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Force India VJM07

Mercedes engine and lightweight chassis creates platform for innovative F1 car

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On the same team?

Rivalries in the pits can hold everybody back. Cohesion is essential

The erupting aggravation between top drivers in an F1 team regularly calls media attention to the often-conflicting goals of the starring players.

What does not get mentioned is the underground battle that can erupt between engineers assigned to particular cars in the team. The rest of the grid is a common challenge, but basically the yardstick of performance is your other team car, as it probably has the same level of inputs, engineering and components, thus it will be used to compare driver effectiveness. Ipso facto, when you are ahead, you are better than your oppo, a major consideration at the end of the season when contracts are being signed.

The number of teams that succumb to this internecine war is quite spectacular, the infighting sometimes reaching management problem-list levels. A shame, because they are missing the synergistic effect of doubling your inputs to solve the ever-lacking running time in these impoverished days. Talent, be it in driving, setting-up or preparing the car, wins races, but teamwork and intelligence wins championships.

However brilliant your design team is, it all boils down to this: 'Every organisation, not just in racing, needs just one core competence. Tactical execution.'

Before data-logging bared all about the car's behaviour, it wasn't unknown for cabals of engineers and mechanics to pass false information to the other car, even producing 'counterfeit' set-up sheets. A more subtle trick was to notify of setup change near the end of the session, or claim some crucial change did not get informed because of the rush of work during the outing.

Teams work well when there is respect between the members, but it also needs guidance and direction. Good teams work together almost telepathically; no instructions needed, as everyone knows what needs to be done and the whole process runs on greased rails, smoothly and without hitches. That state of bliss is achieved when the team is mature enough to have done many races together, and becomes apparent in endurance racing, when your car comes home to the pits with a corner or other chunks missing.

The other way is when the teams practice thoroughly all countermeasures to problems that could conceivably surface. As motivational gurus would say 'If you fail to plan, you plan to fail.' And that extends backwards in time to designing for the type of racing it will do. Look at Audi's bodywork, with bits that can quickly be kicked away by the driver whenever he attacks the scenery, so as to be able to bring the car back to the pits.

A good driver will carry the car, and keep it ahead, but he is still driving machinery that has been designed, built, tested and developed, maintained, transported to the track and upgraded by a team. Hence the team's usual moan, 'We make it, they break it.'

Depending on the size and budget of the team, members will either be doing several jobs, or will have a specific role. Whatever the scale of the organisation, every team member must have a clear understanding of the scope of his role and responsibility, be able to do it in the time available, and coordinate with other mechanics and engineers.

Good teams work together almost telepathically

All this work will be measured in competition every two weeks on average by pitting it against other groups of people, and there you will be weighed by that ruthless judge, the stopwatch. Preparation and foresight are will also be judged in terms of reliability, e.g. having fewer mechanical faults than the opposition.

Racing is the epitome of 'right here, right now'. The banter and bragging all ends here. You can't hide behind theories and excuses. It is there in numbers and everyone can see the positives and negatives of your team's performance. The race weekend highlights all your shortcomings as a team, the ultimate laboratory experiment for measuring collective performance. Other teams can also read the numbers and exploit your deficiencies, be they human or mechanical. If your knowledge, organization or team cohesion is deficient, you will lose.


XPB

The best-run teams have clarity in their aims, structure and communications

To knit all these together needs a strong manager, but one who is not afraid to delegate and trust sub-managers, not forgetting to lead, communicate, inspire and motivate people. He will personify the team's spirit and unify the members in achieving the vision.

Sub managers must do their part without giving conflicting messages. Team members who moan in private about the failings of upper management undermine the whole spirit of the team and create cliques. Some imply that they know better – that the team would win if they were in charge. This attitude breaks teams.

The pressure of responsibility brings the fear of failure, which could mean the loss of a job. If members freeze at difficult choices, taking risk-adverse decisions, it means a failure of evaluation and going the safe route. This means you are farther from the edge, thus not maximizing all your possibilities, a perfect recipe to be beaten. Others will go the extra inch.

You must have an organization where all understand the chain of command, like an army, but feel able to discuss alternatives and produce constructive comments, that aid getting results. At the same time, you have to recognise those moments when backs are against the wall and co-operate with the team to follow a given directive. At this point, talking about things will not solve anything. Just do it.

Understanding the problem allows it to be solved logically and efficiently. Documentation is useful, but doesn't replace the old hand's accumulated knowledge. Listen to the old farts, they've been there and have the T-shirt.

I'd also advise teams to monitor the tweet count of its members during race weekend with a careful look at the time stamp against the race schedule. The number of tweets will be inversely proportional to the workload. Better still, confiscate any smartphones and iPads and watch track productivity increase by an order of magnitude.

My conscience is clean; after all, I can be monitored at @RDV69 in the interest of full disclosure. But beware, 'Fools go there for wisdom, the wise, for disappointment.'

It's simple: if every individual is performing at a high level, you're good. Respect, motivation, engagement, attitude and energy is what counts. If you don't have these, it's no go. But if you do have them throughout the team at a high level, you're off to the races.

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Competitive market

Could a closely matched grid of works teams and customer cars revive Formula 1?

There's an old saying about lunatics running the asylum. While I wouldn't necessarily class all the top management of F1 teams as fit for such incarceration, it's seldom a good idea for those with a vested interest being the ones making the big decisions for the greater good of the business or sport (is there a differentiation nowadays?) in which they are involved.

I experienced this first-hand a good number of years ago when CART in the USA went into self-destruct mode due to the individual egos and self-interest of certain individuals taking priority over good sense and vision. Despite re-incarnation as Indycar and the provider of some excellent and close racing, it has never recovered its status; even the Indy 500 no longer has the iconic recognition that it used to have. So take heed establishment F1 teams, with your recently affirmed cabal structure and myopic, "I'm all right Jack" attitude.

Until someone appears who, while taking the teams' input into account, is strong enough to wrest the key decision-making from them, other means of closing the gap between the haves and the have-nots need to be pursued.

TEAMS AT RISK

One course of action proposed and which could make a real difference is for the major Formula 1 teams to supply their cars to the smaller outfits.

This has been a contentious issue for some time. In the earlier years of Grand Prix racing this practice was common – in fact, with commercial sponsorship then restricted mainly to trade support from petrol companies etc, it was the only way that constructors such as Maserati could survive. When Grand Prix racing became F1, the same expediency applied to the likes of Cooper and Lotus; I recall Rob Walker's team running Jo Siffert very competitively in privately-entered 49Bs. This practise survived until the 1980's (RAM Racing with Williams FW07s) but much less successfully, presumably leading to the Ecclestone-inspired insistence on every F1 team designing and constructing its own chassis. This had credence in (a) making F1 unique, (b) avoiding a grid largely composed of identical machines, and (c) acting as a sufficient hurdle to jump to keep out the dreamers and time-wasters. Whatever the reasons this mandate has worked well, until recently that is. Now we are in 2014 with teams risking disappearance due to the costs of competing not matching the sponsorship achievable.

The advantages of 'customer' F1 cars are clear. As long as the cars are accessibly priced, together with the guaranteed provision of parts and comprehensive technical data – but don't by any means expect it all! – it would save these teams a huge amount of money in conceptual R&D, design, tooling, crash-testing and manufacture. For the supplying constructor teams, it means better amortisation of their investment and another revenue stream, the prime reason of course why they might want to go along with this. (Mind, this isn't all gain – providing an effective customer service requires added manpower and resources and the manufacturing task is greatly increased, while still having to meet the same critical deadlines). Most significantly however, it should result in the back end of the grid possessing much more competitive equipment than their limited resources can produce. This is particularly the case for fledgling teams, or even long-time constructors which continually disappoint, such as Sauber. They could focus on optimising and developing the performance of the cars that they have bought and learning from this. Without design and manufacture costs in their budgets, they could rely less on paying drivers and hire real talent instead.

XPB

Super Aguri-style customer teams could be the solution to F1's current crisis

SO HOW MIGHT IT WORK?

Firstly, there has to be an FIA-imposed limit on how many teams can be supplied with cars not of their own concept and construction. F1 must not remotely become a one-make formula. Secondly, there could be, say, a 3-season limit on a team relying on customer cars. Already-established teams could take a breather from being a constructor in order to obtain better results and re-group financially. After that, if they are a true competitor, they will want to go back to their own-built chassis. If not, perhaps they should race somewhere else... For a new team, it gives the possibility to get sufficiently established and resourced to become a constructor at the end of the mandated period.

It should result in the back end of the grid possessing much more competitive equipment

Thirdly, availability of the power units needs to match the customer cars for which they are designed; in fact this might well dictate the teams' choice of chassis. Long gone are the days of bolting a different engine to the back of an F1 car.

Fourthly, although the temptation might be to sell/acquire the previous year's inventory of a top team's cars and parts as a complete package, at a significantly lower price, the regulations should probably forbid this and insist on current-year cars only being permitted, to keep up the standard. Clearly, second hand (pre-used?) cars wouldn't work anyway when there has been a significant technical rules change, such as has happened for this year. It would be up to individual negotiation to agree what comes with the cars and to ensure that the initial specification is the same as the works machines. Development parts for customers, if included in the deal, will always be at least a few steps behind – but so what? Let the customer team show its ability by carrying out its own development; if it doesn't have at least these engineering resources it shouldn't even contemplate being in F1.

Purists might baulk at the idea of customer F1 cars, but provided it's handled sensibly it might be the best way of ensuring full Grand Prix grids for the immediate future. Along with equitable division of the TV money of course. Don't hold your breath.

Back to the front

Force India is punching well above its weight, and there could be more surprises to come

BY SAM COLLINS

Force India is often considered the perpetual midfield team, permanently anchored to the battle for 6th position in the constructors' championship. But the new-for-2014 rulebook has tipped things in the favour of the Indian-owned, British based team. At the third race of the 2014 season it scored its second ever podium finish, and it has shown great reliability with only one non finish due to mechanical failure. Every other finish it could have achieved has been in the points with one exception where the car failed to finish due to driver error. Only the dominant Mercedes team has a better finishing record in 2014. Indeed this is the best ever start to a season for the team under any of its previous guises, including that of Jordan. The car Force India is using to achieve these results is called the VJM07 which, as the name suggests, is the seventh design under the teams current ownership. The car uses the best in class Mercedes AMG HPP PU106 Hybrid 'Pegasus' power unit which is certainly a major factor in the team's strong form.

With the power train on the VJM07 all outsourced – engine from Mercedes HPP and transmission from McLaren – the Force India engineers are left with what amounts to a chassis development project with all that it entails: structures, packaging, vehicle dynamics and aerodynamics.

'When you put aside the power unit and simply look at the area of the car that we control then you realise it's mostly an aerodynamic project' Force India Technical Director Andy Green explains.

DOWNFORCE ISSUES

'What we were trying to achieve was trying to claw back some of the losses from losing the Coanda exhausts. The drop in performance from losing that exhaust system was significant, especially on the exit of the corner when the driver goes back on the throttle, it created a lot of rear downforce.'

The Coanda exhausts served largely the same purpose as 'blown diffusers' of previous years, using the plume of exhaust gasses to seal off the outer edges of the diffuser and prevent vortexes from the base of the rotating tyre from entering the region. At the end of 2013 these designs were outlawed and all cars must have a single centrally mounted tailpipe. But with the arrival of the new hybrid power units in 2014 such a concept would be ideal.

'We knew with this car, and the new power units, that there would be very high torque levels, so you would want to throw even more downforce at the rear because that is where the performance lies. So we knew that having it taken away would be a big hit. So this car was simply about regaining some of that, getting more load on the rear and we have got some way towards it but it's nowhere near what we had. We are continuing in that direction, that's our aim, but it's just so hard,' Green continues.

This means that much of the development work being done by the Force India engineers is about making very small gains, iterative developments that on the face

"We increased our target after the opening races to finish fourth in the constructors' championship"

of it would not seem to have any significance. 'Even at Monaco, where the cars are travelling relatively slowly, a few hundred grams of additional aero load on the rear is noticeable by the drivers this year. You look at the numbers and you think how on earth will they feel that? But they do. And every time we do a small experiment in that area they pick it up and make the performance. It's a very powerful area,' Green reveals.

As anyone who has set up a competition car will know, not all of a car's traction comes from aerodynamic loads at the rear, and in many classes mechanical grip is dominant, so it is no surprise that this area of the VJM07's design is of particular interest to Green and his engineers even in a racing class which is dominated by aerodynamics.

The intricate organic design of the rear suspension uprights has drawn a lot of interest

SUSPENSION BALANCE

'The mechanical side of it is very important as well to maximise performance in that portion of the corner. It's a bit of a conflict, because you want to soften the car and give it loads of movement at the rear to deal with the kerbs and that bit of the corner but it inherently brings other things in other areas of the corner. You can't just go softer to get compliance for the corner because the car moves around too much and you don't have an aero platform capable of maintaining its load through that movement, so it's a balance and we then have to look at suspension systems that change that characteristic as you go from slow speed to high speed,' Green explains.

Development continues, but Force India Technical Director Andy Green had hoped for more mid season upgrades

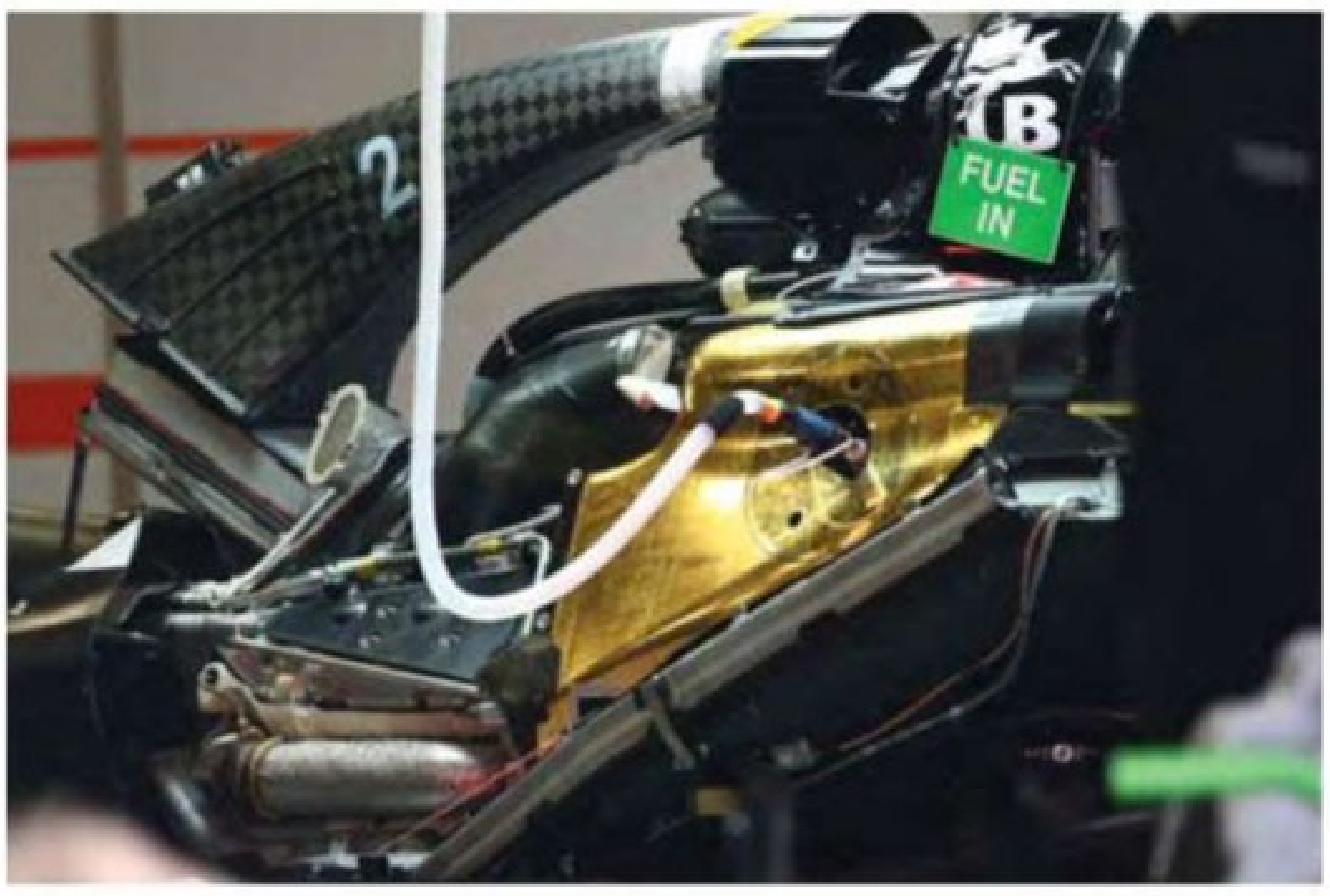
This is not a unique problem in racing and is common to all aero dominated classes, but with high torque levels in Formula 1, it is more pronounced. However most, if not all teams on the grid, have taken measures to minimise it, including Force India. 'We had an interconnected suspension system at the end of last year and we used the data from that to develop a new system for this car,' Green admits. 'We tested it in Bahrain after the race and we have used it in a couple of races (Shanghai and Barcelona), but it still needs further refinement so it's now back in another rework. We felt we could have raced it at Monaco, but we were not comfortable with the limits it was setting with respect to the tyres, so I didn't want that restriction on us. I wanted to set the car up freely. Doing that allowed us to explore a lot of different avenues. It was the right thing to do, if we had the updated system that we introduced at Canada then we would have raced it in Monaco but it was not ready. It's a lot of work and expense, but it's an area where we know we are behind compared to the competition so there is more to come there.'

The interaction between aerodynamic performance and mechanical performance,

The aero-assisting Coanda exhaust system is outlawed for 2014, with all cars now restricted to a single central tailpipe

The team cars look almost identical and meet weight regulations, but one chassis is built on a lighter carbon monocoque

The car displays high levels of mechanical grip, with or without the interconnected suspension setup



Mercedes PU106A power unit was an unknown quantity, but performance has been strong so far

especially at the rear of the car has forced the team to tackle some fairly challenging compromises. This is especially evident with the rear uprights which have a very intricate and almost organic design.

'They are single piece aluminium parts machined from solid, the design is integrated into the cooling system of the brakes, so a lot of the intricacy of them is about trying to get the airflow right around the brake disc,' Green reveals. 'There is an aerodynamic aspect to them and of course there is the structural aspect as we want to keep the wheel and wishbones attached, which is significant as there is an aerodynamic desire to get rid of the suspension. If the aerodynamicists had their way they would just pull all the suspension members off of the car, as they just get in the way. So we have a system at the rear where the wishbone is so high that it is in line with the driveshaft, and that brings about problems with structure. Trying to keep the wheel placed where we want it on the road is very difficult as we do not have the space between the upper wishbone and the lower wishbone. The upright has nothing to hold on to, so we have to throw a lot of material at it which is why it looks quite meaty. It is purely to try and keep the tyre pointing where we want it to. So we have a compromise on aerodynamics and it adds a significant weight to the upright to do that.'

MERCEDES POWER

The uprights themselves have drawn admiring glances from rival teams, not least because the relatively small Force India team does not have the capability in house to manufacture such parts.

