Infiniti's European Technical Centre and Red Bull Racing, both in the UK. This will see the winners working on key projects for Infiniti, which is the luxury arm of Nissan, and for the F1 Red Bull race team.

The five available roles will cover vehicle dynamics, vehicle design, aerodynamics and electronics, with those applying expected to have relevant academic backgrounds. All will be exposed to the close technical crossover between Red Bull Racing and Infiniti, including the use of hybrid technology.

Candidates will go through a three-stage process and ten will be selected in each of Infiniti's markets to attend their regional finals where they will complete a series of engineering tasks. One winner from each region will go on to secure the 12-month placement.

For more information visit www.academy.infiniti.com

The heat is on

There is little doubt that electric race cars will continue to fill up our grids in the future. However, for electric racing to ever reach its full potential, its inherent issue of thermal management needs to be solved. Luckily, this year's class of engineering students studying MSc Advanced Motorsport Engineering at Cranfield University are taking on this challenge as part of their Group Design Project.

The Cranfield Formula Electric Series (CFES) will consist of five teams competing against each other in true motorsport fashion. Each race team will design the thermal management system for an electric version of a Formula BMW, with the aim of achieving maximum performance and safe operation throughout a twenty minute race.

The final designs will be presented and virtually raced in front of some of motorsport's leading figures on the May 14 Industry day. The project is supported by companies and teams such as Williams Advanced Engineering, Virgin Formula-E Team, the National College for Motorsport (NC4M), Cranfield Motorsport Simulation (CMS), Altair Hyperworks, AVL, ChassisSim with various prizes awarded by the MSA and Racecar Engineering.

If you would like to attend the Motorsport Group Design Project Day on the 14th of May then please contact Jess Greenwood at j.greewood@cranfield.ac.uk

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CAUGHT

Steve Addington, the crew chief on the No.51 HScott Motorsports Chevrolet in the NASCAR Sprint Cup, has been fined \$25,000 after ballast was seen falling off the car during the Las Vegas round of the championship. Team owner Harry Scott released the following statement in its defence: 'The No.51 experienced a malfunction during the Kobalt 400 at Las Vegas Motor Speedway that resulted in a P3 infraction being assessed to the team by NASCAR. The issue was unintentional and we regret its occurrence.'

FINE: \$25,000

Paul Wolfe, the crew chief on the No.2 Penske-run car in the NASCAR Sprint Cup, has been placed on probation until December 31 after NASCAR officials discovered that the right and left rear quarter panels on the Ford had been modified after the qualifying inspection at the Las Vegas race. Sprint Cup regulations state that OEM-manufactured body components cannot be modified, unless there is a need for them to be stiffened, or for other components to be attached to them.

NASCAR issued Sprint Cup squad Stewart-Haas Racing with a written warning in the wake of the Daytona 500 after its Danica Patrick-driven Chevrolet was found to be running with an unapproved heat shield. NASCAR said the problem part was an 'unapproved left-side driver heat shield; the outer exterior exhaust heat shield panel must follow the horizontal surface plane of the left side floorboard forward section to the bottom edge of the left side toe board'. No further action was taken.

IN BRIEF

Xtreme car crime

NASCAR Sprint Cup squad Team Xtreme was the victim of what looks like an opportunistic theft after one of its Chevrolet racecars was stolen while it was in transit to the Atlanta round of NASCAR's premier race series. The car, which is raced by Travis Kvapil, was taken from a car park outside a hotel close to the track early on the Friday morning before the race, only to be found dumped in a nearby wood later that day. The car had been on a trailer towed by a pickup truck rather than in the team hauler because of expected logistical difficulties due to severe weather.

Porker snatchings

Porsche has reported new records in terms of deliveries, revenue and profit in the 2014 fiscal year. Vehicle deliveries were up 17 per cent on the previous year (with 189,849 sold) while revenue rose by one-fifth to €17.2bn. Meanwhile, the operating profit grew by just over five per cent to €2.7bn. On top of that, the number of people working for Porsche reached a new peak at the end of the year, with 22,401 employees, an increase of 15 per cent on 2013. Porsche's flagship motorsport programme remains its LMP1 assault in the WEC.

BUMPER F3 grid

The Formula 3 European Championship has attracted a huge grid for this season, with 35 confirmed entries. This is a record turnout for the FIA-backed championship, which replaced the Euro Series for the 2013 season. There will be 11 teams represented, with British single seater powerhouse Carlin supplying the biggest fleet of cars (six), while its German rivals Mücke Motorsport and Motopark will enter five cars each.