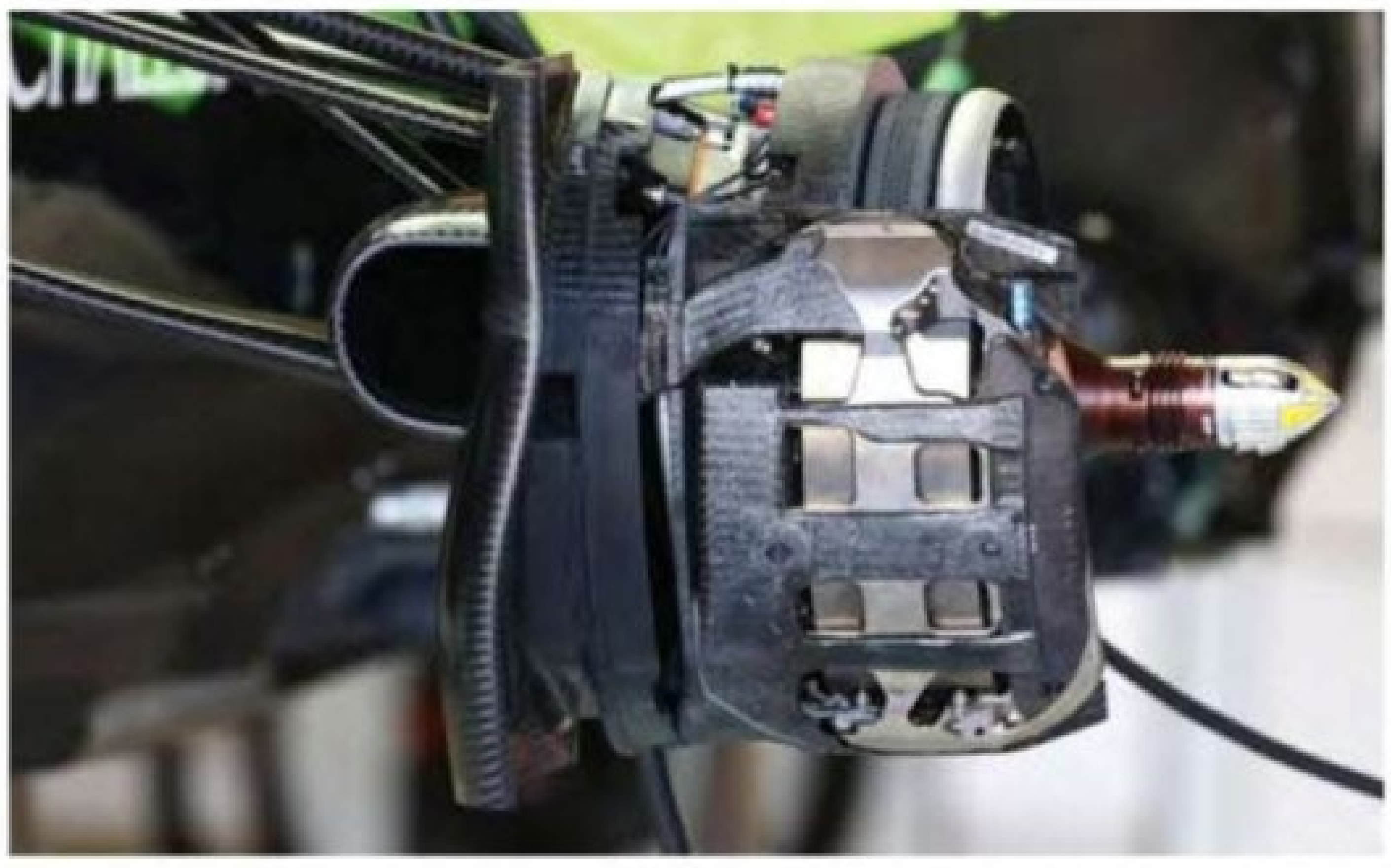
'It was a very iterative process to get to that design shape. It's very complex machining and they are beautiful to look at. Obviously it's computer controlled and we try to do as little hand finishing as possible. We don't have the capacity to do that in house so it's farmed out. We don't consider them a sacrificial part; that part will last the whole season. They cost so much that we can't afford to replace them unless they are accident damaged,' Green admits.

Another key area of trade offs for the Force India engineers to deal with was something of an exploration into the unknown, the installation of a highly advanced and unproven power unit, the Mercedes PU106A.

At the start of the season Green claimed that 'It's been a massive job to accommodate all the changes to the power unit – it's the biggest change I've

The Mercedes powerplant has kept cool so far, but bodywork changes could result in higher engine temperatures

witnessed in the sport since I started in 1990. Cooling has been the biggest challenge - most of last summer was taken up trying to understand the cooling requirements of the power unit, and how best to optimise it in the chassis. There's a lot more to cool and you are weighing up the performance of the power unit versus the performanceof the chassis and aerodynamics, and trying to hit the optimum on each one of them. We've had to develop a completely new tool set to examine, analyse and optimise it.'



Front brakes use AP componentry

GETTING HOTTER

But once the pre-season testing and the opening races were complete, Force India, as well as some others in the pit lane, realised that their cars were overcooled and the power units would be able to survive in an environment that was more hostile than first thought. However Green is not overly concerned by this.

'We had to be conservative at the beginning, so we were overcooled and still are. If we were not then we would not have had the capacity to backtrack if we made a mistake. It turns out that we were well below the limits which allowed us to do what we did pre-season and in the early races. Since then, the limits on the cooling have increased as Mercedes has given us even more margin, so we are now in a process of revising the bodywork and cooling package which will then remove the headroom we have on cooling, and turn it into performance. We are looking forward to getting that on the car sooner rather than later, perhaps in Austria or Silverstone. We do need it as we are desperately short of downforce on the car. We have a very aggressive programme to get some more load on the car. '

Green feels that the VJM07 has yet to unlock its full potential and, despite solid results, he believes that there is still more to come. 'We know we have a deficit to the rival teams because we can see what they have done, and we know where we are and where we could be from the wind tunnel model, it's just that we haven't got it on track yet. But we know the others around us have a superior load level to us.'

Despite this, the car has qualified and finished well consistently through the year, despite Green's belief that the car has less downforce than the other three Mercedes powered designs (the works car, Williams and McLaren). It seems that even though it was not running a state of the art interlinked suspension system, the VJM07 still has naturally good mechanical grip.

'The car is bringing results though, and it's pleasing for us to perform the way we did in Monaco. It shows that it's not just a horsepower car. We don't need the big long straights to get performance; we out qualified a McLaren and both Williams on a circuit known for being a downforce track, so we know the car is not bad, it's got reasonable mechanical grip, the aero can't be that bad and we know there is a lot more to come. We are quietly happy with it so far. We thought Monaco would be our weakest track. We have some good races to come. It shows we have a drivable car, we know they both have more downforce than us,' Green enthuses.

Although the team believe that the car has a deficit in downforce Green is wary of pushing too hard in that direction, and has learnt the lessons of the teams recent past. 'It's part of the remit we set at the start of this project, it's got to be drivable. A few years ago we had an issue where the team was just chasing downforce without any consideration of how the driver drives the car,' he says. 'There is a lot more performance to come there, when you talk to the drivers you know there is a long way to go.'

"It would be criminal to let Nico drive an overweight car"

LIGHTER CHASSIS

One challenge that was not widely discussed at the start of the season, but one faced by all teams, was meeting the weight limit. Initially Green and his engineers were not overly concerned but once the first chassis was built and tested it became clear that perhaps it was more of a headache than first thought. 'At the start of the year we knew we were marginal on weight so we did a lightweight programme,' says Green. 'Everything we did over the winter was performance vs weight, everything,' he stresses.

'When we put the car on the scales with our driver Sergio Perez we did not have an issue with the car weight at all – there was enough ballast to move around so that was fine. We were OK we thought, but when our other driver Nico Hulkenburg got in the car we realised we needed a bit more, so we knew we had to develop a lightweight chassis for him.'

This was no minor undertaking for the Silverstone based team, which essentially had to go back through the entire car and rework almost everything, after the first test. It also means that the two Force Indias competing in 2014 are different designs.

'We realised we had to do something as soon as chassis 1 was completed, chassis 3 is the

THE PINOCCHIO EFFECT

'I love these noses,' Andy Green jokes. 'We were constrained by a set of regulations that forced us to come up with unexpected consequences. The problem is the aerodynamic drive is always to lift the nose up. We do everything we can to lift it up and if there is a way, we can do it. The rules allowed us to lift 75 per cent of it up and leave 25 per cent of it down and unfortunately it's aesthetically not the nicest thing. We tried to mitigate it with the paint job but there is not much we can do. It's likely to change next season. I think it will be better next year.

'A few of the teams have put a soft start on the nose, almost sacrificial in some cases. We have seen teams knock it with a jack and it has fallen off. But that's not part of the impact structure, it's just there to meet the regulations, meaning that the impact structure is higher up which is what the FIA was trying to avoid. The structures are still lower than last year, but not at the height the FIA wanted.'

lightweight car and we pulled a few kilos out of it. The two designs look identical and come out of the same mould, so you can't see any difference, but it's all in the laminate the number of plies and what materials we use. You can't see the difference unless you are on the scales. It required a new homologation, a new crash test, everything. It's a fully homologated car, separate to the other car. It was a lot of work and for a team with limited resources it was a bit of a strain. It moved the weights around the car too. It was a big thing, but we knew how important it was. We could not let Nico have an overweight car as that would have been criminal,' Green states candidly.

KEEPING IT LEGAL

Lightening the chassis of VJM07/03 meant that the weight distribution of the car was significantly altered, something that the Formula 1 technical regulations do not allow, so the Force India engineers had to change many other parts of the car to ensure that the lightweight car remained within the parameters set by the FIA. 'From the very early days of the car we are setting up a model of the car making sure the weight is in the legal window, with all the component weights, all the positions and all of the C/G's. The model then tells us where the overall car C/G and W/D is, and we have a one per cent window to work in,' says Green. 'It's a 5kg mass moving from the front wheel centre line to the rear wheel centre line, so it's very small over 700kg and you have to be right on it. I anticipated some things getting heavier so we made sure our target was slightly forward of the legal limit knowing things at the rear would get heavier.' Force India gave itself room around the front of the car to adjust the wheelbase, helping to shift the balance where necessary. 'When the car was built and went on the scales it was exactly where we wanted it be,' says Green. 'Both lightweight and heavyweight chassis are identical in that respect.'

With Force India now in fourth position in the constructors' championship (at the time of writing) the team could be on for its best season in Formula 1, at least with the current name over the door. But the team feels that the car is not all that it could be, only describing its performance as 'solid'.

'It's not the best car we have ever done by a long shot,' Green admits, 'it's got issues that we are trying to solve. In no way are we thinking we have done a great job and that this is a fantastic car. The exact opposite, to be honest. There is a fantastic amount of potential in it we've got to unlock. When we come out of the other end it will be very strong though.'

Despite the disappointment with the car's performance, race results have allowed the Silverstone organisation to reset its ambitions. 'We started as planned and hit our targets, though we would have liked to bring more upgrades. We increased our target after the opening races to finish fourth in the constructors' championship and we are going fight tooth and nail to hold onto that. It would be the best ever finish ever for Force India and we are going to give it everything we've got. It's going to be some good fighting,' Green concludes.

That fight will be a tough one, with former world champion teams Williams and McLaren both using the Mercedes power unit, but those are scalps that Andy Green and his engineers would be happy to take.

TECH SPEC

Chassis construction
Carbon fibre composite monocoque with Zylon side anti-intrusion panels

Front suspension
Aluminium alloy uprights with carbon fibre composite wishbones, trackrod and pushrod. Inboard-mounted torsion springs, dampers and anti-roll bar assembly

Rear suspension
Aluminium alloy uprights with carbon fibre composite wishbones, trackrod and pushrod. Inboard-mounted torsion springs, dampers and anti-roll bar assembly

Transmission
Mercedes AMG F1 8-speed semi-automatic with seamless shift

Dampers
Penske

Wheels
Motegi Racing forged wheels to team specification

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

Brake system
AP Racing

Fuel system
ATL Kevlar-reinforced rubber bladder

Electronic systems
FIA SECU standard electronic control unit

Lubricants
Petronas

Engine
Mercedes-Benz PU106A Hybrid, Internal Combustion Engine: Capacity 1.6 litres, V6, bank angle 90°, No of valves 24, Max rpm ICE 15,000 rpm, Max fuel flow rate 100 kg/hour (above 10,500 rpm)

Fuel injection
High-pressure direct injection (max 500 bar, one injector/cylinder), Pressure charging Single-stage compressor and exhaust turbine on a common shaft, Max rpm exhaust turbine 125,000 rpm

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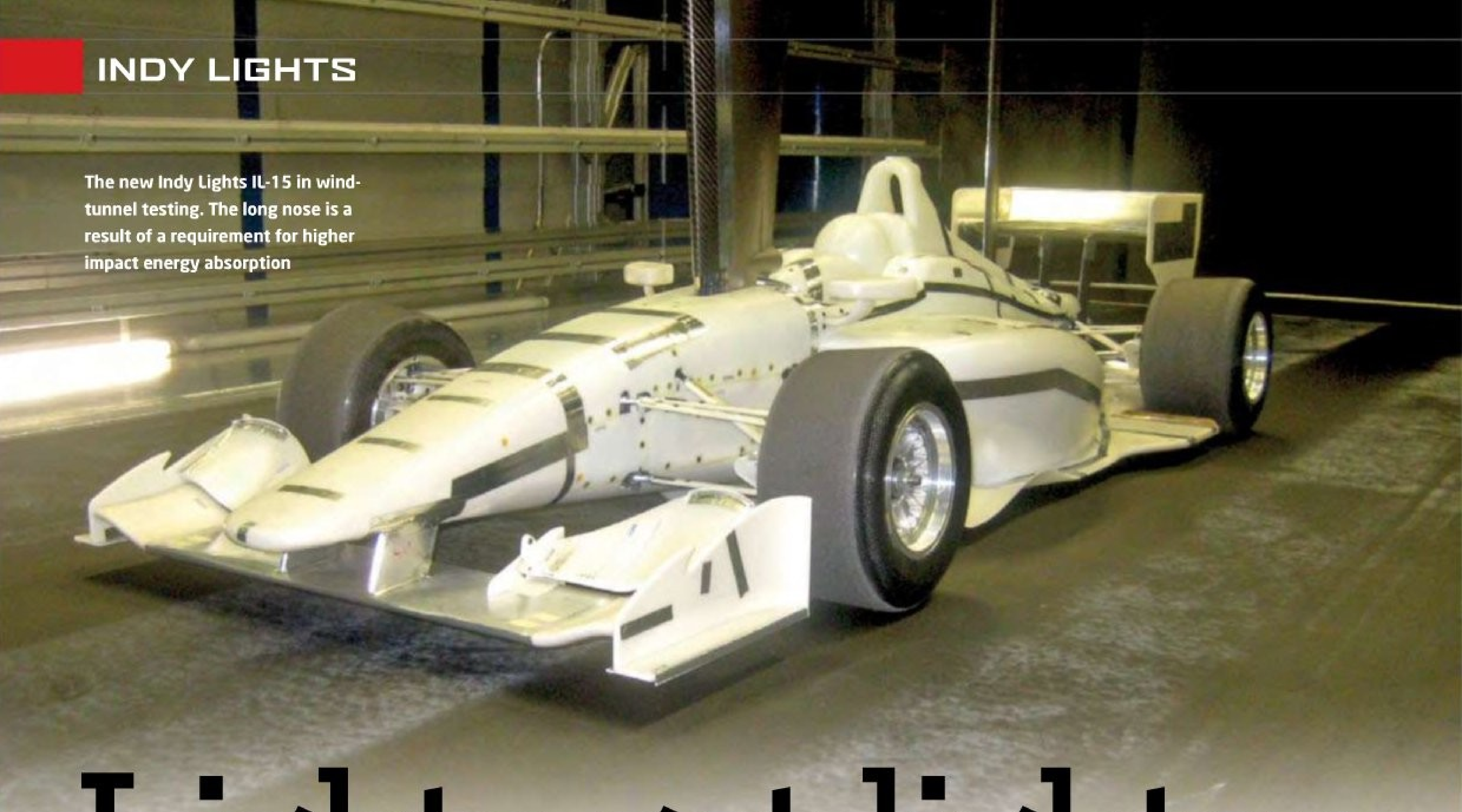


The new Indy Lights IL-15 in wind-tunnel testing. The long nose is a result of a requirement for higher impact energy absorption

Lights get lighter

Replacing the antiquated 2002 Indy Lights design, the new IL-15 from Dallara is a leaner blend of modern European and Indy Car technology

BY IAN WAGSTAFF

The next generation of Indy Lights car, the IL-15, was unveiled behind the Indianapolis Motor Speedway's Pagoda on the Friday before this year's Indy 500. It was none to soon. Earlier that day a mere eleven cars had contested the Freedom 100, the formula's flagship event.

However close the racing, such a small field of cars looks lost in the Brickyard's vast spaces. Last season's contest saw perhaps the most dramatic finish of any motor race while this year's 40-lapper saw Gabby Chaves' lack of regard for history when he pipped Sir Jack Brabham's grandson, Matthew, on the line. The cars, though, are now geriatric and a replacement is long overdue. After a false dawn, it's finally here, masterminded by Dallara project manager/chief designer, Antonio Montanari.

The IL-15 underlines the growing dependence on Dallara by Indy Car with final assembly taking place at the Italian company's factory on Main Street, a proverbial stone's throw from the IMS. It also reflects the company's head of R&D and US racing Andrea Toso's thinking with regard to the US scene, which he observes is culturally different to that in Europe. It continues his thinking with regard to such as the avoidance of interlocking wheels but with the lessons of the DW-12 Indy Car (or IR-12 as it is more correctly known internally at Dallara) taken into consideration, there is some difference in the result.

Montanari was chief designer on the Indy Car, as well as the new Indy Lights car. Evaluating the DW-12's performance over the last couple of years has enabled his team to make what have been described as incremental improvements.

Unlike the DW-12, the front wings of the 1400lb, carbon composite chassis, IL-15 are wider than the bodywork so that no part of the front wheels is exposed in a nose to tail collision. This, says Toso, means that he did not have to repeat the controversial rear bumpers of the current Indy Car. Increased under-wing width in front of the rear wheels also reduces wheel-to-wheel contact. 'We have a different solution but basically the idea is the same,' says Toso. Other safety features include full-length anti-intrusion panels and a lengthened nose for energy absorption. The interior cockpit hip panel padding is produced from extremely durable EPP (expanded polypropylene) foam, a different product from EPS (expanded polystyrene) and generally regarded to have better multiple hit performance as it is not permanently deformed in an impact. A considerable amount of time was spent on sled testing to identify EPP as the best product to use. The thickness is three inches behind and 1.5 inches under the driver.

There is more structure around the driver's head, which gives the IL-15 more of a European look

Another feature is the energy absorbing side pod inlet structure. The entrance to the radiator inlet duct is a separate structure and on the display car has been bonded on. The intention is for the front portion of the pod to provide an additional energy absorbing structure, bolted to the side of the monocoque on the actual race cars. This adds to the traditional feature of the side-mounted radiators being energy absorbing devices.

The headrest profile has been slightly updated from the DW-12, reflecting current FIA thinking. There is more structure around the driver's head, the monocoque having been raised in this area, which gives the IL-15 more of a European look.

There is, though, much of the DW-12 in the Lights car, 'more than you can see,' remarks Toso. The cockpit is one example, it being possible to take the seat from one and put it in the other.

Top: Suspension geometry and components are designed to be adaptable to road tracks and ovals Above: It's hoped that the 'sexier' IL-15 cars will attract new teams to the Indy Lights series

Other examples include the bulkheads, the oil tank behind the monocoque and the anti-wheel locking features on the side of the car. The two cars have the same wheel base and almost the same track width yet with the less bulky side pods and the absence of rear bumper, the IL-15 does look smaller. (The length is 192 inches, the width 75 inches.) The body of the display car show at the launch and then moved to the foyer of the Dallara factory is said to be correct in shape if not necessarily in construction, although is has been built using production tooling.

Toso points out the IL-15's simplicity. Unlike the current Indy Lights car but in similar fashion to the Indy Car, the same suspension, uprights and drive shafts can be used for road courses and ovals. This means a low amount of labour is required, as is a reduction of inventory.

Andersen Promotions, which now runs the whole of the Mazda Road to Indy programme, has been responsible for deciding on the suppliers, former IndyCar vice-president of competition, Tony Cotman having headed the bid and design and process. Included amongst the component manufacturers involved are Performance Friction, supplying the cast iron brakes, and Tilton for the carbon clutch. Motegi will manufacture the aluminium wheels with techno-mesh design, Cooper Tires will provide the tyres, the dampers are from Dynamics, and Life Racing will make the paddle shift. Cosworth sales director Kirsty Andrew, points out that the Northampton company will be responsible for the steering wheel and display, the data logger unit, the loom, power distribution unit and chassis sensor kit. The dampers and springs are carry-over items from the existing formula. The six-speed semi-automatic gearbox is also basically the same Ricardo unit as found in the old Indy Lights car, with the teams being able to retain most of the internals, including ratios. The engine is from another British supplier, AER. The search has been on to find a backer for the engine and although none has yet been announced, Dan Andersen, a former team owner and the founder of USF2000, confirmed that it will be badged. As Toso points out, 'a proven engine was required that would last a whole season without a rebuild.' There does seem to be a focus on using tried and tested components.

'NICE BUT CHEAP'

A new supplier to Indy Lights indicates the increasing links between Indy Car and Indy Lights machinery. Oxfordshire-based SS Tube Technology systems supplied exhaust systems to 29 of this year's starters in the Indianapolis 500, but has had no previous Indy Lights business. SS Tube's Indianapolis-based US representative Michael Desautels already had a relationship with Cotman through his Indy Car work and it was on his advice that he approached Andersen. Running turbo exhaust systems can work out to be extremely costly unless done well and thus top level Inconel has been specified.

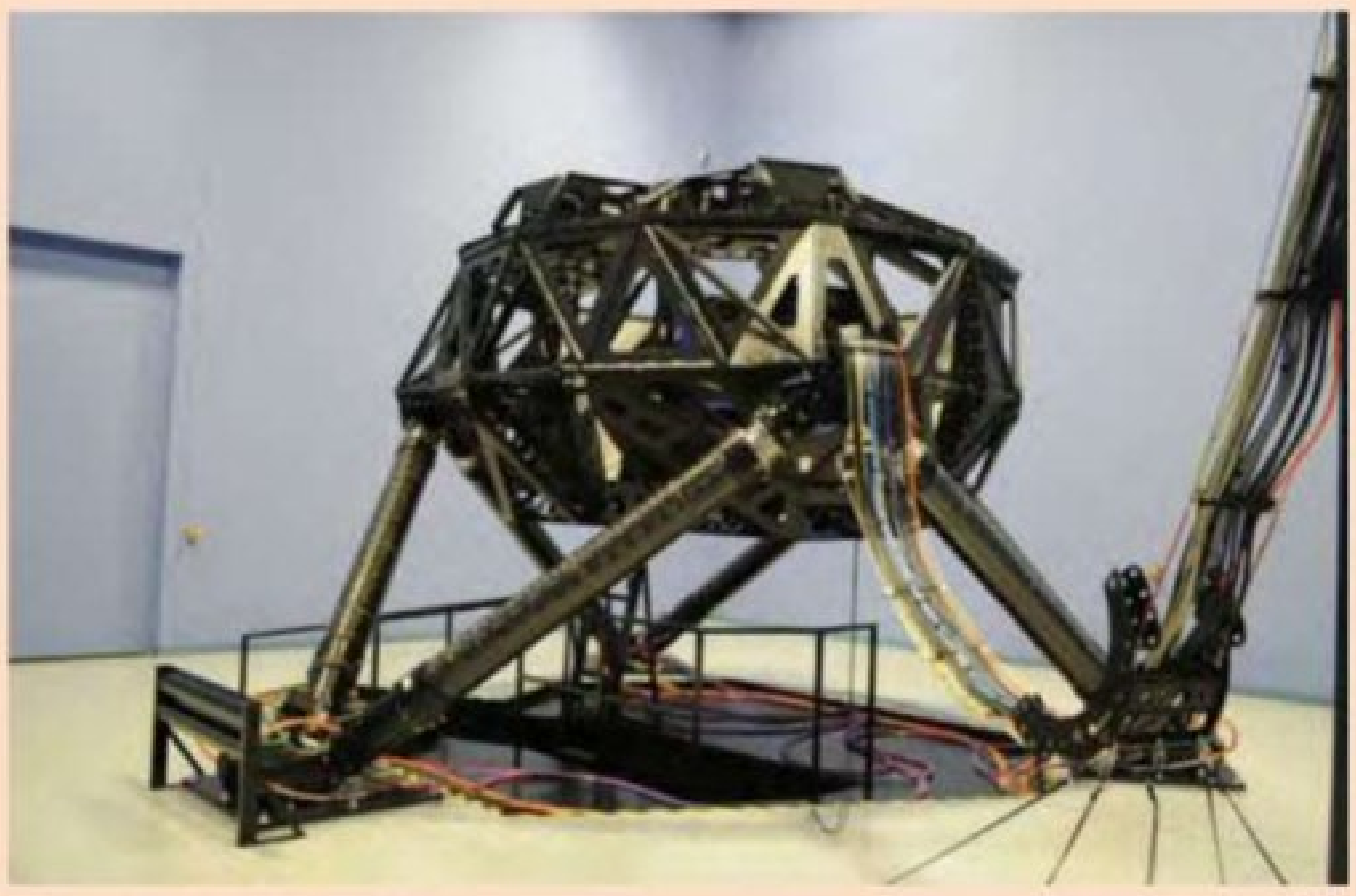
THE NEW DALLARA SIMULATOR

About a month before this year's Indy 500, Dallara began operation of a driving simulator with Moog motion platform at its factory on Main Street, Indianapolis. This is similar, apart from a few software updates, to the one installed in 2010 at the company's Varano de'Melegari, Italy headquarters. According to Vincent Grilli-Meunier, who is responsible for the Indianapolis simulator, there is at least one customer in the US who also wants to use the Varano-based one and it is important that they are almost the same.

The US simulator is, not surprisingly, aimed at use by the Indy Car teams and therefore has a DW-12 chassis mounted inside. The next development will be for it to be used by customers of the new Indy Lights IL-15. 'We want to allow customers to be able to drive the car before it is available to them,' says Grilli-Meunier.

The simulator consists of a 4-metre OD motion platform, the DW-12 cockpit with full driver controls, active seat belts, 180-degree video screen, Dolby surround audio system and sound and heat generators. Sixty-inch struts move the platform to simulate on-track motion based on laser scan tack profile and vehicle model inputs. The motion, audio and video are all controlled by Dallara-developed software. Because high lateral g forces need to be replicated, the platform needs to be able to move a considerable distance. The Indianapolis simulator is limited to 2g peak acceleration.

A public launch of the facility, with about 250 guests, took place on the Thursday before this year's Indianapolis 500. Andrea Toso, Dallara's head of research and development and US racing business, was also presented with the 48th annual BorgWarner Louis Schwitzer Award for the simulator. Presented by the SAE, this recognises individuals for innovation and engineering excellence in race car design associated with the Indy 500.



Speaking at the launch, Gian Paolo Dallara, president and founder of his eponymous company, remarked; 'when you design a new car, you put into it all the knowledge gained on previous cars. Mr Cotman and Mr Andersen said they wanted it "nice but cheap"!'

Andersen reckons that Dallara has achieved this aim. 'It is clear to me that they can build both beauty and quality into their cars while keeping the costs in line.'

Cotman says that what was wanted was something 'lighter, faster and sexier. Dallara listened to what we wanted.' He also says that in designing the IL-15, much was learnt from accidents that have occurred with the DW-12.

Although this is the first time that his company has worked with Andersen Promotions, Dallara sees the IL-15 as possibly just one more step along the road to Indy Car domination. He dropped a large hint when he then said, 'It is important for us to do the whole chain [of formulae]. If you want a smaller car, Mr Andersen, we are ready to do it.'

There are rumours that the bottom two rungs of the Mazda Road to Indy ladder, USF2000 and Star Mazda, could be combined and there is no doubt that this is business Dallara covets. 'If the relationship is good, I think [Andersen] will consider our cars, we already make smaller ones,' adds Toso who obviously relishes his work in the US.

In trying to increase the relevance of Indy Lights and make the Mazda Road to Indy akin to a soccer league with promotion, Andersen Promotions will be awarding a three race Indy Car contract to the 2015 champion, which will include a drive in what will be the 100th Indianapolis 500. A world wide advertising campaign, advising would-be competitors of this, will shortly be underway.

The car shown at Indianapolis was merely a display vehicle, with the prototype scheduled for a shake down at Dallara's headquarters in Varano de'Melegari near Parma, Italy before testing later in the summer with GP2 driver Conor Daly and 2012 Indy Lights champion Tristan Vautier at Mid Ohio, the Indianapolis road course and the Milwaukee Mile before both drivers try it out on the full Indianapolis oval. 'We are also working on getting a couple of current Indy Car drivers (to test it in September),' adds Cotman.

AER-P63 ENGINE

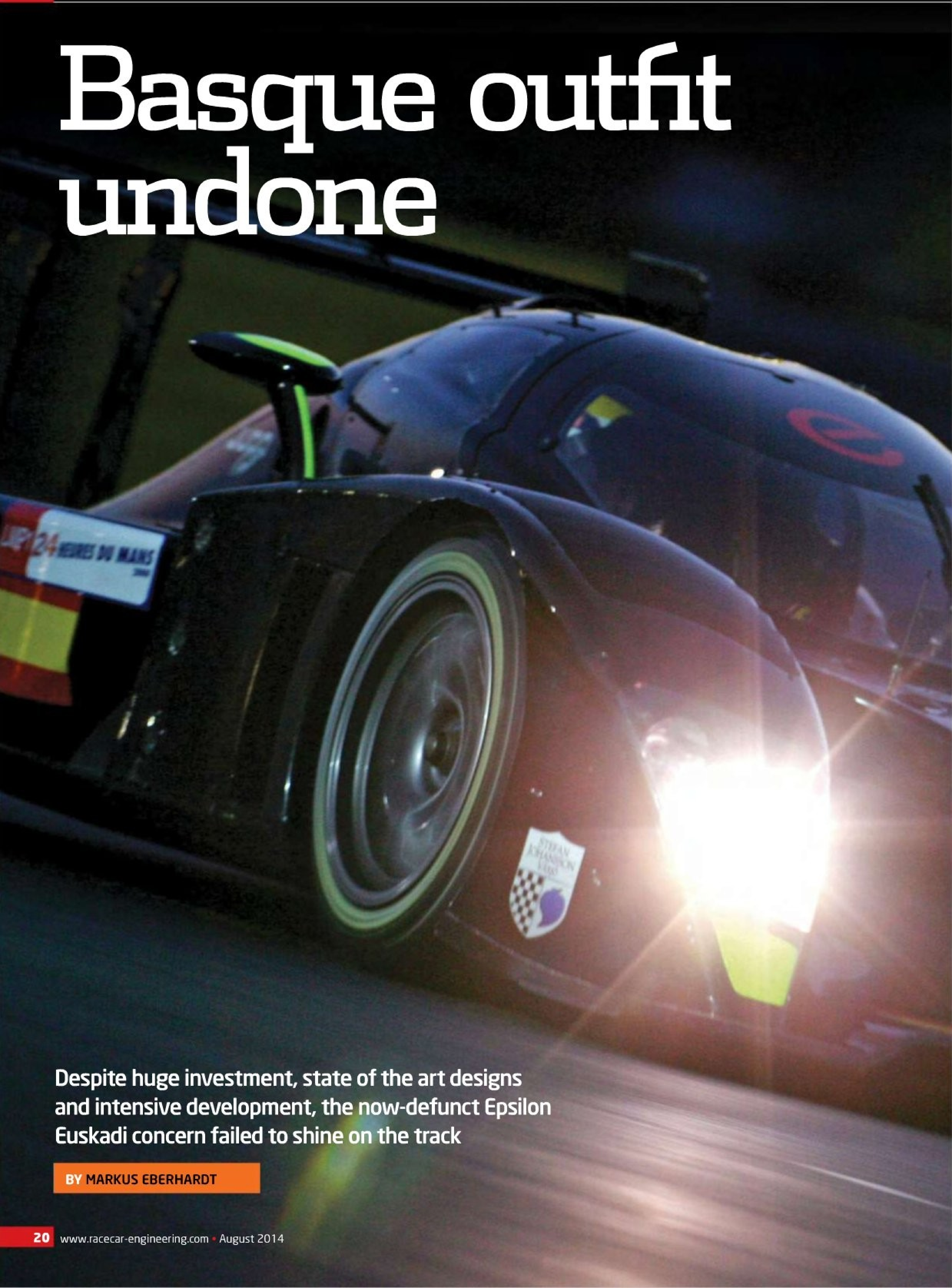
The engine chosen by Andersen Promotions meets, according to Dallara's Andrea Toso, a number of basic requirements. It is simple, proven, lightweight and low cost. Costs had to be comparable to the existing car.

The all-aluminium fully-stressed (although braces alongside the engine to join the front of the bell housing with the rear of the monocoque are being evaluated), 2.0-litre, turbocharged, four-cylinder unit from Basildon-based Advanced Engine Research, known as the AER-P63, is based on the efficient AER P-70 which was used in LMP2 with Mazda MZR-R badging. Its output is 450hp plus 50hp for push-to-pass. At 230 pounds dry-crated, it meets the criteria for lightness. Features include carbon plenum, carbon inlet runner and trumpets as well as drive-by-wire throttle control. The AER features Life Racing developed engine electronics with full active-knock control, ignition-angle learning, advanced boost control and integrated gear-shift strategies.

Supplying the power unit for a feeder series is nothing new to AER, for, as its managing director Mike Lancaster points out, it already produces engines for the Formula 1 feeder GP3 series. Lancaster also states that the P63 has been 'designed to be flexible for future changes and to be reliable and cost effective.'

The installation is said to make it easy to maintain. Its modern engine electronics combined with turbocharging mean that it is in line with current motor sport thinking as Formula One and various LMP prototypes upgrade to smaller, turbocharged engines. It also matches the trends of the road car manufacturers.

Basque outfit undone



Despite huge investment, state of the art designs and intensive development, the now-defunct Epsilon Euskadi concern failed to shine on the track

BY MARKUS EBERHARDT

In the 1990s Michael Lecomte founded a new Spanish motorsports team under the name of 'Epsilon'. It originally contested the new Nissan Open Telefonica Series, taking the title in the first year. Lecomte then got in contact with the Basque driver Ander Vilarino, gaining access to new sponsors and the goodwill of the local Basque authorities. In 2003 Lecomte founded a new company, Epsilon Euskadi, and moved to a new facility in 2004. Epsilon Euskadi was supported by the local authorities and created therefore a master's degree in conjunction with a local university to train young engineers. Ex-Benetton team manager Joan Villadelprat was hired as the company CEO, and Epsilon Euskadi entered the World Series by Renault.

His task was not easy...to be competitive against works teams like Audi and Peugeot

However, the company wanted to get more media coverage and decided to contest a higher level championship. It analysed the possibilities and found the best coverage to be in Formula 1, Indianapolis and Le Mans. Clearly an ambitious outfit, the team chose to compete in highest sportscar class, LMP1 not only as a team but as a constructor with its own design of car. The new prototype would also be made available to customers and put the Epsilon Euskadi name out there with well-known companies like Lola, Oreca or Pescarolo.

John Travis, who had already worked for Lola, Penske (PC-26,PC-27 and PC-27B) and for the stillborn Superfund Formula, was hired to design the new car with support by Epsilon Euskadi's small group of engineers and students of the Master's degree course at the local University. His task was not easy, he had to develop a sports prototype which should be competitive against works teams like Audi and Peugeot on a fraction of their budget.

One advantage Travis did have was time. Starting from a clean sheet of paper, the schedule had the car down to run in early 2007. A few of the main elements of the design were soon fixed such as the use of the Judd 5.5-litre GV engine and a coupe monocoque.

CLOSED CAR CONCEPT

The coupe route was taken for two very simple reasons. Firstly, the regulations allowed a lower roll-hoop structure for a closed car, which offered the chance for a lower driver position. Secondly, the closed car produced less drag for the same downforce as a result of the better airflow over the cockpit canopy towards the rear wing.

An extensive CFD-program was run using STAR CCM to evaluate different bodywork with closed flanks, detached front pontoons and nose concepts (open or closed) as well as front splitters, rear wing designs and air scoop shapes.

Special attention was paid to manipulating the sidepod shape and putting scallops on, in the search for the best flow from the front diffuser out of the sides of the car and trying to get it back under the car to help to feed the rear diffuser.

In August 2006, the first wooden mock-up of the cockpit was built to enable the team to start work on the ergonomics. The original project plan had the final drawings fixed by the end of August, but this was delayed as Epsilon Euskadi started to also investigate an open top version of the design to be used in the LMP2 category

Travis eventually finalised his drawing work in January 2007. His final concept was an LMP1 with a closed front panel with a low pointed nose, a large two-step front splitter, detached front fenders, scalloped side pods, exhaust outlets on top of the rear panel, a small cockpit canopy with a NACA-duct in the roof as air intake for the engine. Travis preferred a low nose with a

These renderings show an early version of the EE1 LMP1 car. We can see a closed front bodywork, low nose, a front splitter raised in the middle in two sections, cooling intakes besides the cockpit, a different scoop on the roof, closed sidepods with one turning vane in the diffuser exit and top mounted exhaust outlets

large front diffuser and he felt that the car would not need the addition of dive-planes to be balanced for the high downforce circuits.

Travis and the Epsilon Euskadi team had spent a lot of time on developing the door concept along with special hinges, but they were outlawed. When the new Peugeot 908 HDI FAP was revealed with three shuttered radiators in the sidepods for oil and water cooling and for the intercooler, the Euskadi team was outraged. The oil cooler was located in an area where the door templates cut through the monocoque and the bodywork. This was the solution Travis had designed. He immediately asked the ACO why this solution was now legal and was told that the ACO had rethought their own requirements and had come to the conclusion that the Peugeot solution is now legal.

This decision caused the delay of the build of the first wind tunnel model. The new rule interpretation allowed a larger flexibilty in design of the sidepods. So the cooling layout could be changed and that influenced the whole aerodynamic concept.

Travis finished his drawing work on the new design in July 2007 and Fondmetal started to build the wind tunnel model.

These renderings display John Travis' final version before the Peugeot 908 appeared. We see still a strong resemblance to the version in the pictures above but the front fenders are now open at the rear and the sidepods are scalloped at the underside of the leading edge to create a larger front diffuser exit area. Note also the small NACA-duct in the engine cover. This was later changed to serve the engine with more air

The new concept had a different front splitter concept, supported by two pylons on a very narrow and now raised nose. The cooling air was directed through the suspension to the intakes in the sidepods. The front suspension was covered by fairings and the engine cover showed an air scoop for the engine.

TWO-SECTION MONOCOQUE

The chassis of the car, which was now called the EE1, was formed of a narrow Nomex honeycomb monocoque with carbon fibre skins. The monocoque was made of two main parts; the cabin and a front suspension box which was bonded in. Internally, it had two boxes below the doors, a dash bulkhead and a seat back/fuel tank bulkhead. The patterns were designed by Italian firm Nisci while the manufacture of the pattern and the monocoque as well as the bodywork was done by Camattini.

The engine oil tank was moulded into the rear bulkhead of the chassis and the underside had special pockets for the attachment of ballast. With the ballast mounted in front of the driver it was possible to switch the weight distribution forward. The monocoque was a stiff part with a torsional rigidity of 40,000 NM/degree and a weight of 80kg.

When the new Peugeot 908 was revealed the Euskadi team was outraged

The Judd V10 engine produced 630 bhp at 7.000 rpm and weighed 130kg. It was attached to the monocoque as a fully stressed member and connected to the six-speed transverse gearbox via a carbon-fibre bellhousing with a 3-plate AP clutch inside. The transverse gearbox had initially been designed by Alan Tagg of the Austrian company Pankl.

The Pankl gearbox featured a cast aluminium oil case and a full carbon fibre case with titanium inserts similar to the gearbox layout used inside the BAR Formula1 car. But as Pankl withdrew from the gearbox market, the team found a new supplier. Ricardo, which supplied gearboxes for the Audi team's LMP cars, then adopted the Pankl design and manufactured the gearbox, though with a magnesium casing in favour of the carbon fibre layout. The whole unit weighed 55kg and a carbon fibre structure was attached to the rear of the gearbox to carry the support for the rear wing.

The suspension uprights were made of cast titanium manufactured by CRP. Double steel wishbones were used front and rear with spring/damper units activated via pushrods and rockers. The pushrods inserted into the uprights and not onto the wishbone for reduced loads. At the front, the spring/dampers were located vertically double shear inside the suspension box in front of the monocoque's footbox. This layout was also chosen in favour of keeping everything as low a possible. For this the Eibach coil springs were also mounted concentrically over the Penske dampers, but 50-60mm lower compared to a conventional coilover arrangement. At the rear the spring/damper units were arranged inside the bellhousing angled downwards at the same

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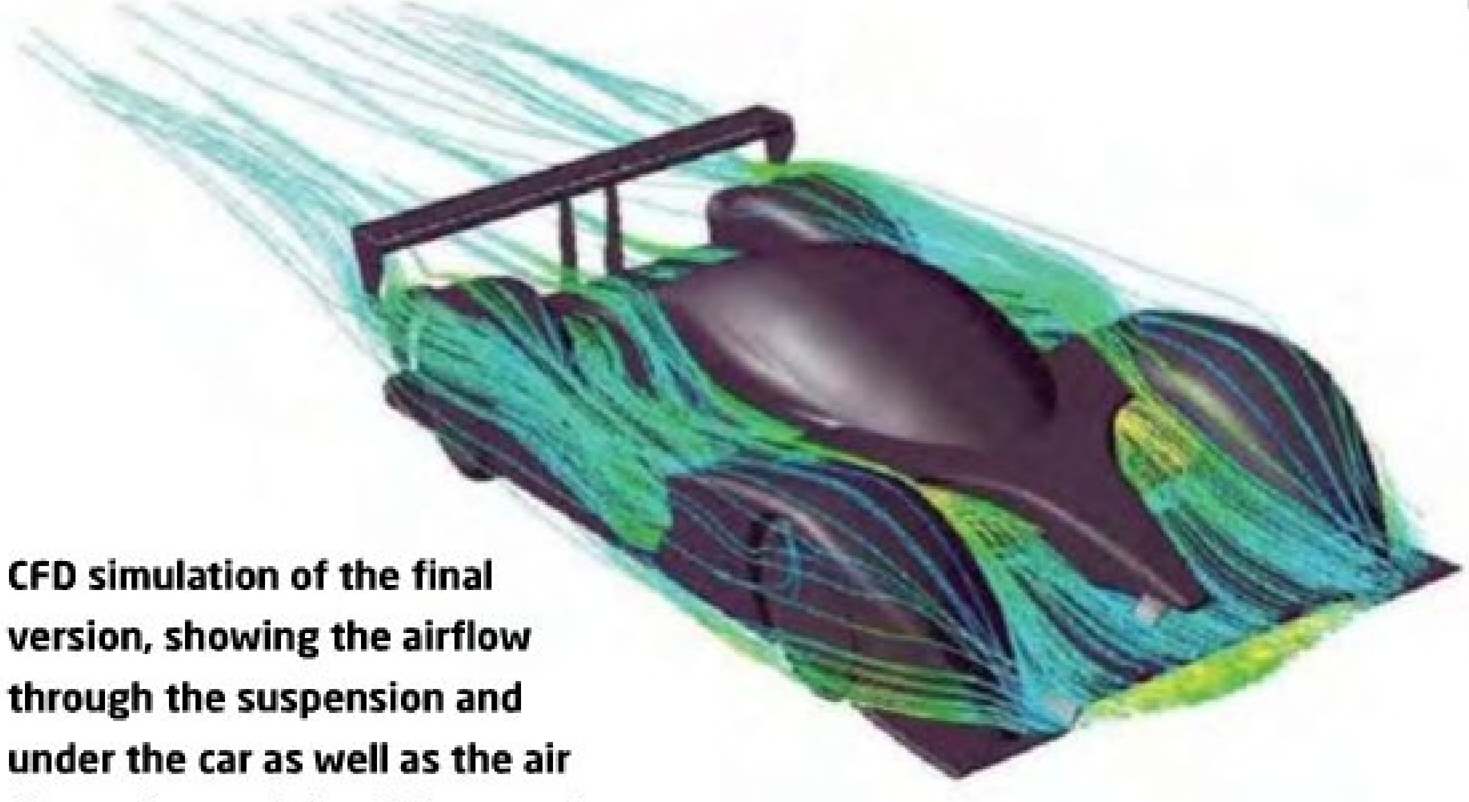
This rendering shows the final EE1 layout with a small high nose, open front bodywork with wheel fairings with the air directed to the cooling intakes via the suspension, lower scalloped sidepods and a new scoop on the engine cover



CFD simulation of the final version, showing the airflow through the suspension and under the car as well as the air directed out of the diffuser exit and over the bodywork

The 40 per cent wind tunnel model in the Aerolab wind tunnel. The rear fender is not connected to the diffuser, unlike the carbon render above

This wind tunnel model shows louvred panels on the front wheel fairings. But more interesting are the different valance panels. We see the same wheel fairings as in the model above but then we have a small valance panel above the wheel fairings and a second pair connected to the sidepods directly above the cooling intake. This arrangement shows similarities to the Peugeot 908 version

angle as the front plate of the gearbox. A transverse third element, comprised of a bump rubber in a canister which linked the rockers together, was added front and rear to control the ride height, and created a roll-free third spring. A brake setup of Brembo carbon discs with six-piston calipers was used and they were mounted as low as allowed by the uprights. BBS wheels with Michelin tyres completed the suspension system.