Tyre test

Four NASCAR Sprint Cup teams were invited to take part in a March 10 Goodyear tyre test at Charlotte Motor Speedway and Hendrick Motorsports, Richard Petty Motorsports, BK Racing and Furniture Row racing all had one car on track. The following day NASCAR opened it up to any team and 11 cars took to the track to log data for the upcoming Charlotte events.

Canada circuit on track

Plans for Canadian Motor Speedway in Fort Erie, Ontario continue to surge ahead with Jeff Gordon aiding in the design of the \$400 million project that will feature a three-quarter mile banked oval and two mile circuit.

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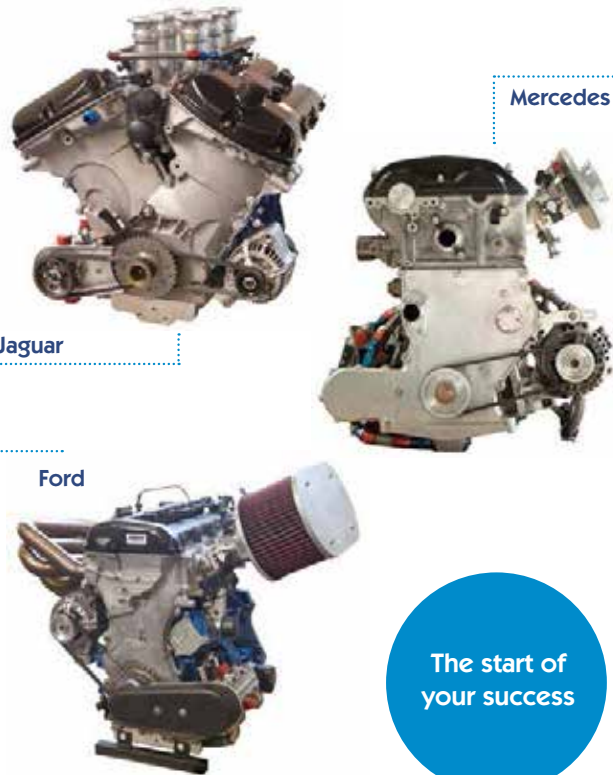
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INTERVIEW – Trevor Carlin

Seven up

With seven separate campaigns, including a new US programme, 2015 promises to be a very busy season for Carlin. Its boss somehow found time to tell us all about it

By MIKE BRESLIN



Who's the busiest man in motor racing? This year it's possibly Trevor Carlin. The man who runs the ultra-successful single seater squad that bears his name has just embarked on what has to be his most intense season ever, running 20 cars in seven single seater programmes: 'I imagine it's the most we've ever done, but I'm too busy to count,' he quips.

These championships are: MSV Formula, Formula 3, GP3, Formula Renault 3.5 (WSR), GP2, Indy Lights and Formula E, the latter in conjunction with Mahindra. That's quite a workload in anybody's book, but then that's just the way Trevor Carlin likes it, not least because it's his relentless ambition that drives his organisation forward, while it's also the way he keeps hold of his valuable staff.

'It keeps the team busy and allows me to continue to employ good people. It's strengthening the team, so it's all good,' Carlin says. 'You don't want to lose anyone. If you've got good people, ambitious people, the only way to keep hold of them is to grow.'

Carlin's been growing since it set up as a British Formula 3 operation back in 1997. Prior to that Carlin himself worked in Formula Ford, then for Ralt in the States, before becoming one of the best known names in British F3, first with Bowman and WSR, then with his own outfit. Since '97 the company has expanded and now employs around 90 people, while in 2009 it was bought by Graham Chilton, father of Max, and his company Capsicum – Carlin's own job title is now sporting director.

Formula 3 is still at the heart of the operation, but no longer in the UK, what with the demise of British F3 last year, of which Carlin says: 'If you've got no competitors then you haven't got a championship. And to be honest, it was the teams, like us, like Fortec, Double R and T-Sport, that artificially kept the championship alive for five years longer than it should have stayed alive anyway.'

Bring back Formula 2

Carlin is still very much involved in F3, though, in the burgeoning European Championship, in which it will run a fleet of six cars this year. 'You've got very good promotion from the FIA,' Carlin says. 'You've got some great events, which are DTM and other FIA events. It's a serious championship, it's well promoted, and you've got serious teams doing it.'