Cooling was made by two Marston water-to-air radiators and heat exchangers located in sidepods inside a carbon-fibre ducting structure. The position allowed short pipes and a concentration of mass near the centre of the car. The intake was located in the front of the sidepods above the scallop of the diffuser exit. The route of the hot air out of the car was split with a louvred outlet in the sidepods and an exit in the rear of the car. Brake ducts were moulded on the inner side of the wheel arch with separate ducts on the uprights. The brake discs were enveloped by shrouds. At the rear brake cooling was made by two NACA ducts in the rear panel with carbon fibre ducts routed to the brake ducts.

A twin element rear wing was attached at maximum height with central supports and large endplates connected to the bodywork with two small flip-ups. The front diffuser had a simple layout with three main sections and two strakes. Adjustments for more downforce could be made by ride height changes, more rear wing, a gurney flap on the rear tail and the increase of the front diffuser strakes up to six.

In total, the EE1 had 600 hours in the wind tunnel

Just as the construction of the first EE1 was reaching its final stages in late December 2007 Travis left the team in order to design a new A1 GP car. Sergio Rinland, who had recently joined the team, had to assume the responsibilities for the project. Rinland took over the design of the LMP1 car, which was by then nearly 90 per cent finished. In total, the EE1 had 600 hours in the wind tunnel with roughly the same amount of CFD time.

TEETHING TROUBLES

With first car built, the team had high expectations and ambitious plans to be the best of the petrol powered cars in the LMP1 class that season. The car's weight was very low, at 825kg, allowing the use of 80kg ballast under the monocoque. The first shakedown of the Epsilon Euskadi EE-1 LMP1 was made on the airfield of the Victoria airport in Spain on 28th February 2008.

The car's first run at Paul Ricard in March proved somewhat more problematic. Starter motor and electronic sensor troubles affected running during a two day test. The all-black livery also showed up the lack of sponsors.

One month later the EE1 took part in its first race, a Le Mans Series round at Barcelona, but it had not done any more testing since the troubled session at Ricard. The EE1 qualified 17th, 4.9 seconds behind the pole sitting Peugeot 908. It was clear over the next few races that the car needed to improve, so Rinland started an aggressive development program. Shortly before Le Mans the team found a substitute for the role of a chief designer with Walter Biassati,

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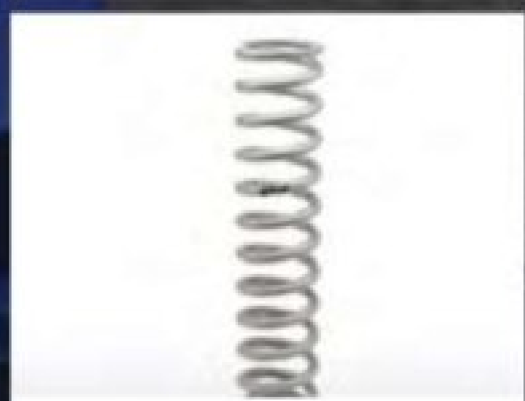

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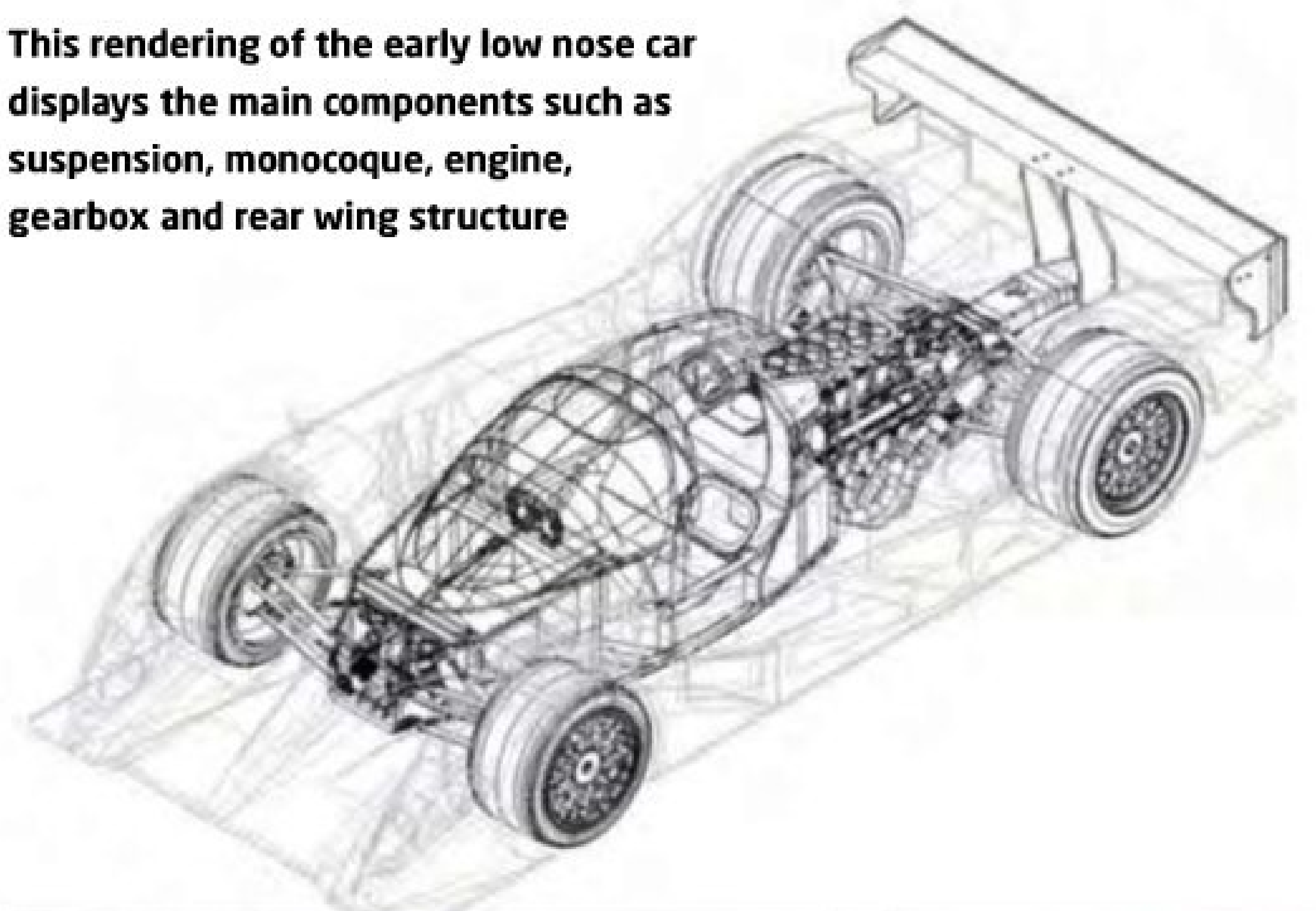
The monocoque of the EE1 car in the Ycom facilities



This rendering of the early low nose car displays the main components such as suspension, monocoque, engine, gearbox and rear wing structure

Colour coded view clarifies the individual bodywork panels of the refined high nose EE1. Note intake scoop replacing original NACA duct

The Judd V10 meets the monocoque. The bulkhead has a cut-out for the oil tank between the upper engine mounting points

additionally in June 2008 Franck Sanchez was engaged as head of the aerodynamic development while Henri Durand also joined the aero team.

At Le Mans, Epsilon Euskadi appeared with a two-car team and a revised EE1. The updated car featured new suspension geometry for improved traction and a new aerodynamic package which comprised rear wing, front splitter, changed louvres on the front and rear fenders, air intake, a revised flip-up on the trailing edge of the rear cover, brake ducts front and rear and front wheel fairings.

Internally, the bellhousing design, fuel tank, the cockpit and dashboard configuration, pedals and a few more minor items were all slightly revised too. Despite this, in qualifying both cars were well off the pace, although this is partly due to the fact that – compared to the front running diesels – the Judd engine was at least 100bhp down on power.

After Le Mans, where the gearbox failed on both cars, the team conducted some straight line tests to check the aerodynamics and work on the adjustments. At the Nurburgring, the car showed better performance in fast turns, but the car was still four seconds off front-running pace.

Despite late-season improvements, the team finished last in the championship, and had clearly failed in their ambitious plans. The car lacked testing time, which was partly a result of running out of time due to the door-related redesign, a lack of money, customers and sponsors.

Rinland designed a new car for 2009. 'The biggest disadvantage was the unreliability due to compromises taken on the design mainly of the gearbox and also the fuel tank, among other things,' he said. 'The serviceability was too compromised for an endurance car, making the work of the mechanics too hard for no reason. The drag was low as we were always within the fastest cars on the straights, but the car was initially not very efficient.'

SIMPLIFIED STRUCTURE

The main targets for the new car were an improved aero efficiency and improved reliability and serviceability. The shape of the new monocoque was nearly the same, but it was a simpler structure made all in one piece. Weight was reduced by 10kg to 70kg with an improved torsional rigidity by 9 per cent to 49.050 NM/degree.

The gearbox was replaced by a simpler 6-speed Xtrac gearbox with an aluminium case. The carbon fibre bellhousing was also gone, replaced by a more conventional aluminium case. 'The Pankl concept was loosely adopted, but a few very important aspects were ignored, making it too unreliable for endurance racing,' Rinland explains. 'Normally you do a carbon fibre bellhousing for weight and rigidity, but in this case the second characteristic was missing, making it again unreliable for endurance racing.'

The suspension layout was also changed for a better accessibility. New geometry was introduced with double steel wishbones and new Metal-Matrix-Compound (MMC)-uprights manufactured by Pankl. The spring/damper units at front were located horizontally and transverse to the centre line on top of the pedal box, while at the rear they were housed longitudinally on top of the gearbox. Pushrods actuated the units via rockers front and rear.

The design team also adopted Penske J-Dampers. A dual flywheel system was mounted inside a damper housing operated by a rack and pinion. The damper housing was mounted transversely connecting the suspension rockers. The sense of this system was then a force (the up or down movements of the wheels) which was applied to endpoints of this device. The flywheels accelerate to produce an opposite and equal force.

Even with the narrow wing mandated by regulations, the EE2 had more downforce than the EE1, and lifted the L/D figure from 3.23 up to 4.3:1. The car produced 2,156.97kg downforce at 200mph (Cz = 3.00) with an estimated frontal area of 1,80m².

'It would be easier to explain what we left as a carryover from EE1 to EE2 the car was so different,' Rinland reveals.

The 40 per cent wind tunnel model of the EE2 in the Aerolab tunnel. Obvious changes are the new rear brake scoops on the rear fender and the much more scalloped sidepods

'We left the shape of the roof, the windscreen and the side windows of the doors up to a point. Everything else was completely new.' The Epsilon Euskadi EE2 used a curvy splitter similar to the unit used by Acura with a structure at the outer edge similar to solutions on the end-plates of Formula 1 front wings. The underbody was fitted with between 2 and 6 strakes depending on the circuit requirements. The lower wishbones were attached at the raised nose of the monocoque without the use of keels. The whole tail was shortened so that the new narrower twin-element rear wing with new end plates and also new central supports overlapped the tail.

TECH SPECS

Epsilon Euskadi EE1 dimensions

Length: 4645mm
Width: 2000 mm
Height: 963mm
Wheelbase: 2980mm
Weight: 825kg ballasted up to 900 kg
Front Track: 1684mm
Rear Track: 1571mm

Epsilon Euskadi EE2 dimensions

Length: 4645mm
Width: 2000mm
Wheelbase: 2980mm
Weight: 767kg ballasted up to 900kg
Front overhang: 918mm
Rear overhang: 603mm
Front ride height: 45mm
Rear ride height: 77mm

Epsilon Euskadi F1 project:

Length: 5040mm
Width: 1800mm
Wheelbase: 3240mm
Front overhang: 1200mm
Rear overhang: 800mm
Front ride height: 33mm
Rear ride height: 75mm

HYBRID RESEARCH

The whole EE2 concept appeared more modern and advanced and more aggressive compared to the EE1. The weight was further reduced by seven per cent which was near the LMP2 minimum weight, with a fantastic balance of 48 per cent at the front and 52 per cent at the rear. Sadly Epsilon Euskadi stopped the whole project before it was complete due to a lack of money.

In 2009 the team worked on hybrid studies for the EE2 in conjunction with students of the Cranfield University and METCA. Three different hybrid layouts were evaluated. The first and most efficient was the use of flywheel based system which should be mounted behind the V10 and above the gearbox. It should significantly reduce the fuel consumption and save six fuel stops at Le Mans.

The second system used capacitor storage which required a large power pack inside the monocoque and a redesign of the bellhousing for the motor generator unit. That was also necessary with the use of lithium batteries located under the monocoque. This solution had the best weight distribution but not so good track performance.

The final layout which was chosen for the EE2 was a front axle KERS system with either a flywheel or an electric motor system. The power of the electric motor was at 60KW (78 bhp), which was then standard.

Epsilon Euskadi could not get the necessary money together to build and run the car. The financial crisis hit racing hard, and the company folded.

F1 – WHAT MIGHT HAVE BEEN

Joan Villadelprat and his team decided to take another route to be part of top motorsports and felt able to get the funding needed for their plans. The team applied for an entry into Formula 1.

In April 2010 news the news broke in the press that Epsilon Euskadi already had a scale model in the wind tunnel to be prepared for 2011 season. People did not believe it and a lack of photographic evidence of a design made many believe that it was just spin. But it was not a joke or spin, Rinland and his team had really developed an F1 car and the half scale model had undergone extensive testing. The results showed a highly advanced car featuring a very high nose with turning vanes underneath, very scalloped sidepods, a low rear end with double diffuser and a fin on the engine cover.

But at this time Epsilon Euskadi had major problems, the whole factory and team was nearly completely financed by the Basque regional government which wanted to establish Spanish technology parks in the region. But in 2009 the political scene changed and the the new local government tried to stop the payments to Epsilon Euskadi. One year later attempts became reality. Villadelprat wasn't able to get any further money from the Spanish government and attempts to get funding from the middle east also failed. In 2011 Epsilon Euskadi went into administration. What was left – besides an empty high class motorsports facility, complete with its own wind tunnel – were two fully developed projects which sadly never made it. 'It was unbelievable. So much work for absolutely nothing,' says Rinland ruefully.

Today, with the world market still recovering from a financial crisis, the F1 car is a case of what might have been. However Rinland is still developing projects for racing, and will likely return with another highly advanced design sooner rather than later.

The pictures above show the stillborn 2011 Epsilon Euskadi F1 car in the wind tunnel. Compared to contemporary Virgin and HRT cars, this represents a much more advanced design

Russian evolution

Lada entered the World Touring Car Championship as a privateer in 2008, but the company took an interest and it is now a full factory effort

BY ANDREW COTTON

Much was made of Lada's entry into the World Touring Car Championship as a privateer programme, led by Viktor Shapovalov under the Russian Bears Racing programme in 2008. It was, said Shapovalov, an attempt to entice the factory to take an interest, but with the financial crisis interest from the mother company was low, and the programme finished after a brief foray in 2009.

With changes of management support for the WTCC programme came and went, but in 2012, Lada decided to return, and in a big way with extended talks to build a circuit around the Togliatti factory in Russia in addition to the racing programme.

Although the circuit didn't happen (there is a Rallycross track there instead), the company started to back the racing project, maintaining links with former British champion James Thompson who drove the car in 2009 and this year has linked up with Rob Huff and Russian driver Mikhail Kozlovskiy.

The base car is the Lada Granta, not the most suitable car for the Championship but one that next year will be replaced by the new Vesta, and the team is expecting a big improvement. The Vesta is designed by ex-Mercedes designer Steve Mattin, who was also responsible for the Volvo S60 concept, on a new platform that will be lighter, wider, and will be unveiled at the Moscow Motor Show at the end of August. 'Lada and Renault will present new models and now it looks like everyone is interested in motorsport,' said Shapovalov after the Moscow race in June.

Development of the Granta was hampered, as with Honda and Chevrolet, by the timing of the change in regulations. Citroën's entry was dependent on the regs being brought forward by a year, although design work couldn't start until mid-season, 2013. This compromised not only the 2013 Lada, but also the 2014. A hurried visit to Lada's full-scale wind tunnel facility to develop and homologate an aero package meant the team took a gamble and, aerodynamically, lost.

> **"It is a very small car. It is difficult to find a place for everything inside it"**

'It is difficult to develop something strong in these circumstances,' said Shapovalov. 'This Granta model is not so good for racing. Everything except the engine is designed and developed in Russia, but we didn't have much time to design everything. We will not stop developing this car, but maybe now won't put so much effort into it. This is a one-year car. This car is not the same proportion as everyone else, so the aerodynamics was the worst subject. It is also a very small car, it is difficult to find a place for everything inside.'

While the team struggled to adapt to the new regulations in 2014, which stipulated that the cars had to be lower, wider and more powerful, while also running on bigger wheels, the main issue for the team was that the base model of Granta was not suitable for racing. The

Narrow base platform doesn't help with the new regulations of wheelarch extensions

base model is too narrow, which means that the lengthened parts are so long that flexing is a big issue. One of the big problems for the drivers is that the steering rack is taken from a Renault production car, and often needs to be changed as it bends and locks in high speed corners.

IMPROVEMENTS FOR 2015

Shapovalov admits that the car is too narrow. 'The suspension is totally different to the others,' says the Russian. 'Our base car doesn't have subframes, for example. Of course this was difficult, but suspension is not the main problem today. The main problem is the speed and the proportion of the car. Weight as well, but it is not so dramatic. The full view of the car is the main problem. If you want to develop something aerodynamic, we don't have the top speed. The problem is traction, not enough speed, not enough grip because everything flexes in a small car. It is a very short car, and in the past the car that has a very short wheelbase never was so fast.'

This compromise design is a temporary measure. Next year, the team will work with French constructors ORECA on the new Vesta, which has a base model sized somewhere between the Citroën and the Chevrolet Cruze. ORECA, which developed the diesel SEAT, has produced a 1.6-litre, four-cylinder turbo engine for the Granta and will undertake a full development programme in 2015. Lada will make use of ORECA's design team, and CFD facilities, and expects the programme to make a step change forward in the next six months as it plans to tackle the might of Honda and Citroën in the championship.

Cockpit view shows structural and control details of the 2014 Granta

TECH SPEC

Body
Type of body: sedan, with in-welded safety body shell
Number of doors: 4

Weight and dimensions
Length: 4479mm
Width: 1950mm
Wheelbase: 2556mm
Minimum weight: 1100 kg (including driver)

Engine: Global Engine LADA
Displacement volume (l): 1. 6
Top power, HP/rpm: 380
Max torque, Nm/rpm: 440/3500-4000

Bore: 83,05mm

Stroke: 73,7 mm

Compression ratio: 12,5:1

Controlling system: Magneti Marelli

Transmission
Gearbox: Hewland; 6-speed, cam, sequential gearbox
Transmission: Front-wheel drive
Clutch: 2 disc carbon clutch "AP Racing"**Wheel differential**: increased friction

Chassis
Front and rear suspension: McPherson, cylindrical springs, KW adjustable gas shock absorbers; adjustable stabilizer
Steering: Hydro power steering

Brake System: Dual, without a booster, with adjustable brake "front/rear" effort
Front brake caliper: 4-piston, "AP Racing"
Front brake discs: Ventilated, 378.5 mm in diameter
Rear brake caliper: 2-piston, "AP Racing"
Rear brake discs: Ventilated, 280 mm in diameter

Wheels: All aluminium, forged
Dimensions: 10x18

JAMES THOMPSON'S VIEWPOINT

'First of all we have to get some continuity between the cars, all three cars are different and parts won't fit from one to the other without some modification, so that has to be changed. If we could overlay the information we could move forward faster.

Mechanically the car is not too bad. You are talking about a 7000 Euro base car. We are confident for the future with the evolution of Lada road cars and for now, we are making the best of what we have with what is available to us. Fundamentally, the car is poor aerodynamically which now, in an aerodynamic formula, is a box that we haven't ticked. The car is also very heavy. You have to address those two fundamental aspects of the championship; you need the ability to lose the weight when you are given the opportunity, and we need a good balance between drag and downforce.

Unfortunately we have high drag, but I think that the fact that the car is so narrow and given that we had to extend the car widthwise, it would be very difficult to get the aero efficiency that we need. The two things, aero and weight can be fixed, that bit is not the problem. We know what we need to do, but the timescale this year there is no way to do it. We have entered into this Championship, we are at the back of the grid, but if we could address the weight and the aero, we won't be far away.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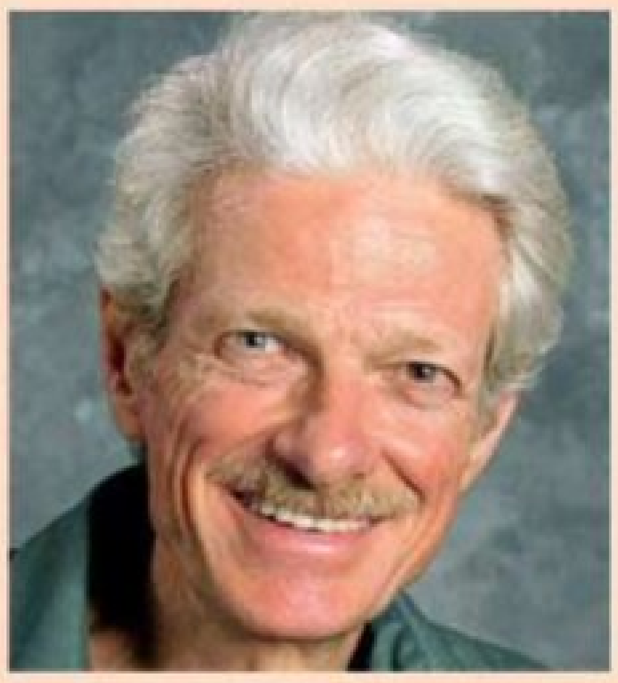

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Third spring configurations

Understanding interconnective suspension principles

QUESTION

What are the differences in the characteristics of a third spring that is actuated by swaybar movement, one that is actuated by a pivoting T bar type swaybar, and one that is hydraulically actuated? I have given it a bit of thought, but don't have it fully defined. I think hydraulic actuation with linked hydraulics would fight a swaybar...I would like the thoughts of a real expert on the subject.

THE CONSULTANT SAYS

I always remind people that the tyres have no eyes, and only respond to the forces they are subjected to. They don't know or care what the suspension system looks like. Often, the specifics of a particular design or setup count for more than the general conceptual nature of the layout.

That said, there are certain possibilities and limitations governing the forces generated with different types of layout.

Some readers may not know what a third spring is. It is a spring that acts on both wheels of a front or rear pair together. It acts only in ride, and not in roll. It is generally only found in cars with ample downforce. However, it has some other possible uses as well.

T-bar and pushrod connection setup in use on an Oreca 03R LMP2

To begin with, it might be a good idea to review the modes of suspension movement. A front or rear suspension system, or half-car, is described as having two modes:

1. **Ride: synchronous motion of the two wheels; both moving together**
2. **Roll: oppositional motion of the two wheels; wheels moving opposite directions**

Any possible displacement of the wheel pair can be expressed as a ride displacement and a roll displacement.

A four-wheel system, or full car, has four modes:

1. **Heave: synchronous motion of all four wheels; synchronous ride at both ends**
2. **Pitch: oppositional motion of front and rear; oppositional ride at both ends**
3. **Roll: oppositional motion of right and left; synchronous roll at both ends**
4. **Warp: oppositional motion of diagonal wheel pairs; oppositional roll at both ends**

Any possible displacement of the full car system can be resolved into some amounts of heave, pitch, roll, and warp.

The car will have a definable pound per inch (or N/mm) rate at the wheel (wheel rate) in each of the four modes. These rates will vary somewhat as the suspension moves. For some purposes, it may be desirable to have some of them vary dramatically.

Any springing device that acts on two or more wheels can be considered an interconnective spring. Interconnective springs can be arranged to elastically resist synchronous motion of the wheels affected (to be an anti-synchronous springing device) or to elastically resist oppositional motion (to be an anti-oppositional springing device).

Springs that act on individual wheels elastically resist all four modes of movement.

Any interconnective suspension device that affects a wheel pair resists two modes, or in some cases just primarily two modes. Anti-roll bars (swaybars) resist roll and warp. Third springs resist pitch and heave.

CONNECTION OPTIONS

By interconnecting interconnective devices, it is possible to get elastic resistance to only one mode, or primarily only one mode.

Third springs normally take the form of a coilover acting on the top end of a T-bar style anti-roll bar in a pushrod and rocker suspension. The T-bar is a vertically mounted torsion bar with a transverse member across its top end. At its lower end, it is held so it can rock fore and aft, but not rotate or rock side to side. The T-bar is operated by a secondary set of pushrods from the rockers that operate the main coilovers. The bar rocks freely in ride, but is twisted in roll. The third coilover is attached in the middle, at the top of the torsion bar. It is displaced when the T-bar rocks, but not when it twists. It often has a rubber snubber, to give a steeply rising rate. Sometimes the snubber is the only spring. Sometimes dual-rate or rising-rate coil springs are used.

A hydraulic third spring generally acts on shaft-displaced fluid from the main shocks. It is essentially a common remote reservoir, with a stiff spring of some kind. This works fine. Things get a bit more difficult if we need to provide a motion ratio for the third spring different to the ratio for the individual wheel springs. If large forces are required, the pressures can get quite high, as a typical 5/8" shock shaft only provides about ¼ square inch of piston area.

I don't recall ever seeing a third spring on a passenger car-style anti-roll bar, but I can imagine ways to do that. One possibility is to add a third arm in the middle of the bar, and arrange a snubber or coilover to act on that. This puts the third spring in series with the two halves of the anti-roll bar, unlike more normal third spring setups, where the third spring and the a/r bar are in parallel.

It would also be possible to add a Z-bar (like an anti-roll bar but with one arm pointing forward and one pointing back), acting either on the anti-roll bar arms or directly on the control arms or axle. It would be possible to use a "swing spring": a transverse leaf spring mounted so it can pivot in the middle. This could also act either on the anti-roll bar arms or directly on the control arms or axle.

Conventional third spring systems are being superseded by advanced systems like this one on the Porsche 919. Details are as yet undisclosed

RESISTING ROLL

We can get any instantaneous wheel rates in the four modes that we want, using only individual wheel springs and either anti-roll bars or third springs. Why use both anti-roll bars and third springs at once? Why use one device that acts in roll and warp, and another that acts in pitch and heave, when we already have individual wheel springs that act in all four modes? The answer is that we may want different rates of rate change in the various modes. Spring rate, or wheel rate, is the first derivative of force with respect to displacement. The rate of change of that is the second derivative of force with respect to displacement. We may want to tailor that differently for the different modes.

When high downforce winged race cars first appeared, it became desirable to arrange for the suspension to stiffen as it compressed. Designers first tried arranging for increasing wheel rate from the individual wheel springs. This had the disadvantage that the car's elastic roll resistance distribution became highly pitch-sensitive. Third springs afford a way to get a steeply rising wheel rate in pitch and heave, without having the same in roll.

The biggest benefit of hydraulic interconnection is the ease of connecting front and rear wheels

Does a hydraulic third spring not only not resist roll but actually create a pro-roll effect? Generally, no. It would actually be more likely for such an effect to occur with a coilover acting on a T-bar. If the coilover attaches at a significant distance from the centre of the torsion bar, it could have an over-centre spring effect that would actually try to add roll displacement once some roll displacement occurred. There would also be bending loads on the torsion bar. There would have to be some means of laterally constraining it at its top end, while still letting it move fore and aft. I'm not suggesting there would be any reason to want to do this.

This seems to suggest that anti-synchronous spring devices promote roll, rather than merely not resisting it. If the device pushes the inside wheel down when the outside one comes up, won't it actually add roll? It doesn't. It just freely permits roll, while holding the car up.

For passenger cars and trucks that carry large fuel loads, it is desirable to have overload springs, usually at the rear, that act only in ride. If the overload springs act also in roll, rear roll resistance increases as the rear gets heavier and the springing gets stiffer. This aggravates the tendency for the added weight at the rear to generate oversteer.

The most common way to add ride rate without adding roll rate is a set of air shocks that fill from a common valve. However, metal or composite springs that act only in ride and have a rising rate offer considerable potential for rear suspensions of trucks and cars – especially front-drive sedans, which today commonly use rising-rate individual wheel springs.

Hydraulic interconnection of the shocks at one end of the car is okay, but the biggest benefit of hydraulic interconnection is the ease of interconnecting wheels that are far apart, particularly front and rear wheels. It's possible to interconnect front and rear third shocks hydraulically. If both the shocks compress when the suspension compresses, it affords greater stiffness in heave than in pitch. If one of the two shocks is a "puller", the interconnection can provide greater stiffness in pitch than in heave. If we connect a pusher shock at one corner of the car to a puller shock at the diagonally opposite corner, we resist roll and pitch without resisting heave and warp. If we hydraulically interconnect anti-roll bars, we can resist roll while achieving soft suspension in warp.

By pursuing the various possibilities, it becomes apparent that we could just have hydraulic cylinders or rams at each wheel, and connect all of these to a single central module that contains various springing and damping devices.

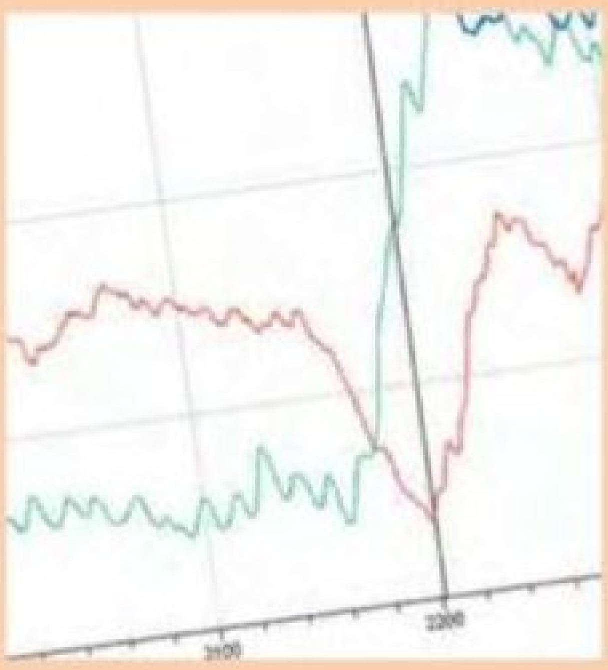
ELIMINATING SPRINGS

Kinetic, in Australia, have worked extensively on warp-soft interconnected suspension, and have obtained many patents in this field. They have worked with the University of Western Australia to produce a series of very successful, albeit complex and expensive, Formula SAE cars.

They have successfully used just "third springs" and anti-roll bars, omitting the individual wheel springs. What's more, the system only has one anti-roll bar!

The two most recent UWA FSAE cars have used a cost-reduced warp-soft suspension. The simplified system uses beam axles front and rear, connected by an unsprung composite undertray that is stiff in bending but torsionally flexible. The undertray incorporates tunnels for aerodynamic downforce. The resulting channel sections provide the desired combination of beam stiffness and torsional flexibility.

The front and rear ends of the car are held up by swinging composite leaf springs. There is a damper at each corner, with no spring. An anti-roll bar behind the driver attaches to the undertray in the middle of the car. This provides all the elastic roll resistance. Sufficient adjustment of distribution is achieved by moving the attachment points for the anti-roll bar links on the undertray fore and aft.



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

Pressurised conditions

Monitoring turbo data to improve efficiency and avoid meltdowns

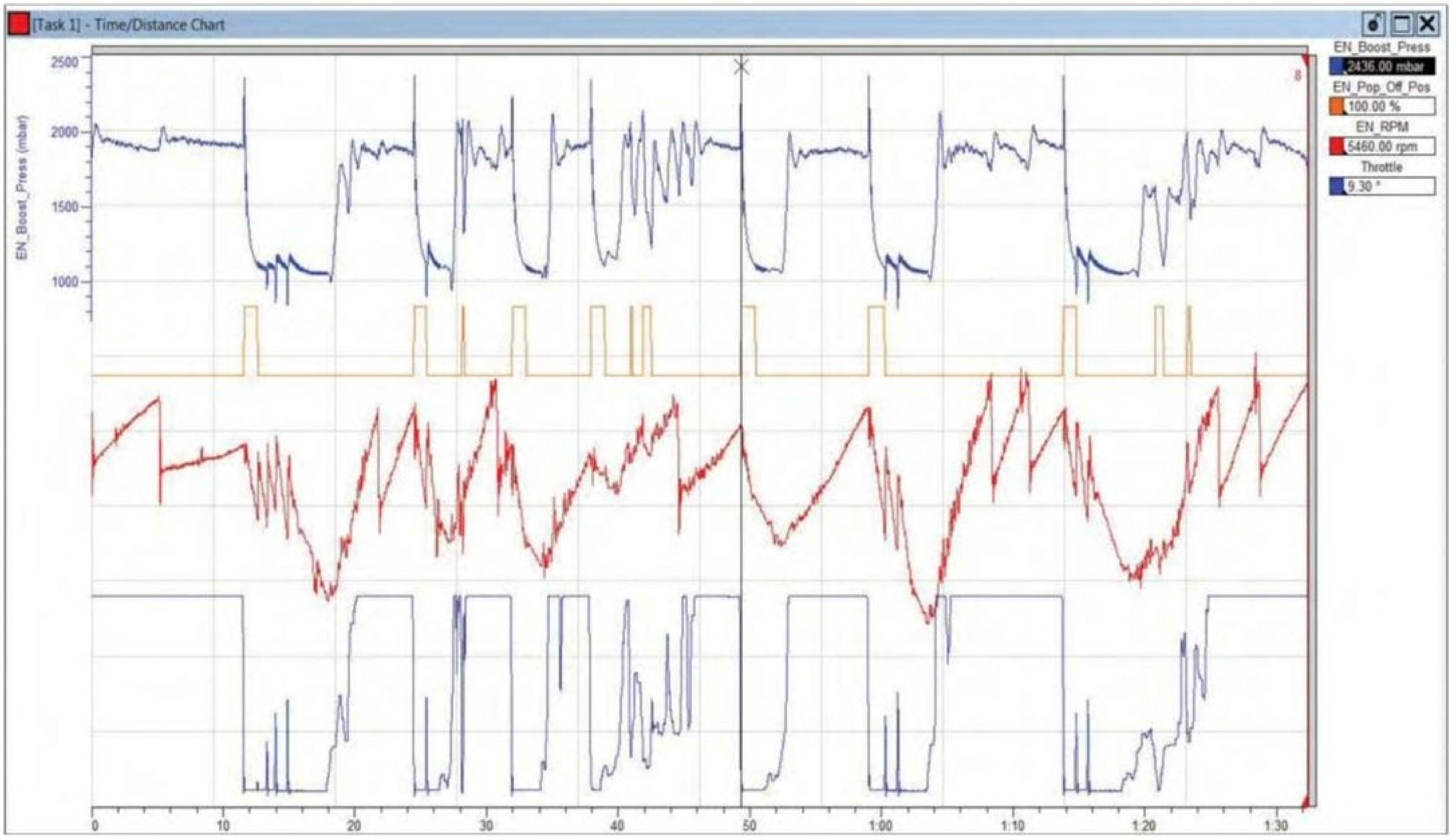
This year's Le Mans 24 hour race turned out to be a classic reliability vs speed affair with Audi prevailing as the most reliable LMP1 car on the grid. Their car wasn't the fastest but it won the race. You could even say it wasn't that reliable either, both cars suffered what would normally would have been classed as a race-ending catastrophe and at the very least should have ended all hope of a podium. In Audi's case, though, they simply opened their playbook on the turbo-swap page, got their special team ready and before the spectators had finished their drink of choice the car was back out on the track and very much in contention.

The role of the turbocharger in an engine application is to provide large volume of air at elevated pressure to the engine in order to increase the ultimate power output. Without going into to specific details about the functionality of a turbocharger we essentially have a turbine driven by the exhaust gasses which in turn spins a compressor that forces air into the inlet manifold of the engine. Normally a wastegate or pop-off valve controls the boost pressure, but varying the angle of the vanes in the compressor can also be used to control the boost a bit more accurately.

ESSENTIAL VARIABLES

In terms of monitoring and controlling a turbine, the boost pressure is the key variable. This value tells us the most about the state of the turbocharger. Additional values of interest are, amongst others, the speed at which the turbocharger is spinning, exhaust gas temperature at various locations, and wastegate actuator position. In general, monitoring anything on that side of the engine is difficult due to excessive heat and pressure, so in many instances it is not possible to measure all the values that we would like. However, armed with the rpm of the engine, boost pressure and throttle position we should be able to tell whether the turbocharger is working properly or not. In the example below, we can see the correlation between the three values as well as how the pop-off valve is used to release the pressure when the

Basic data for boost, pop-off valve operation, revs and throttle position can reveal a lot



By monitoring the boost level and boost signal behaviour, it should be possible to detect any fault

throttle closes sharply. Note the data does not relate to the Audi LMP1 contender in any way!

The turbocharger can fail in multiple ways, but there are two main symptoms: The lack of boost, resulting in less power and over-boost, resulting in a very fast car followed by eventual failure. The latter is not always catastrophic if the engine is capable of taking the pressure levels, but in most forms of motor sport there is a limit to how much boost pressure is used, so this failure mode could result in a disqualification. We should be able to monitor the health of the turbocharger simply by watching the boost level and making sure the values are within limits. Further information can help here. For example, monitoring the position of the wastegate makes it possible to see whether the wastegate is moving correctly or whether there is a possible mechanical fault developing. If the turbocharger has a variable vane system, then there is always a chance that the vanes start sticking and are unable to rotate to the correct angle of attack. As the turbocharger is spinning extremely fast and the temperature inside it is extreme, it is very difficult to measure this directly. However by monitoring the boost level and boost signal behaviour, it should be possible to detect any fault there.

With more and more race series allowing (or even mandating) turbocharged engines, there will no doubt be some interesting developments in the design and build of turbochargers in the coming years. There is also no doubt that the Audi team is already looking at what ever happened to theirs at Le Mans in order to improve their design, even if changing one didn't cost them the race.

Audi mechanics did a remarkable job in swapping turbos mid-race. Monitoring systems helped to identify the problems before they proved to be catastrophic, or lead to disqualification

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Split decisions

CN sports racers can yield interesting and sometimes surprising results

We continue our studies of two Group CN sports racers from constructor Tiga Racecars. Both the cars featured in this session are now branded 'Tiga' after LMP2 driver and businessman Mike Newton acquired the Tiga name in 2012. With neighbours Orex Competition and aerodynamics consultant James Kmieciak, development continued on these CN cars, and we were fortunate enough to get some glimpses of their aerodynamic behaviour.

'Tiga CN12A', based on an earlier Chiron design, in blue, red and white, **Picture 1**, and 'Tiga CN12B', an update and evolution of a WFR design, in orange **Picture 2**, differ strikingly in the location of their rear wings, Tiga A's being very low. Dimensionally the cars are also very different, Tiga A being 220mm narrower and 115mm shorter. Last month we saw how the cars compared and also looked at some front end alterations to Tiga A. This month we'll focus on Tiga B.

FRONT END COMPROMISES

The front of Tiga B has removable forward infill sections between the nose and the wheel pods (see **Picture 3** and compare to **Picture 2**). For racing in 2013, this was done to improve cooling (the radiators are in the sidepods with intakes set into the forward sides of the sidepods), but the car was felt to be better balanced with the infills fitted. Would the data back this up? **Table 1** reveals all.

So this was a pretty clear-cut result. Not only was there a 25 per cent loss of front downforce following removal of the infills, there was also a 4 per cent loss of rear downforce and a small increase in drag (1.8 per cent). The balance also shifted significantly rearwards too, and even with the infills the car was already a bit low on front downforce.