He's also pleased with the way the FIA has started to address the confusing nature of the single seater ladder in Europe, and with its plans for the future; even though this could mean the end of GP2 and FR3.5, with the return of Formula 2 in their place. 'It's a waste, not using the F2 title,' Carlin says. 'Because it's all well and good us, motor racing people, sitting around chatting about GP2, GP3, Renault 3.5, Auto GP and so on, but if you go down the pub in the evening and you tell someone that you do World Series, they haven't got a clue what you're talking about. But if I told them I was doing Formula 2, they'd say "oh, that must be just under F1", and they would understand. The sooner

they clarify this, then the more chance we've got of getting more people watching the sport.' *The FIA announced the re-introduction of Formula 2 in the World Motorsport Council meeting in March, 2015 - Ed.*

As for the chassis replacement the above would entail, Carlin says: 'The FR3.5 car's been around for donkey's years and so has the GP2 car, so I think it's about time we had a new car anyway... But we're talking 2016 or 2017, so it's not tomorrow.'

Something that is very much today is Formula E, as the inaugural championship has been ongoing over the winter. Carlin says it's been a logistical rather than a technical challenge. 'The biggest issue is trying to cram so much into one day. You're limited on resources and personnel and you've got to do two practice sessions, qualifying and a race, all in a very short period of time, and somehow manage to charge up your batteries, too.'

The future's bright

At the other end of the spectrum there's MSV Formula. Carlin has been looking for a suitable rung at the bottom of the ladder to compete in since the demise of Formula BMW UK (2004 to 2007), in which it raced, and he even badgered Formula Ford to switch to a winged car long before it bit the bullet (Formula Ford has now morphed into MSA [F4]). 'The young drivers want something sexy, they want something contemporary, and they want something relevant,' he says. 'It's a good looking car, it's got the right amount of performance, it's got the right



A Carlin-run Dallara in European F3 action last year – this year the team will be running six cars in the championship

XPB

level of grip, which is low, and it's got tyres similar to F3, which is important. The whole thing is pretty good, and it's a cost effective car to run – hopefully – which means the drivers can get plenty of mileage.'

Not nearly as much mileage as Carlin himself is set to clock up in 2015, though, chiefly because of the most exciting new development within the organisation, its move to the States. Carlin now has a new arm based in Poughkeepsie, New York State – sharing space with the Dyson sportscar squad – from which it will run an Indy Lights operation this year in preparation for a full IndyCar assault in the future. Carlin says he was attracted by the new Lights car, which he believes should level the playing field as all the teams will be starting from scratch.

But surely Poughkeepsie's too far from Indianapolis? 'Well, to be honest I wanted to be almost anywhere apart from Indianapolis. No disrespect to Indianapolis, but I wanted us to have our own identity, and our own staff, in our own little network, and if you go to Indianapolis you end up employing people who are ex-other teams, and it is a team of 'ex' people. That's not to say we might not move to Indianapolis. But, you know, Poughkeepsie is probably two hours from New York. London's only six hours from New York, so, I could commute if I had to.'

Don't be lulled into thinking Carlin is underestimating the job at hand, though, far from it: 'We've got some experienced American guys on the team and we're fairly confident that on street and road courses we will be competitive. We're also fully prepared to take a little time to get up to speed on ovals, because they're super quick, super specialised, and you have to treat them with respect. We are not going to turn up and expect to go P1 on ovals; we need to learn our craft, learn our trade.'

Carlin's American dream has every chance of being fulfilled, but what then for the organisation? LMP is certainly a possibility, he says, but F1 would only now be looked at if the circumstances were right – Carlin himself was sporting director at the Midland F1 team in 2005 so he knows the pitfalls. His hopes for where Carlin will be in five years' time are realistic, then: 'Hopefully we will carry on doing what we're currently doing. If we're still here and we're competitive, still training young mechanics, young engineers and young drivers, and still winning races, then I'll be very, very happy.' And very, very busy ...'



RACE MOVES

XPB



Martin Whitmarsh, the former team principal at McLaren F1, has taken up the post of CEO of the Ben Ainslie Racing America's Cup sailing team. Whitmarsh parted company with McLaren at the beginning of 2014. The Ainslie team already had Formula 1 links through its consultancy deal with **Adrian Newey** and Red Bull Technologies.

Gavin Brown, managing director of Haymarket Exhibitions – the company behind the Autosport International show – has died. Brown's background was in the fashion business and he became involved in exhibitions when his company set up Clothes Show Live for the BBC in 1989. **Kevin Costello**, CEO at Haymarket Media Group, said: 'Gavin's warmth, good humour and optimism were much cherished by current and former colleagues and by industry contacts around the world.'