The likely mechanisms here are interesting. The infills would have had raised pressure on the forward-most part of their upper surfaces, and although this might have been mitigated by reduced pressure on the convex transition at the rear of the upper surfaces of the infills, there was clearly an overall and significant net benefit.

Table 1: The effects of removing the forward nose infills on Tiga B, changes are in 'counts', where 1 count = a coefficient change of 0.001

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With	0.493	1.371	0.374	0.996	27.3%	2.781
Without	0.502	1.235	0.279	0.955	22.6%	2.460
Changes	+9	-136	-95	-41	-4.7%	-321

Picture 1: Tiga A, small and beautifully formed

Picture 2: Tiga B, a very effective CN car

Picture 3: Removing the nose infills had a significant effect

Picture 4: Splitter end fences proved to be potent

Picture 5: Deeper end plates were potentially beneficial

Picture 6: Top rear corner notches perhaps sprang a surprise...

Picture 7: Apertures above the wing did make a small difference...

Picture 8: Cutaway end plates made a notable difference...

Table 2: The effects of front splitter end fences

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Without	0.515	1.251	0.260	0.990	20.8%	2.429
With	0.544	1.433	0.487	0.946	34.0%	2.634
Changes	+29	+182	+227	-44	+13.2%	+205

Table 3: The effects of bigger rear end plates

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Original	0.515	1.251	0.260	0.990	20.8%	2.429
Bigger	0.516	1.294	0.250	1.044	19.3%	2.508
Changes	+1	+43	-10	+54	-1.5%	+79

Table 4: The effects of removing the top, rear corners of the end plates

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With	0.516	1.294	0.250	1.044	19.3%	2.508
Without	0.517	1.294	0.248	1.046	19.2%	2.503
Changes	+1	=	-2	+2	-0.1	-5

Table 5: The effects of opening apertures above the wing's main element

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Closed	0.517	1.294	0.248	1.046	19.2%	2.503
Open	0.517	1.286	0.245	1.041	19.1%	2.487
Changes	=	-8	-3	-5	-0.1	-16

Table 6: The effects of cutaway end plates

	CD	-CL	-CLfront	-CLrear	%front	-L/D
'Square'	0.517	1.286	0.245	1.041	19.1%	2.487
'Cutaway'	0.517	1.272	0.250	1.022	19.7%	2.460
Changes	=	-14	+5	-19	+0.6	-2.7

It's relatively unusual to see a fairly significant increase in rear downforce at the same time as a big front downforce increase, but that is what happened here. This was probably down to the infills encouraging more flow over the top of the car and hence to the rear wing, enabling it to generate more downforce.

The lower drag with the infills in place was likely to be the result of less air passing through what would be a more convoluted downstream route, including through the radiators. This would unfortunately tally with less effective cooling. With such a reduction in aerodynamic effectiveness though, it would certainly be worth pursing ways of achieving better cooling that enabled the infills to be retained.

BALANCE RECOVERY

Having removed the forward body infills as described above, various means of recovering front downforce and a better balance were then tried. The most successful single modification was to fit end fences to the splitter, as shown in **Table 2** (**Picture 4**). Note that other changes were made between this and the above mentioned trial.

Despite the apparent simplicity of large rectangular end fences then, this was a very efficient modification, 182 counts of total downforce for 29 counts of drag amounting to an incremental -L/D gain of 6.28:1. In proportionate terms, front downforce went up by over 87 per cent and, with the associated decrease in rear downforce of 44 counts, produced a very useful forwards balance shift to a level that is getting close to the desired 35 per cent to 38 per cent front range, given the 40/60 static weight distribution split. Finally, cutaway end plates that also incorporated the above apertures and additional top, rear cutouts were tried (**Picture 8**), and **Table 6** shows no drag change again but a modest loss of rear downforce.

Next month we'll examine the radical wing location on Tiga A.

Thanks to Mike Newton at Tiga Racecars, Dave Beecroft and crew at Orex Competition and James Kmieciak at Percam Engineering.


1
LE MANS 24 HOURS 2014
WINNING TEAMS CHOOSE DUNLOP TYRES
The Le Mans 24 Hours race provides some of racing's most challenging conditions. In 2014 Dunlop teams filled all three podium places in the only class in which tyre brands compete head to head*.
JOTA SPORT #38
TYRES: DUNLOP
MOTUL
2014 LE MANS 24 HOURS (LMP2 CLASS)
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2: THIRIET BY TDS RACING - LIGIER NISSAN (#46 THIRIET / BADEY / GOMMENDY)
3: SIGNATECH ALPINE - ALPINE NISSAN (#36 CHATIN / PANCIATICI / WEBB)
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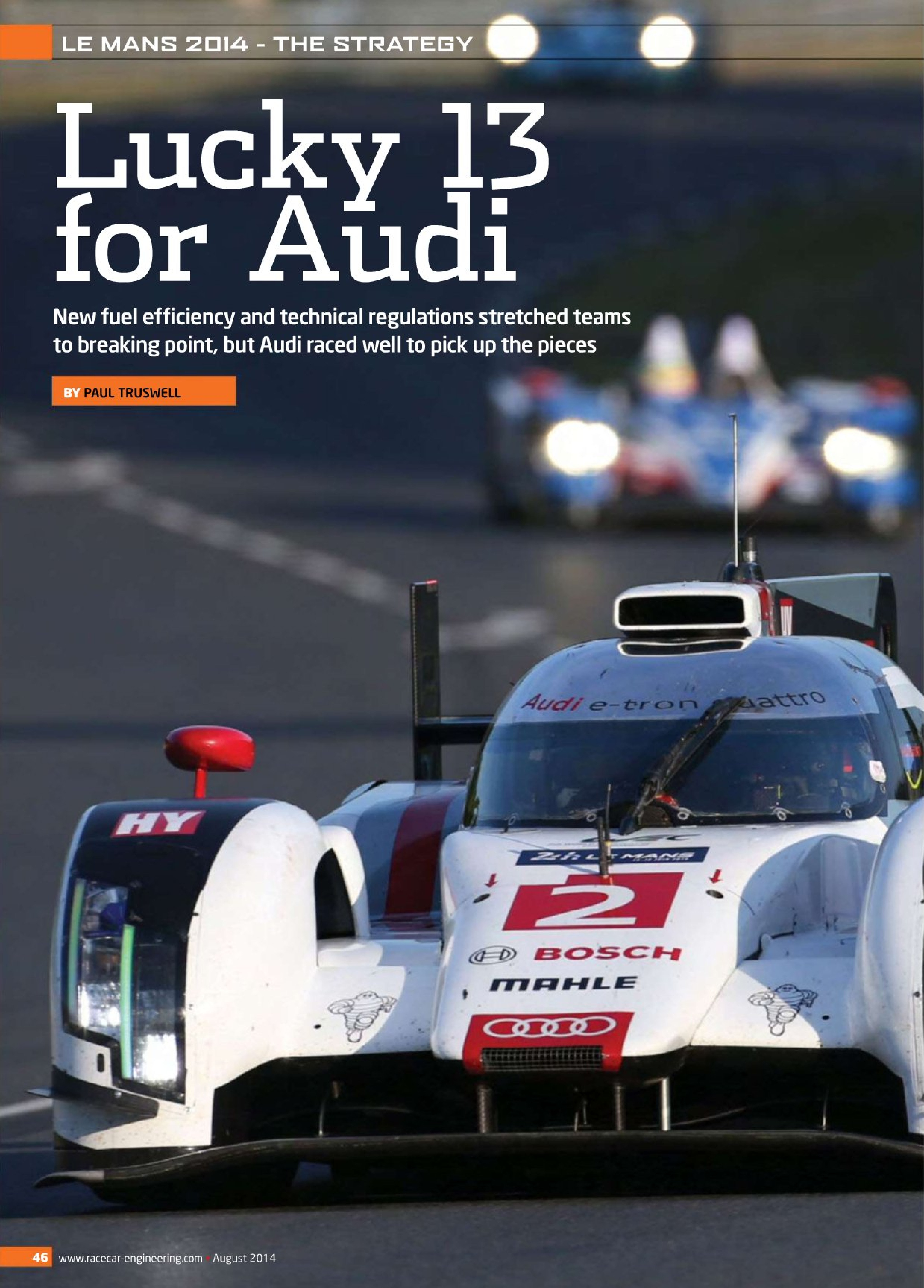
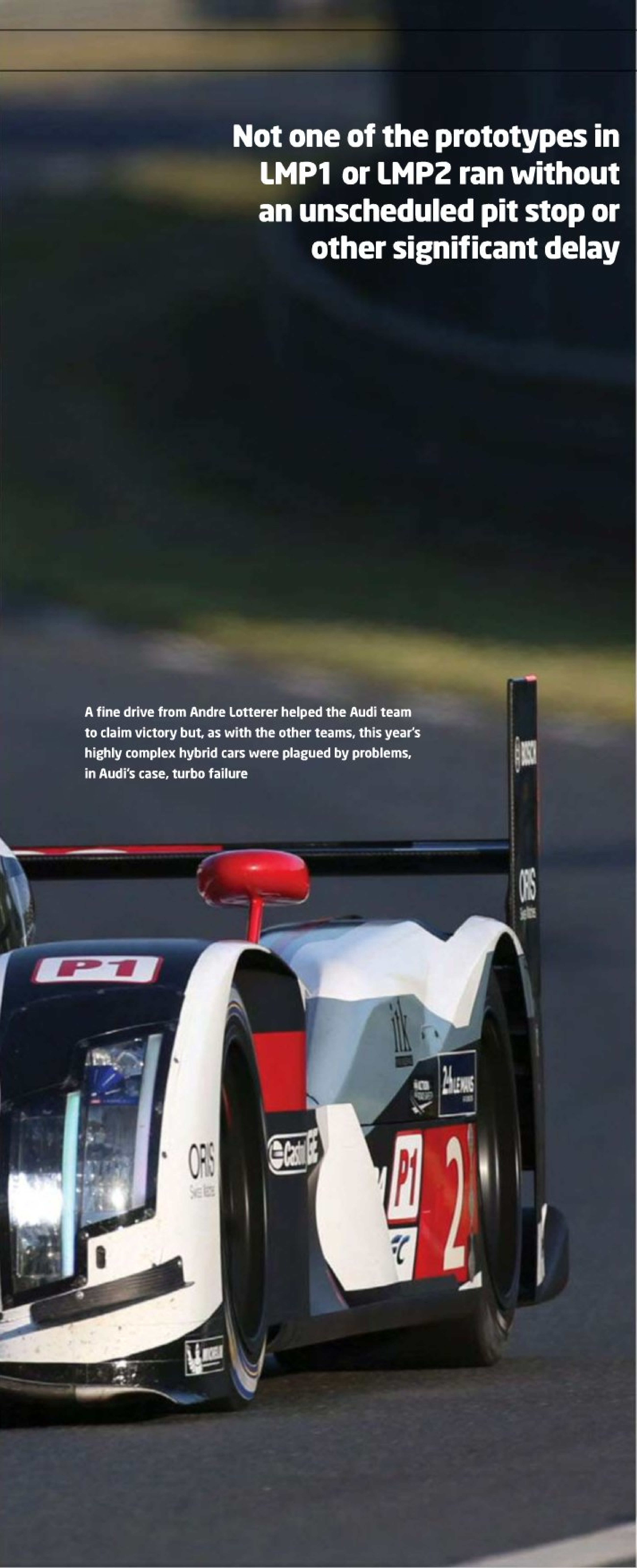
Lucky 13 for Audi

New fuel efficiency and technical regulations stretched teams to breaking point, but Audi raced well to pick up the pieces

BY PAUL TRUSWELL





Not one of the prototypes in LMP1 or LMP2 ran without an unscheduled pit stop or other significant delay

A fine drive from Andre Lotterer helped the Audi team to claim victory but, as with the other teams, this year's highly complex hybrid cars were plagued by problems, in Audi's case, turbo failure

XPB

'Sure we are well-prepared, and we have a good fast car, but we will have to be very good, as the one thing we can be sure of is that the Audis will finish.' So said an upbeat Alex Wurz a few minutes before Fernando Alonso waved the French flag to get this year's Le Mans 24-hour race underway. In the view of many onlookers, he was absolutely right to be confident: this was a race that Toyota could have won. It was the third attempt at the race for the Cologne-based Japanese cars, and with two wins out of two in the preceding 2014 World Endurance Championship races, the TS040 Hybrid cars, boasting almost 1000hp came to France with high hopes.

While Porsche, with their smaller capacity turbo V4-engined 919 entries could not be counted out, no-one really expected them to be contenders for outright victory, especially when the weather forecast for the weekend was for warm, largely sunny conditions, which would most likely put the reliability of the cars – yet to complete a 6-hour race without problems – under further strain.

QUESTION TIME

There were two main questions before the race: first, how quick would the Porsches be? Would they be able to carry the challenge to Toyota in the early stages? And second, how far back would the Audis fall? Would they be close enough to take advantage of any problems ahead of them and steal a victory?

History provided the answers, of course, as Audi achieved a one-two victory, by the largest margin since 2007 – three laps: but analysis of other questions is made more difficult by the choice of both Toyota and Porsche to run their two entries in significantly different configurations. The complexity of 2014-specification LMP1 hybrid cars means that, even with sector times and top speed information, finding the minute details of what was actually happening in the cars is ultimately impossible.

Since keeping within fuel limits is all-important, engineers are constantly in touch with their drivers, telling them when they have to slow down and when to push. The regulations specify how much fuel is allowed to be used in two distinct ways: first is the instantaneous limit and second is the (lower) average limit over three laps. The ACO regulations suggest that the minimum distance that the fuel of Toyota and Porsche can take them is 13.9 laps; for Audi, it is 13.2 laps. If the fact that Porsche was able to manage 14 laps was therefore not a surprise, that Toyota could only manage 13 was. The conclusion can only be that the Toyotas were running right at their limit and perhaps that it was unable to use every last litre in the tank.

Even that conclusion is not so straightforward – Porsche no14 (driven by Jani, Dumas and Lieb) consistently did 14 laps, whereas the no20 car (Webber, Hartley and Bernhard) only did 14 laps later in the race, as is shown in the table of stint comparisons. Quite how close the Toyota was to managing 14 laps on a tank is unclear, but it may have been a strategic decision not to try: it seems strange that both Audi and Porsche completed longer stints during Safety Car and Slow Zone periods, but neither of the Toyotas ever went more than 13 laps throughout the race.

In recent years at Le Mans, we have become used to cars being driven flat out from start to finish, and remaining trouble-free throughout the 24 hours. Considering the extent of the new technology this year, problems were to be expected, but it was still a surprise that not one of the P1 or P2 prototypes ran without an unscheduled pit stop or significant delay.

Fastest Stints

No	Car	Driver	From	to	laps	Average Lap time
1	Audi	Di Grassi	11:33:56	12:18:42	13	3m 26.6s
2	Audi	Lotterer	09:50:39	10:35:03	13	3m 24.9s
7	Toyota	Sarrazin	19:16:13	20:00:57	13	3m 26.5s
8	Toyota	Buemi	10:40:05	11:24:45	13	3m 26.2s
14	Porsche	Jani	09:43:09	10:31:38	14	3m 27.8s
20	Porsche	Bernhard	09:32:50	10:18:07	13	3m 29.0s

Total time spent in pit lane

Car	Total time at end of race	Total time at 21 hours
1	59m 22.3s	55m 05.2s
2	58m 12.4s	53m 49.7s
7	N/A	N/A
8	1h 34m 10.3s	1h 29m 20.7s
14	2h 22m 46.6s	59m 30.3s
20	N/A	29m 17.9s

Stint analysis

No.	Car	No. of stints										
1	Audi	33	1x17 laps,	1x14 laps,	23x13 laps,	1x10 laps	2x9 laps,	1x8 laps,	2x4 laps,	2x1 lap		
2	Audi	30	1x14 laps,	23x13 laps,	2x12 laps,	2x11 laps,	2x10 laps,					
7	Toyota	DNF - 18	14x13 laps,	1x12 laps,	1x11 laps,	1 x 10 laps,	1x4 laps					
8	Toyota	32	24x13 laps,	4x11 laps,	1x8 laps,	1x5 laps,	1x3 laps,	1x2 laps				
14	Porsche	28	1x18 laps,	1x15 laps,	10x14 laps,	10x13 laps,	1x12 laps,	1x11 laps,	1x9 laps,	1x8 laps,	1x4 laps,	1x1 lap
20	Porsche	DNF - 27	1x18 laps,	1x15 laps,	3x14 laps,	18x13 laps,	1x12 laps,	1x10 laps,	1x8 laps,	1x7 laps		

Toyota comparison

		Before accident				After accident				After accident		
		Stint from	Stint to	Average Lap time		Stint from	Stint to	Average Lap time		Stint from	Stint to	Average Lap time
8	Lapierre	15:39	16:24	3m 27.5s	Lapierre	00:48	01:33	3m 29.4s	Buemi	03:27	04:13	3m 29.6s
7	Wurz	15:42	16:27	3m 26.5s	Wurz	00:00	00:46	3m 28.2s	Sarrazin	03:06	03:51	3m 29.4s

Time Spent in Pits

No.	Car	No. of stops	Total Time in Pits
1	Audi R18 e-tron quattro	32	59m 22.3s
2	Audi R18 e-tron quattro	29	58m 12.3s
8	Toyota TS040 Hybrid	31	1h 34m 10.3s
14	Porsche 919 hybrid	27	2h 22m 46.6s
12	Rebellion R-One	38	1h 23m 46.4s
38	Jota Sport Zytek-Nissan	35	57m 10.0s

Time Spent in Pits by Le Mans winning car

Year	Car	
2013	Audi R18 e-tron quattro	47m 14s
2012	Audi R18 e-tron quattro	40m 59s
2011	Audi R18 TDI	33m 56s
2010	Audi R15 TDI	35m 25s
2009	Peugeot 908 Hdi	40m 03s
2008	Audi R10 TDI	31m 56s
2007	Audi R10 TDI	40m 07s
2006	Audi R10 TDI	44m 11s
2005	Audi R8	33m 53s
2004	Audi R8	35m 45s

THE CRUCIAL ACCIDENT

In terms of problems, the first car to strike trouble was the Porsche of Neel Jani. Pitting at the end of the ninth lap for fuel system repairs cost 20 minutes and a drop to 51st place.

Next to go were the no3 Audi of Marco Bonanomi (permanently) and the no8 Toyota of Nicolas Lapierre (to be repaired) after hitting the barriers in the monsoon conditions that greeted the competitors on the Mulsanne straight on lap 26. Lapierre managed to get the noseless Toyota back to the pits after a delay of ten minutes on the track, and then spent a further 49 minutes in the garage having the damage repaired. Whether it was actually as good after the accident as it was before is a point for discussion.

The Toyota Comparison table shows how its performance compares with that of the no7 Toyota (before it retired), both before and after the accident. What is abundantly clear from this is that the two Toyotas were very different - the no8 car (of Anthony Davidson, Nicolas Lapierre and Sébastien Buemi) was around a second a lap slower than the no7 (Alex Wurz, Stéphane Sarrazin and Kazuki Nakajima). The obvious conclusion is that the no8 car was being prepared to finish at all costs - and thus maximise its chances in the World Endurance Championship, while the sister car was looking for speed and outright victory.

After the repairs were completed, Sébastsien Buemi took the no8 Toyota back into the fray, in 49th place, having

Porsche 919 ran lean, and led on Sunday morning before engine problems

Andre Lotterer super-stint							
From time	**To time**	**From lap**	**To lap**	**Laps**	**Average lap time**	**Pit stop time**	**Notes**
09:50	10:35	293	305	13	3m 24.9s	1m 27s	Takes car over from Fassler
10:36	11:20	306	318	13	3m 25.2s	57s	Fuel only
11:21	12:06	319	331	13	3m 27.5s	1m 23s	Tyre change
12:07	12:52	332	344	13	3m 28.2s	57s	Fuel only
12:53	13:33	345	355	11	3m 28.7s	57s	Fuel only


The Toyota led for long stretches before retiring with electrical failure


Bonanomi's Audi was too damaged to restart after the lap 26 accident

lost merely nine laps, despite the delay of nearly an hour, due to the slow running behind the Safety Car. By this time the no14 Porsche had recovered to 43rd place, but the battle for the lead was between just four cars. It seemed unlikely, less than three hours into the race, that eighteen hours later, these two cars would be in fifth and sixth places.

From the outset, the car to watch had been the no7 Toyota TS040 that Kazuki Nakajima put on pole position. It cannot have escaped the attention of the watching Toyota executives that (prior to 2014) the last three Le Mans 24 hour races have been won by the car setting the fastest lap in qualifying.

To be fair, although it had lost the lead on a couple of occasions through pit stops, the Toyota was well established in the lead of the race throughout, and seemed to be headed towards a convincing victory, until sparks were reported coming from the back of the car as a fault in the wiring loom halted its progress coming out of Arnage corner just before 5am on Sunday. Until then, it had looked like a pretty much perfect run, interrupted only by two longer stops caused by having to pit during Safety Car periods.

Could an Audi still have won, had the Toyota not stopped? It would not have been impossible.