Paul Eastman has joined JRM's engineering department dedicated to the Mini World Rallycross Championship programme. Eastman was previously at Prodrive, where he was a key member of the Mini World Rally design team. JRM acquired Prodrive's rallycross Mini project last year.

Jem Marsh, the co-founder of sportscar manufacturer Marcos, a marque that was a mainstay of 1960s racing and is now popular in historic competition, has died at the age of 84. Marsh set up Marcos in 1959 alongside **Frank Costin**, the brother of Cosworth co-founder **Mike Costin**.

Martin Humphries will head up race weekend operations at Eurotech Racing. Humphries was West Surrey Racing's team manager, leading the team to last year's drivers' and teams' championship.

Former race team owner **Roy Kennedy** has died at the age of 77. Kennedy ran cars in Formula 2, Formula 3 and the BTCC, among others, his team first known as Roy Kennedy Racing (RKR), and later as Orbit Motorsport.

James MacNaughton is now motorsport manager at Porsche Cars GB, where he will be responsible for the Carrera Cup Great Britain. MacNaughton comes to Porsche from Goodwood, where he had looked after the Goodwood Road Racing Club for the past 10 years.

Chris Banker is now public relations manager at the Watkins Glen circuit. Banker comes to 'The Glen' from New Jersey Motorsports Park, where he has been manager of communications for the past two seasons.

David Hart is now public relations manager at Mazda Raceway Laguna Seca. Before his move to California Hart he was director of communications at IMSA. He has also worked with the 8Star Motorsports Grand-Am team and he spent 15 years at NASCAR outfit Richard Childress Racing.

Technical and motorsport business people feature prominently in the list of 20 nominees for the NASCAR Hall of Fame Class of 2016. These include: **Richard Childress** (team owner); **Ray Evernham** (crew chief); **Ray Fox** (team owner and engine builder); **Rick Hendrick** (team owner); **Harry Hyde** (crew chief); **Raymond Parks** (team owner); **O Bruton Smith** (track owner) and **Robert Yates** (team owner and engine builder).

NASCAR has announced the five nominees for the Landmark Award for Outstanding Contributions to NASCAR. These are: **Harold Brasington**, founder of Darlington Speedway; **H Clay Earles**, founder of Martinsville Speedway; **Raymond Parks**, NASCAR's first champion car owner; former sponsor **Ralph Seagraves**; and broadcaster Ken Squier.

Scot Elkins has joined the Motorsport Safety Foundation as its chief operating officer. Elkins previously held a variety of senior roles at IMSA, the most recent of which was managing director of technical regulations. The Motorsport Safety Foundation is a non-profit organisation dedicated to improving safety in motorsport.

OBITUARY – Gerard Ducarouge

Former F1 designer Gerard Ducarouge, well-known for the racecars he penned for Ligier and Lotus in the '70s and '80s, has died at the age of 73.

An aeronautical engineering graduate, Ducarouge began working on missile systems at Nord Aviation, but soon moved to Matra-Sports, where he started his motorsport career as part of its Formula 3 programme. At Matra he moved up through F2 and then on to F1, where he became the French company's head of operations.

His Formula 1 work at Matra included the MS10 in 1968 and the MS80 in 1969, with which Jackie Stewart won the first of his three world championships. But it was not all single seaters, and Ducarouge also designed the fabled Matra MS670 sportscars which scored a hat-trick of wins at the Le Mans 24 Hour race and also won the World Championship for Makes in both 1973 and 1974.

Ducarouge moved on to Ligier in the mid-'70s, his JS7 scoring the team's

first victory at the Swedish Grand prix in 1976, while his JS11 was very competitive at the start of 1979, and was then runner-up in the championship in 1980.

After parting company with Ligier Ducarouge worked briefly at Alfa Romeo's 1980s F1 effort and then moved on to Lotus, where his first car – the 94T – marked something of a revival for the British team. Ducarouge cars chalked up six wins for the Hethel-based outfit between '84 and '87, five with Ayrton Senna at the helm.

Spells at Larrousse and a return to Ligier followed before he left Formula 1 for good to return to Matra, where he worked on a range of projects as its development director.

Martin Brudle, who drove Ducarouge-designed cars at Ligier in 1993, commented on Twitter: 'That's sad, reading that F1 designer Gerard Ducarouge has died. Worked with him at Ligier. Stylish, fun and clever man.'