Audi no2 made a crucial pit stop just after quarter past two in the morning, when a front wing adjustment was made. Immediately, its times became two seconds per lap quicker, and it began ever-so-slowly to close up the gap to the Toyota. When the Audi emerged from the pits with the new settings at 2:18am, it was a full two minutes behind, and despite the best efforts of the Toyota drivers, Lotterer and Tréluyer were able to bring the gap down to 1m38s by the time the Toyota ground to a halt. At that rate, the Audi would have needed until 3:30pm on Sunday to overhaul the Toyota – half an hour after the chequered flag was due to fall – had everything else remained equal.

It would have made an enthralling battle; there is no question that the track became quicker as the race wore on and more rubber went down but would the Toyota have been able to make the most of it? The no8 Toyota was only able to increase its pace by around half a second per lap in the Sunday morning 'happy hour', whereas Lotterer's Audi was lapping more than three seconds faster than he had been on the previous evening.

As it turned out, the Audi charge was dented by turbo failures on both its remaining cars. First to falter was the no2 car, which had a slow lap back to its pit in Marcel Fässler's hands, just before 7:30 in the morning. Uncharacteristically, there seemed to be some confusion in the pit as the team decided what to do. Initially, the car was pushed out of the garage and was seemingly ready to go, but then as Fässler fired the engine, the inevitable decision was made to push the car back and change the turbo.

To ease the pain for Audi a little, there was first a slow zone, then a Safety Car, which meant that around 30 minutes of time lost translated to just five laps in terms of track position: such were the problems experienced by everyone else, the car fell only to 3rd place, two laps off the lead lap.

Could an Audi still have won, had the Toyota not stopped? It would not have been impossible

QUICK TURBO CHANGE

At 7:10am, with the no 2 now a lap behind, Marc Gené in Audi no1 led the race, 1m 46s ahead of the no20 Porsche in the hands of Mark Webber. Gené's lap times were comfortably better than those of the Porsche and he had started to extend his lead; by the time the Spaniard came in to hand the Audi over to Kristensen with four and three-quarter hours to go, and Timo Bernhard had taken the wheel of the Porsche, the Audi was a lap up. Even Gené admitted to thinking about the possibility of winning at that stage.

But even in the final four hours of the race the fragility of the new technology was in evidence. Just after 11am, Kristensen brought the leading Audi into the pits after just four laps of the second stint of his shift. After refuelling and an inspection, he was sent on his way again – once more there seemed to be indecision about what to do. At the end of the lap he was back in: the car was pushed into the garage and work began to replace the turbocharger. The job was done in just 17 minutes, but both the Porsche and sister Audi had gone past.

So Porsche led Le Mans, but with less than three hours to go, there was no way that even Mark Webber could get the 919 hybrid to go quickly enough to hold off the flying Lotterer. This was undoubtedly the best drive of the race. He had taken over the wheel of the car just before 10am and drove five stints - 63 laps - on two sets of tyres, twice taking the fastest lap of the race (see table: Andre Lotterer super-stint).

He easily overhauled Webber in the Porsche, but an all-German podium still seemed likely - the Porsche was still six laps ahead of the fourth-place Toyota, which had lost a further 7½ minutes in the pits just before midnight for additional repairs following the Mulsanne smash early in the race.

It was not to be, as first Webber, followed by Lieb, headed slowly to the pit lane. Lieb was eventually classified in 11th place overall and 5th in LMP1, following an appeal to the stewards to be excused the '6 minute rule' for the final lap of the race as Porsche wheeled out the car to take the flag and complete 24 hours.

Porsche's race had been eventful, but the cars had run quickly when they were without problems. Several trips up the escape road at Arnage suggested that there were problems with the brakes, and they never looked likely outright winners, despite the leading for 37 laps. The Porsches were also the only cars in the LMP1-H class that could run for 14 laps on a tank of fuel without the assistance of Safety Car or Slow Zone. The ACO's regulations suggested that both Toyota and Porsche should have had 13.9 laps of 'fuel autonomy'. However, there was an implicit assumption in those calculations that there would be 1.7 litres of unusable fuel in the tank.

All teams spent an hour or more in the pits. Previous average was 35-40 mins

FUEL STRATEGY

Since the fuel consumption requirements for both Toyota and Porsche were identical, it must be concluded that the decision to run 14 laps on the Porsche was a deliberate one, to gain an advantage by spending less time in the pits. In that sense it was successful, although the table for Total Time Spent in the Pits is misleading as both Porsches ran into drivetrain problems.

For this reason, the table also shows times at midday on Sunday, when, of course, we did not know the eventual fate of the two Porsche 919s.

A final point on pit stops. The winning car has not spent so long in the pits since Porsche last won the race outright in 1998, when more than an hour was spent in the pit lane. The table shows the amount of time spent in recent years in the pit lane - although it has to be remembered that the rules defining the opening and closing of the pit exit during Safety Car periods have changed.

In a year when all three LMP1 teams took turns at leading, and with rules aimed specifically at ensuring that improvements were made in fuel consumption, it is worth summarising the fuel economy situation. Figures for actual fuel consumption are not made available this year, but it is possible to use the regulations to work out how much fuel could have been used. The winning Audi e-tron quattro's allowance this year was - to within 20 litres - exactly the same amount of fuel as was actually used in 2013. The big difference is that it completed 379 laps this year and only 348 last.

Audi efficiency won again, but they, as well as Toyota and Porsche, must return in 2015 with more reliability.

GTE CLASS

The GTE class provided intense competition and action throughout, although we were denied a proper close finish. Ferrari didn't change brake pads during the 24 hours, and that was the defining factor. The Aston Martins had hoses come off the power steering units, losing time, the Corvettes were undone by the Safety Car and a faulty air jack, while Porsche just didn't have the pace. It was also predictable that there would be rumblings of discontent at the way that the different cars have their performance balanced in order to ensure good racing.

In 2013, it was the Corvettes that seemed to be somehow unable to keep up; their only hope last year was to compete on efficiency terms, keeping the cars on the track and out of the pits, while the Aston Martin Vantage V8s were able to stretch their legs at the front.

This year the Astons struggled, and Chevrolet's C7 were sitting relatively pretty. Except, of course that nothing is ever easy in GTE, especially at Le Mans. The early stages were complicated by the heavy rain showers, but as the race settled down, the battle was between the AF Corse Ferrari 458 Italias, Chevrolet, Aston Martin and Manthey's Porsche 911 RSR (991) slightly off the pace.

The tables show the average lap times for each car's best 60 laps, and also for Sector 1 (from the start line to Tertre Rouge), Sector 2 (the length of the Mulsanne straight, including the chicanes) and Sector 3 (from Mulsanne Corner to the start-finish line), in order to allow comparisons to be made between the different sectors. For added interest, a further table shows the average of the best top speeds measured through the ACO speed trap on the Mulsanne Straight, just before the first chicane.

The numbers speak for themselves, but Aston Martin would seem to have a fair bit of work to do, assuming that the folk at the ACO have done their sums right.

GTE - Average of best 60 sector times in race.

No.	Car	Sector 1	Sector 2	Sector 3	Total	Percentage Total
51	Ferrari 458 Italia	37.314s	1m 30.365s	1m 48.461s	3m 56.140s	236.14
73	Chevrolet Corvette C7	37.348s	1m 30.003s	1m 48.112s	3m 55.463s	236.14
92	Porsche 911 RSR	37.402s	1m 30.008s	1m 48.760s	3m 56.170s	236.17
95	Aston Martin Vantage V8	37.528s	1m 30.428s	1m 48.991s	3m 56.947s	236.947

GTE - Average of best 60 laps in race.

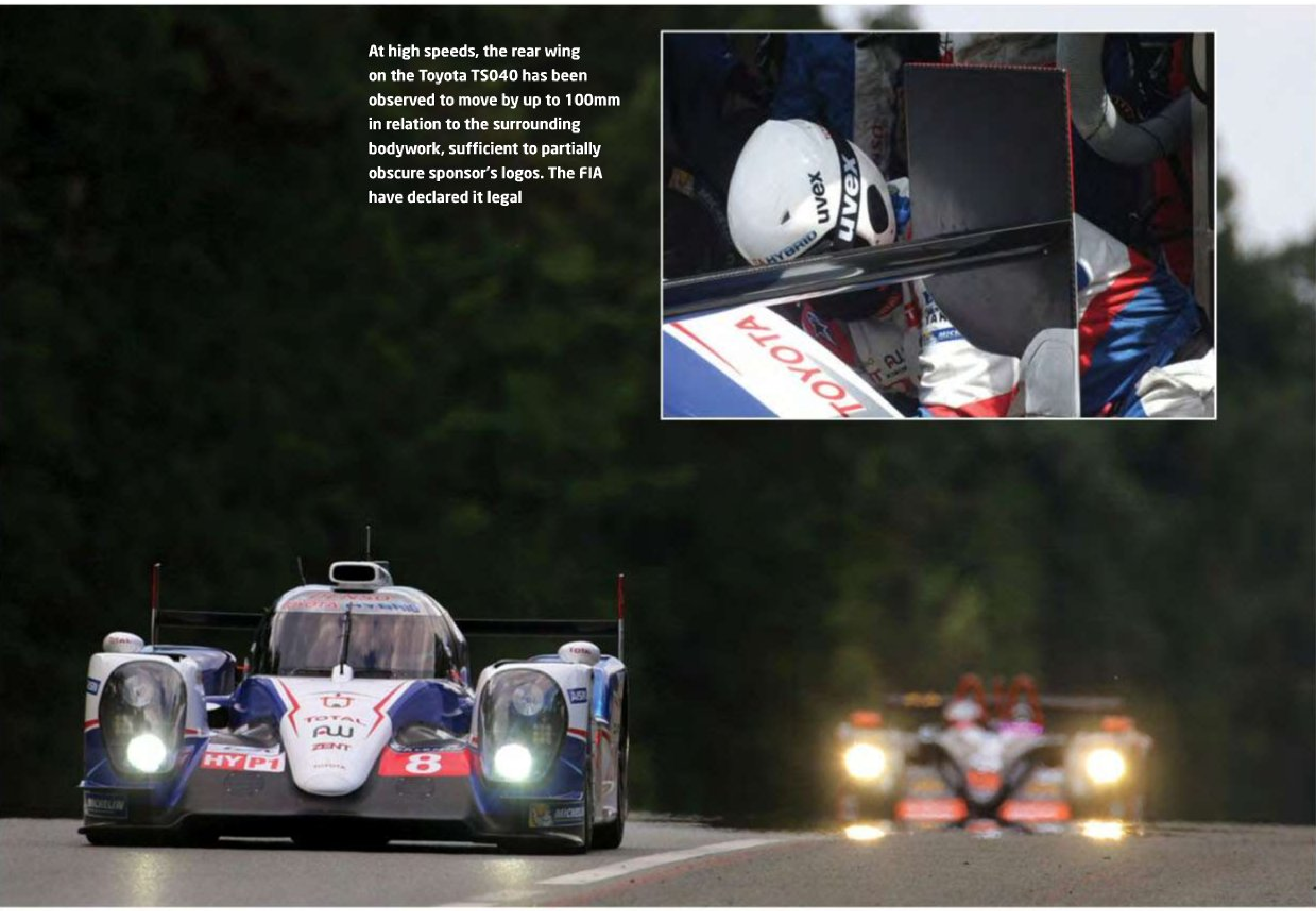
No.	Car	Average Lap Time	Percentage
51	Ferrari 458 Italia	3m 56.475s	0.29%
73	Chevrolet Corvette C7	3m 55.706s	0.00%
92	Porsche 911 RSR	3m 56.514s	0.30%
95	Aston Martin Vantage V8	3m 57.381s	0.63%

GTE - Average of best 60 top speeds in race.

No.	Car	Top Speed
51	Ferrari 458 Italia	294.7 km/h
73	Chevrolet Corvette C7	295.7 km/h
92	Porsche 911 RSR	295.4 km/h
95	Aston Martin Vantage V8	293.2 km/h

Bending the rules?

Flexible body panels on the Porsche 919 caused ructions in the LMP1 community, but Toyota's drag-beating pivot wing and active brakes received the all-clear



At high speeds, the rear wing on the Toyota TS040 has been observed to move by up to 100mm in relation to the surrounding bodywork, sufficient to partially obscure sponsor's logos. The FIA have declared it legal

BY SAM COLLINS

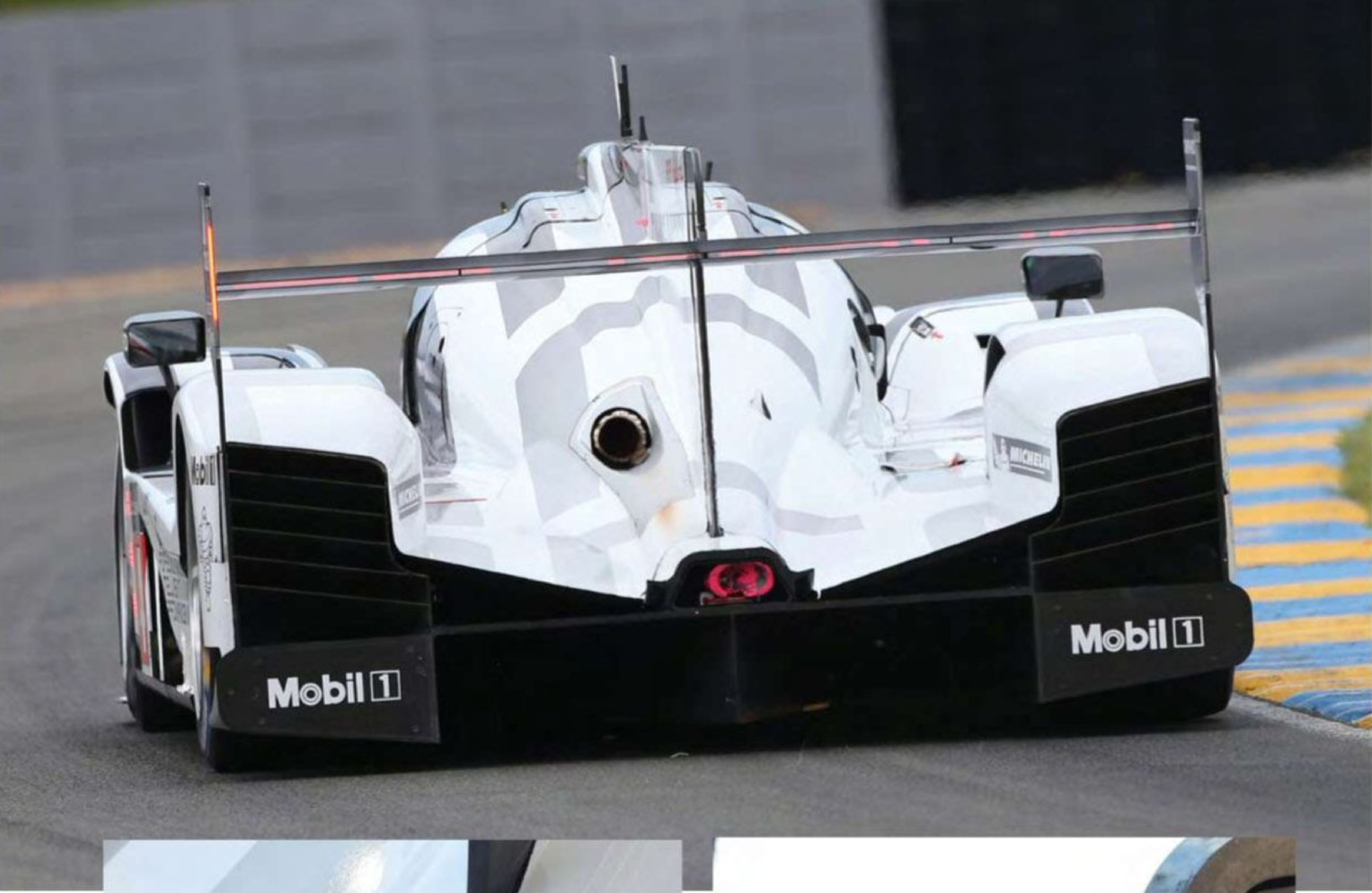
One of the biggest stories behind the scenes of this year's Le Mans 24 Hours was that of moveable aerodynamic devices. WIth the increase in competitiveness brought about by the arrival of Porsche and the introduction of a new technical rulebook the teams have clearly started to look for every small advantage that they can find.

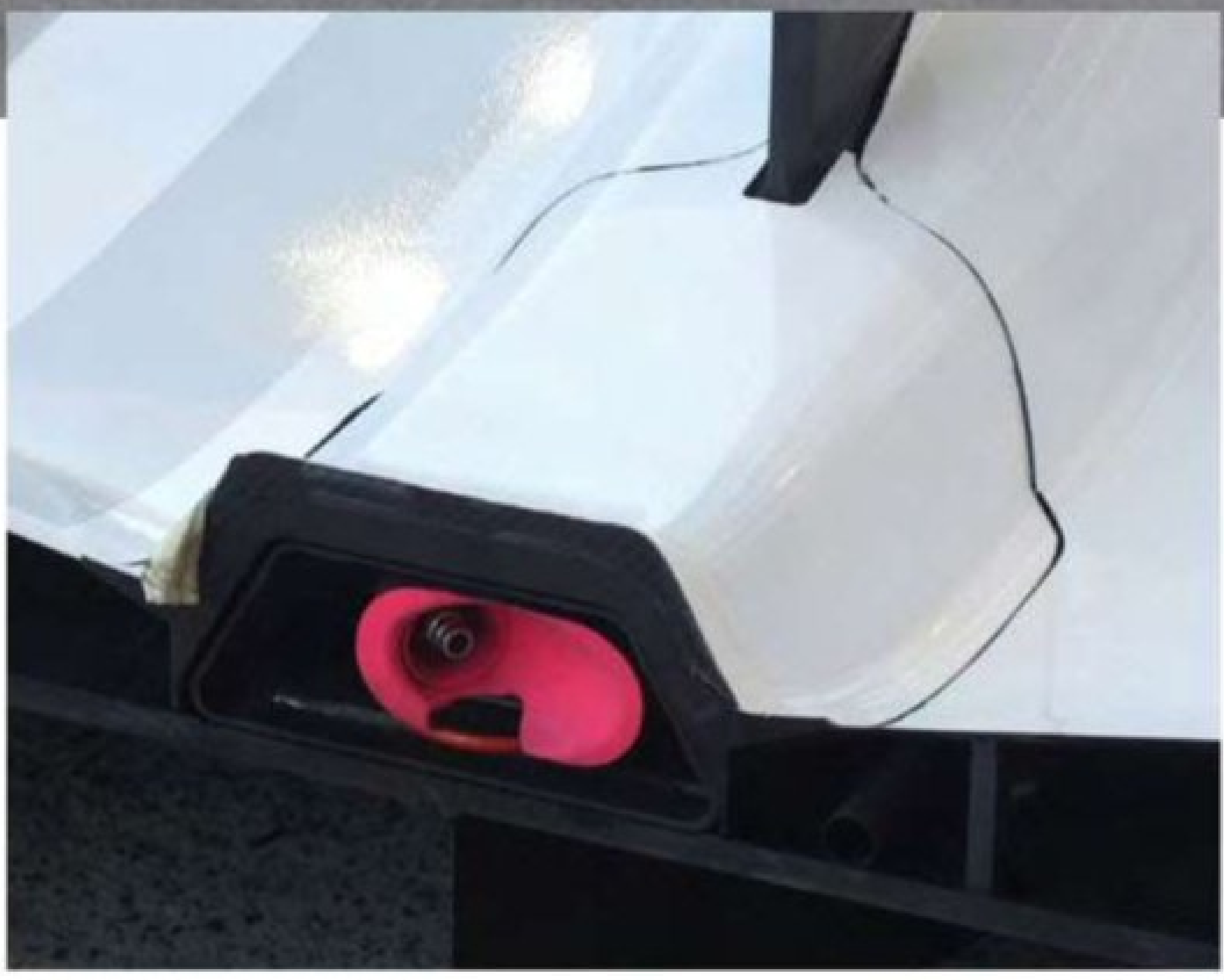
Article 3.4 of the Le Mans Prototype technical regulations is at the centre of the debate, which states that 'Movable bodywork parts/elements are forbidden when the car is in motion' which seems clear, but there appear to be some loopholes.

It all started at the Spa 6 Hours race where it was discovered that all three works LMP1 designs were fitted with flexible floors. It soon became evident that the problem of movable bodywork did not stop there, and rumours circulated of many illegal devices on the cars. The FIA decided that it had to act, and issued a technical directive to all teams, in which it revealed that it had found that all of the cars were, in essence, illegal.

'Regarding the front part skid-block, we have observed during scrutineering that each of your cars had some flexibility in order to prevent any damaging of the underside of cockpit in case of unwanted passage out of track or on kerbs' the clarification read. 'Formally speaking this contravenes article 3.4 of the LMP1 regulations. However as it seems indispensable and used by all of you, we agree not to apply strictly this article for this specific part. In order to be fair to everybody, we will accept a flexibility in that point of 10mm under 500 daN. To be absolutely clear, we make it mandatory to have a stop effect and that this deflection cannot under any circumstances be more than 15mm.'