Gerard Ducarouge 1941-2015

Haas strengthens F1 technical and management teams

The new-for-2016 Haas Formula 1 team has bolstered its squad with a couple of key signings in the shape of experienced F1 men Ben Agathangelou and Dave O'Neill.

Agathangelou is to be the chief aerodynamicist while O'Neill will be team manager, joining recent signing Rob Taylor – a former Red Bull employee – who is to be chief designer at the US-based team. Haas F1 Team has been set up by American

entrepreneur and NASCAR team owner Gene Haas.

O'Neill played a key role in setting up of the Marussia team in 2009, and worked there until it went into administration towards the close of last season.

Agathangelou has most recently worked at Ferrari, concentrating on windtunnel development, but he has experience as head of aerodynamics at Jaguar and then at the team it morphed into; Red Bull. He has also had F1 stints at McLaren, Renault and Tyrrell.

The team's new F1 car is said to be progressing well, with help from Ferrari with which it is in a technical partnership, and a 60 per cent scale model has already been designed.

Haas team principal Gunther Steiner said: 'While there is still a lot of work to do, a lot has already been accomplished to allow the Haas F1 Team to be competitive when we join the F1 grid in 2016.'

Steiner added: 'Our technical partnership with the Ferrari squad has allowed us to develop our car and our people at a truly exceptional pace. The way we're going about our F1 team is completely new and different, but it's working. We're committed to our plan, we're committed to F1 and, most importantly, we're right on schedule.'



Former Marussia man Dave O'Neill has joined Haas F1 as its team manager

RACE MOVES – continued



XPB

Mercedes motorsport boss **Toto Wolff** has further reduced his shareholding in the Williams F1 team, agreeing to sell a second tranche of shares to American healthcare entrepreneur **Brad Hollinger**. Wolff's share in Williams now stands at just five per cent, while Hollinger owns 10 per cent.

Nissan executive **Yutaka Katayama** – widely known as Mr K – has died at the age of 105. Katayama ran Nissan's US operations until the 1970s and is credited as the father of the Datsun Z cars. He was also involved in motorsport, and once managed a team of Datsun 210s on a marathon rally around Australia.

Gordon Smith is now co-owner of NASCAR Sprint Cup outfit Hillman Racing and the team is now known as Hillman Smith Motorsports. Smith is a businessman from the US West Coast who first became involved with the Hillman organisation at the beginning of 2014.

JD King, a competitor and racing administrator at the Sports Car Club of America, was named Member of Excellence at the club's awards. Meanwhile, **Dr George Snively** (safety pioneer), **Ron Sharp** (promoter), **Bob Tullius**

(driver and race team boss), **Roger Johnson** (solo course designer) and **Oscar Kovaleski** (driver), have all been inducted into the SCCA's Hall of Fame.

Former race and rally ace **Marc Duez** has been appointed race director for the new-for-2015 TCR International touring car series. Duez has previously been race director for GP2 and GP3 at Spa and Monaco, and was also assistant race director for F1 at the same venues.

US track operating company Speedway Motorsports Inc. has announced that **Ollen Bruton Smith** is now executive chairman while Marcus Smith has been elevated to the role of chief executive officer – he was previously chief operating officer.

Former NASCAR team owner **Thee Dixon** has died at the age of 76. Dixon was one of NASCAR's first African-American team owners, running teams in its Sportsman, Camping World Truck and NASCAR Sprint Cup Series from the late 1980s until the early 2000s.

Well-known motoring and technical journalist **Ronald 'Steady' Barker** has died at the age of 94. Barker, who made his name writing for *Autocar* and *Car* magazines, raced a self-built Steady Special – a re-bodied Lancia Astura – in the 1950s.

Philip Young, founder of the Endurance Rally Association, has died at the age of 66 as a result of injuries sustained while competing in the Road to Mandalay Rally. Young was behind the rise in popularity of classic marathon rallies and was behind the revival of the Paris to Peking event.

NASCAR's **Jim France**, 70, has made Forbes list of billionaires for his net worth estimated at \$2.1 billion, ranked 894th in the world and 318th in the US.

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In this special edition we look back on the key features run in the magazine over the past quarter of a century, but here, perhaps, it is time to look forward and hypothesize a little. The rate of progress in racing since 1990 has only really begun to change significantly in the last two years, with Formula 1 and the WEC introducing hybrid technology. Before that, in racing as a whole, there were detail changes as series came and went, manufacturers dipped in and out. Huge steps were made in safety, particularly in composites, not only in racing but also in the production car world. Diesel arrived as a performance fuel in 2006 but only recently has racing started to wake up to the fact that technology development is the big prize in modern racing.

Formula 1's first forays into hybrid were not a success. McLaren's solution was banned in 1998 and the decision to drop the technology just a year after its re-introduction in 2009 was embarrassing. Since hybrid technology's re-introduction into F1, the loudest noise has been that of the critics. As Mike Blanchet points out, it has drowned out the noise of the manufacturers who should be celebrating improvements in power, fuel consumption and reliability (the FIA is pushing for fewer engines per season, and the manufacturers are sprinting to try to catch up). Hybrid cars are not slow, and they certainly aren't dull. Look at sportscar racing. Around Interlagos, the WEC cars were seven-and-a-half seconds off Formula 1 pace (with a completely different qualifying system involving the average fastest laps of two drivers). And, in the wet at Spa, Andre Lotterer's Audi R18 was actually quicker than the entire 2014 F1 field in similar conditions. There are reasons for that beyond the powertrain, of course, but the technology is in the ballpark. Perhaps Formula 1 will learn from endurance racing and open up its technical regulations a little more?

We wrote in the April edition about Audi's investment in the company Joule Unlimited, and that could be part of the solution over the next few years too, but there are other areas in which our industry should look. One idea, floated by Audi's Ulrich Baretzky to German magazine *Sport Auto*, is that the motor manufacturers should look at becoming carbon neutral. That can start with racing and would lead to a change in the way calendars are presented, transport is organised, the number of races is calculated, the technology is considered, as are the transport needs of the fans. Everything from testing to racing, from build processes of a new car to a change in regulations or pace

of development when it becomes obsolete, it all has to be considered. The technology in the cars is of minor significance, other than that it feeds the production department of cars, trains, buses, ships and aeroplanes.

With a social responsibility hat on, is there really a need for all these international race series? Could there be a rise of national racing series, such as the British Touring Car Championship and Rally Cross (the perfect format for electric cars)?

For that raw emotion, however, fans will still need their fix, and while the world considers the environment, there is still, in the hearts of the car enthusiasts, space for what Stephane Ratel calls 'dream cars'. With the stock market not in fine fettle, investors are turning to bricks and mortar, and performance cars. In this edition, we feature James Glickenhaus' attempt to re-introduce the world to cars of beauty and to get away from the 'vanilla cars' of this generation. Who can fall in love with the looks of a Toyota Yaris in the same way that the world fell in love with the original Mini, and the Mini Cooper?

Manufacturers will need to hit their CO₂ targets of 95g/km in 2020 across the fleet, and dropping even further in 2025. At the MIA's green conference in January, manufacturers were roundly agreed that these targets could not be met with the current fuel. So, my predictions for 2025 are that there will be a new fuel, developed in racing and introduced to a production car world already. It could be hydrogen, it could be synthetic or it could be something else entirely new. Engines will be just as powerful as they are today, but will require significantly less energy from the fuel. Design will focus on reduction in fuel consumption including gearbox technology, aerodynamics and weight. Racing schedules will change, viewing habits will change and we may be looking at an interactive online audience rather than a grandstand full of people. And that will mean that circuits will need a different business model.

I think that the trend, not just towards hybrid but for change in general, will continue and that motor racing as we know it will evolve faster over the next 25 years than it has in the past quarter of a century. Incidentally, I also doubt that print magazines will be around by then either, and *Racecar Engineering* will be fully interactive online. Wherever we look in our hallowed racing world, this is a time to embrace change and welcome new ideas, not be frightened by it.

ANDREW COTTON Editor

Viewing habits will change and we may be looking at an interactive audience

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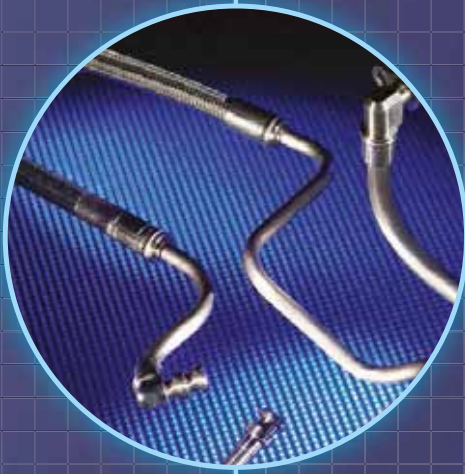
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