In addition the FIA also highlighted that questions had been asked about the flexibility of rear wings, and that it would be performing tests on them at Le Mans. 'We have not been able to perform such test on Low Downforce configurations, so we





Seen at speed, the trailing edge of the rear bodywork on the Porsche 919 is deformed enough to almost contact the rear diffuser. Separation lines in the structure show where the flex is designed to occur. After protest, improvised panel supports were added to prevent movement

ask you to come in Le Mans with all the equipment to perform it. Moreover we remind you that we reserve the right to introduce load/deflection tests on any part of the bodywork which appears to be (or is suspected of), moving whilst the car is in motion.'

Among other criteria, the FIA considered the linearity of the load/deflection curve over the elastic deformation area. Any non-linearity must be only on the plastic deformation area. This applies at any position on the wing. This means, that should we have a doubt that the wing have the required flexibility at 50 per cent of the chord but a significantly higher one at another position, we reserve the right to make a deflection test.'

So with this statement barely seven days old Audi and Toyota were stunned when the Porsche 919 arrived for the official pre race photo shoot ahead of the test day with bodywork that was clearly flexible. It was noted that a significant portion of its engine cover and rear bodywork flexed with a gentle finger push, it would clearly deform at high speed. Additionally some parts of the engine cover extended beyond the rear of the diffuser something that was thought to contravene article 3.5.2 of the technical regulations which states that: 'No part of the diffuser must be more than 200mm above the reference surface and its rear end must be plumb (flush) with the perimeter of the bodywork (rear wing removed).'

The FIA revealed that it had found that all of the cars were, in essence, illegal

Pictures taken of the car running at high speed on test day showed that the bodywork did indeed flex substantially with the outer portions of the engine cover dropping down to reduce drag, something that is thought to have given the 919 a 5kp/h increase in top speed. When the section dropped down it also exposed an winglet style piece of bodywork beneath the rear wing support. This also breached another rule that states that the bodywork in this area should have 'a continuous unbroken surface without cut-outs.'

Toyota were incensed by the blatant use of flexible parts, not only because the FIA clarification was only issued days earlier, but because the team had agreed not to use the flexible engine cover it had used on the TS030 LMP1 in 2013. 'There was a gentleman's agreement between us all that we would not do this and then they come here like this!' exclaimed a senior Toyota engineer.

Both Audi and Toyota queried the design with the FIA and by the time that the 919 Hybrids

"There was a gentleman's agreement between us all that we would not do this"

arrived at Le Mans the bodywork had been trimmed, and a small plate added under the engine cover to prevent significant flex.

That seemed to be the end of the story but rumours surrounding the rear wing of the Toyota TS040 would not go away and during the qualifying sessions it became clear that the wing did indeed move, though crucially it did not flex. The solution used by Toyota, allied to its 1,000bhp power unit saw the car topping 340kph in qualifying trim, significantly higher than either Porsche or Audi.

At high speed the main plane of the wing rotates with the leading edge tipping upwards and reducing the drag of the wing, under braking the wing rotates downwards and the wing functions normally. The central support of the rear wing is quite clearly a pivot with a single fixing at the base of the 'swan neck'. Scratches on the inner face of the rear wing endplate reveal the extent of the movement, with perhaps 80-100mm of rotation at high speed. The rotation can clearly be seen by comparing pictures of the car in low and high speed sections of the track. The upper element of the rear wing has Michelin logos on its outer edges, at low speed the logos are clearly visible but at high speed they vanish as the wing rotates forward. 'The FIA know what we are doing, they have looked at it and said that it is legal, it has passed all of the tests and it does not flex,' explained a senior Toyota engineer. Rival teams have argued that a wing that visibly rotates at speed cannot possibly conform with article 3.4: 'movable bodywork parts/ elements are forbidden when the car is in motion.'

What does seem certain is that the issue will rumble on this season, but few expect that LMP1 cars will have such devices next year.

HYBRID BRAKING

Toyota's braking system caused something of a controversy following scrutineering at Le Mans. Something that had been thought to be common knowledge in the paddock reached the ears of one of some of the Audi engineers for whom it was a revelation.

The brake by wire layout on the TS040 has an automatic 'brake migration' system that sends the bias forwards or rearwards as the car travels deeper into the corner. In essence it is a form of active brake bias, as the electronic management system on the car manages it automatically.

If a driver hits the pedal and feels significant rear locking, the next time he arrives at that corner he would adjust the brake bias forwards to prevent it on a standard racing car. But sometimes as he starts to turn into the corner front locking can result as the wheels are unloaded. The Toyota system, which is in essence identical to those used in F1, mitigates this by using a brake migration tool to automatically send the bias rearwards again as the braking event continues. The drivers have control of how extreme this effect is by using rotary thumb switches on the steering wheel.

The technology is featured on most Formula 1 cars, and Toyota did not feel that the concept was confidential or indeed illegal as its implementation seems likely on a hybrid competition car. However once rival manufacturers became aware of the system they complained to the FIA about its use, suggesting it breaches two parts of the technical regulations.

Article 14.1 states that:
The only connection allowed between the two circuits is a mechanical system for adjusting the brake force balance between the front and rear axles.
While article 14.7 states that:
For vehicles with a Kinetic ERS, a specific braking system is allowed.

- Its function is to ensure the braking of the car strictly in conformity with the order given by the driver.
- Its function cannot be, in any circumstances, to provide the driver with any additional support.

The system may be active.
In particular, this system must :

- Ensure balanced and stable braking, whatever the amount of energy recovered. It must ensure a constant front / rear braking load distribution (sum of the electrical and hydraulic efforts) which can be adjusted only manually by the driver.

Following clarification requests from Toyota's rivals the governing body issued a technical directive regarding brake bias control ahead of the first qualifying session at Le Mans, which states:

Following some questions about the ERS specific brake system, we feel important to clarify that in reference to articles 14.7.1 and 14.7.2:

1) a system that complies with LMP1 regulations cannot:
   - Have any sort of balance adjustment to compensate automatically disc/pad wear or wheel locking.
2) a system that complies with LMP1 regulations can:
   - Have a possibility of selection by the driver of the value of a nominal brake balance (selection made by an HMI like a button/ potentiometer for example).
   - Have a brake balance related to the brake pressure applied by the driver through a pre-definite law (which avoids any possibility of electronic anti-lock system), provided the relation pedal-pressure / brake balance is monotone and without any inflexion point (curvature always the same sine), like could be get from mechanical devices.
   - Have a possibility of selection by the driver of the law defined above (relation pedal pressure/ brake balance. Selection made by another HMI like a button, for example)

This guarantees that at any time, the brake balance is under the direct control of the driver through its selection and the pedal pressure he applies. For a definite set-up chosen by the driver, and a definite pedal pressure, the brake balance remains at a definite constant value, independently of the level of energy recovered or lock of the wheel.

'Our braking system is legal to each word of the regulations,' says Toyota's Technical Director Pascal Vasselon. 'It is written that the system can be active, so the system controls the total brake force and the total brake balance. It is automatic to compensate for a capacitor which is saturated and which cannot recover [any more]. What it cannot do is react to a wheel lock, or the yaw behavior of the car. It is a system that has feedback control loops. You cannot have a feeback loop on the wheel speed or the yaw control, but you can have a feedback loop on the total brake balance and total brake force. That is what we are doing. For a given set of driver inputs, which is the definition of manual, the system will always do the same thing. It doesn't mean that the brake balance is constant.

'Our brake balance is variable according to the pedal pressure, so it is a driver action, like in F1. We didn't invent anything. In F1 before 2014, the brake system was mechanical and we developed an active braking system that works like that. It is adjustable by the driver by pedal pressure and we did it mechanically. It is simple.'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The right stuff

Altair's OptiStruct software was used to optimise the strength and aero elasticity characteristics of the carbon composites for a Formula 1 front wing

In Formula 1 and LMP1 aero, elasticity is a major topic and has been for some years. It is not just about creating an aerodynamic shape that will deform or flex in the right way, it is also creating a structure that passes a range of FIA tests. To do this, the composite structures themselves have to be optimised. In 2008, Force India went through this process to optimise the wing on its VJM01 design using Altair software.

A team, including Dr. Simon Gardner, tackled the challenge with a 3-stage approach to designing the optimum composite structure for a front wing using a programme called OptiStruct 9.0 (then the latest tool).

The design criteria of the wing showed that it must be completed in a highly compressed time frame, meet the stiffness targets set by the regulations, withstand the required aerodynamic loads, be as light as possible and be easy to make.

To do this, the Force India engineers had to use the software to calculate the most efficient ply boundaries, number of plies, fibre orientation and materials to use. They then had to work out the optimal stacking sequence to minimise peak composite failure indices and ensure efficient ply distribution.

It was hoped that the result of this optimisation would yield a minimum mass design, while meeting all criteria in a significantly reduced timeframe relative to traditional methods.

In 2008, typically around 30 per cent total downforce was generated over the front wing assembly and could have in excess of 6kN total force. Front wing stiffness plays a significant role in maintaining the aerodynamic profile, and bending and torsional stiffness must be tailored to meet specific aerodynamic requirements.

Overall view of the 2008 Force India front wing design

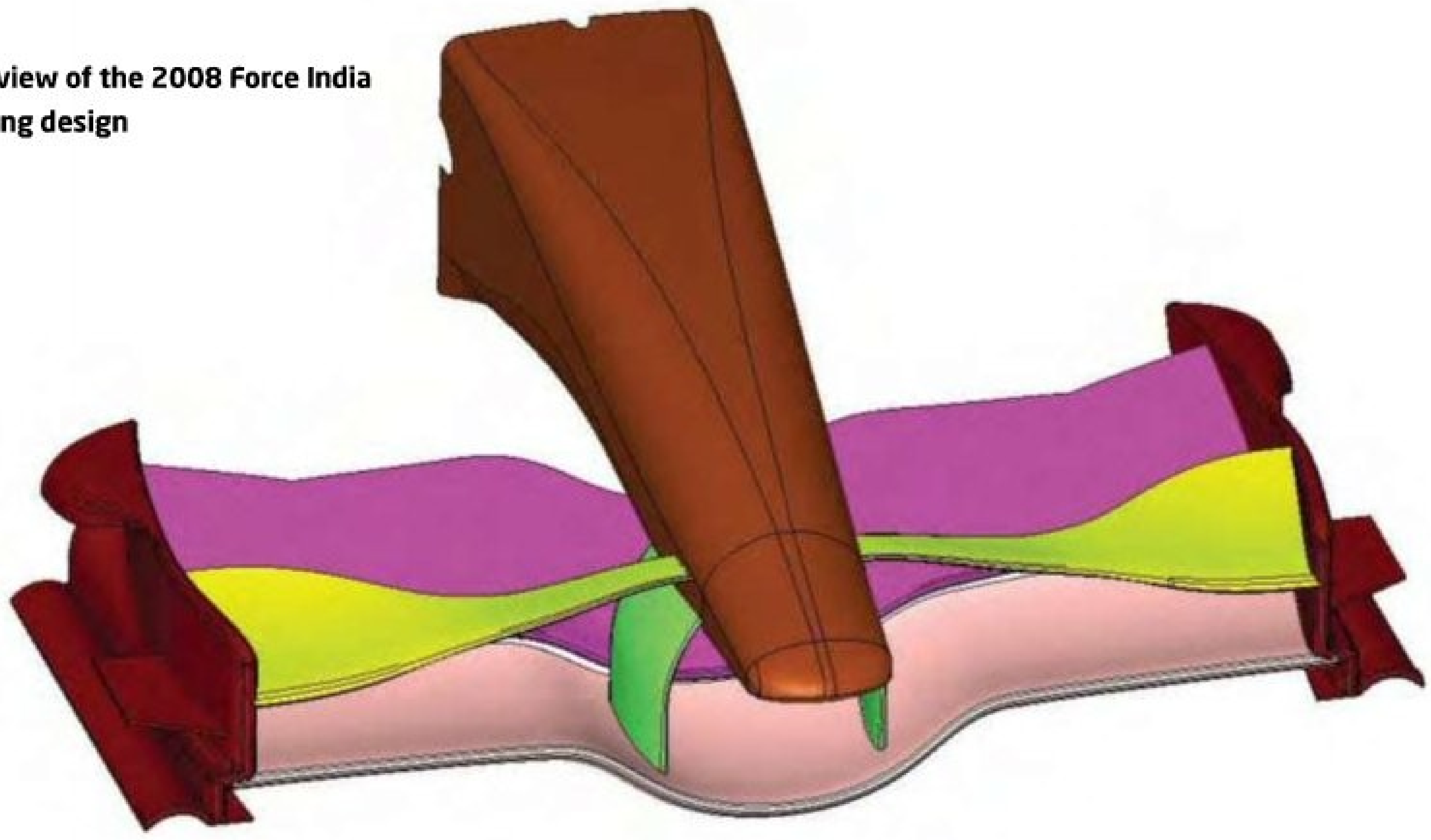
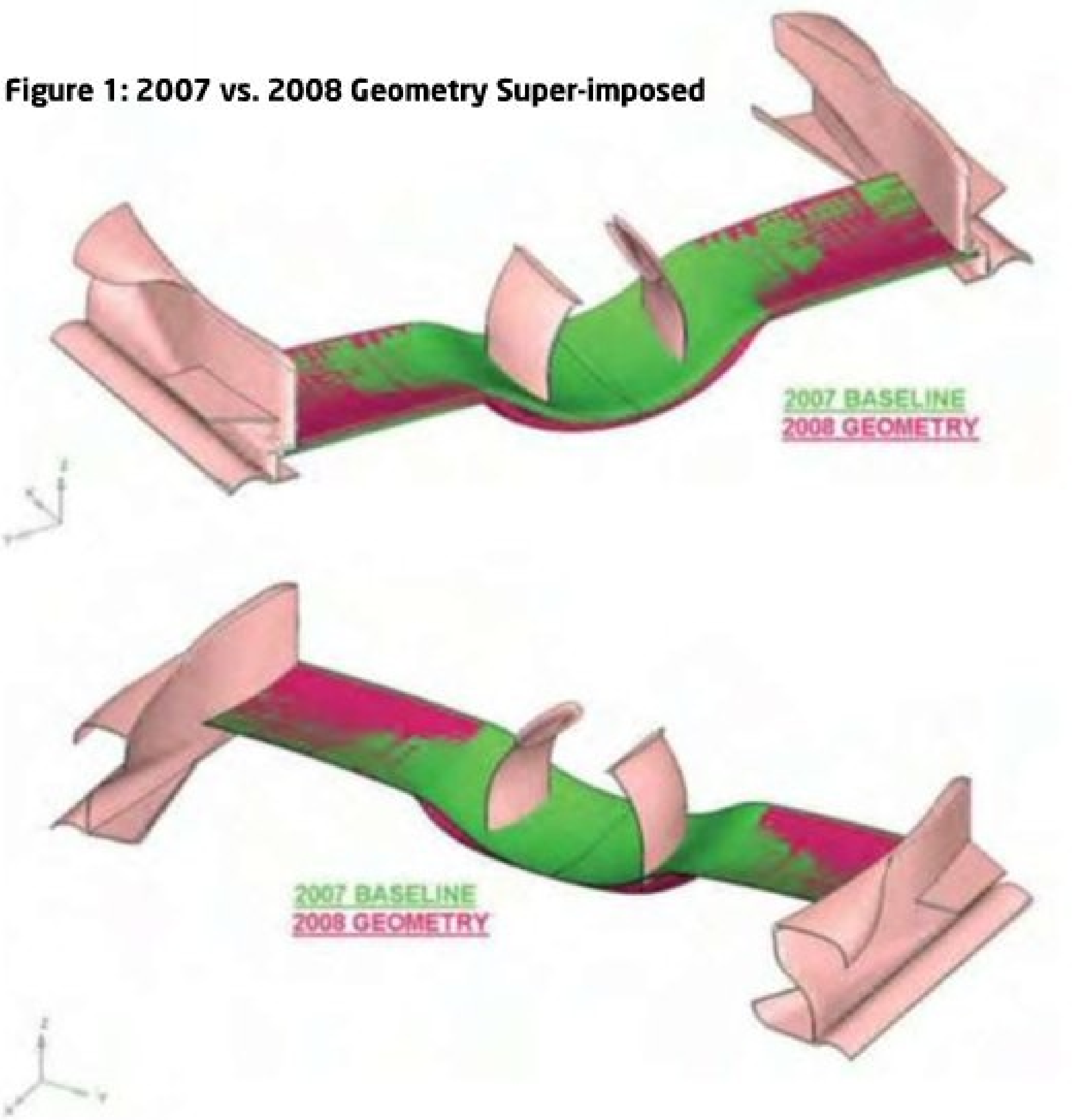


Figure 1: 2007 vs. 2008 Geometry Super-imposed



This means that the design of the front wing must be able to withstand large aerodynamic forces generated by airflow at high speed, while ensuring deflections are managed. Coupled to the aerodynamic constraints, the front wing assembly must pass stringent regulatory deflection tests, while at the same time ensuring that the mass of the assembly is at a minimum. The testing parameters and procedure are detailed in the following extract from the FIA regs.

FIA TECHNICAL REGULATION 3.17.1 (2008)

'Bodywork may deflect no more than 5mm vertically when a 500N load is applied vertically to it 700mm forward of the front wheel centre line and 625mm from the car centre line. The load will be applied in a downward direction using a 50mm diameter ram and an adapter 300mm long and 150mm wide.'

In order to achieve these requirements the front wing is generally constructed from carbon composite, and comprises a wide selection of construction materials and methods. Typically multiple layers of unidirectional (UD) and woven (Cloth) fibres over lightweight core materials.

The objective of the Force India study was to design a new front wing which exceeded the structural performance of its predecessor. As the aerodynamic shape of the wings change from season to season, it was necessary to assess the geometric differences between the wing designs, as shown in **Figure 1**. This is done as a preliminary analysis and simplified isotropic models are built which represented the shapes of the 2007 and proposed 2008 wing being considered.

To assess the comparative geometric stiffness of the two wings it is necessary to find the position of the neutral axis at the end of the wings and apply loads at this location. In order to discover the geometric stiffness of interest (vertical bending and rotational twisting) both wings are subjected to two load cases:

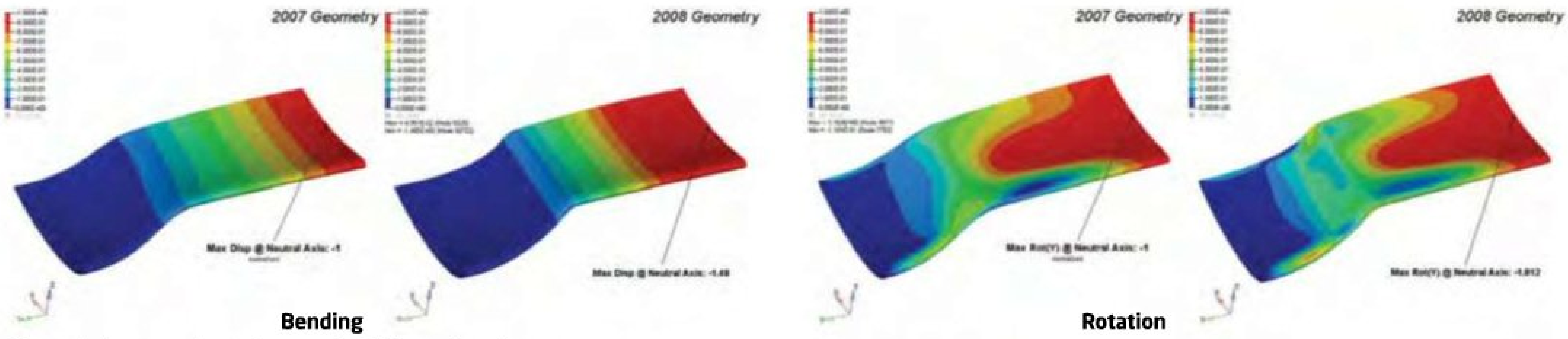


Figure 2: 2007 vs. 2008 Geometric Stiffness Results

1. **A point load is applied in a vertical direction (-Z) - Vertical stiffness**
2. **A torque is applied in Y (across car) - Torsional stiffness.**

The results of this preliminary analysis can be seen in **Figure 2**, and show that the proposed 2008 wing is significantly less stiff in bending (-48 per cent) while the reaction to torsion is not significantly affected.

Once the geometric differences were known, it was apparent that the vertical bending would be the limiting factor to ensure the 2008 geometry out-performed the 2007 wing.

As a further comparison, a more detailed model of the 2008 wing was built, which contained all elements from the front wing assembly. An up-to-date mapped pressure profile and a representative composite lay-up (Laminate Stack) was applied, based on the 2007 wing. This model was analysed for an aerodynamic load case and FIA regulatory load case, as compared to the 2007 baseline model.

As expected, the 2008 wing performed significantly worse compared to the baseline. However the total deficit was not as severe with a maximum difference of ~26 per cent seen, and a considerable increase in composite failure index was observed around the centre transition section.

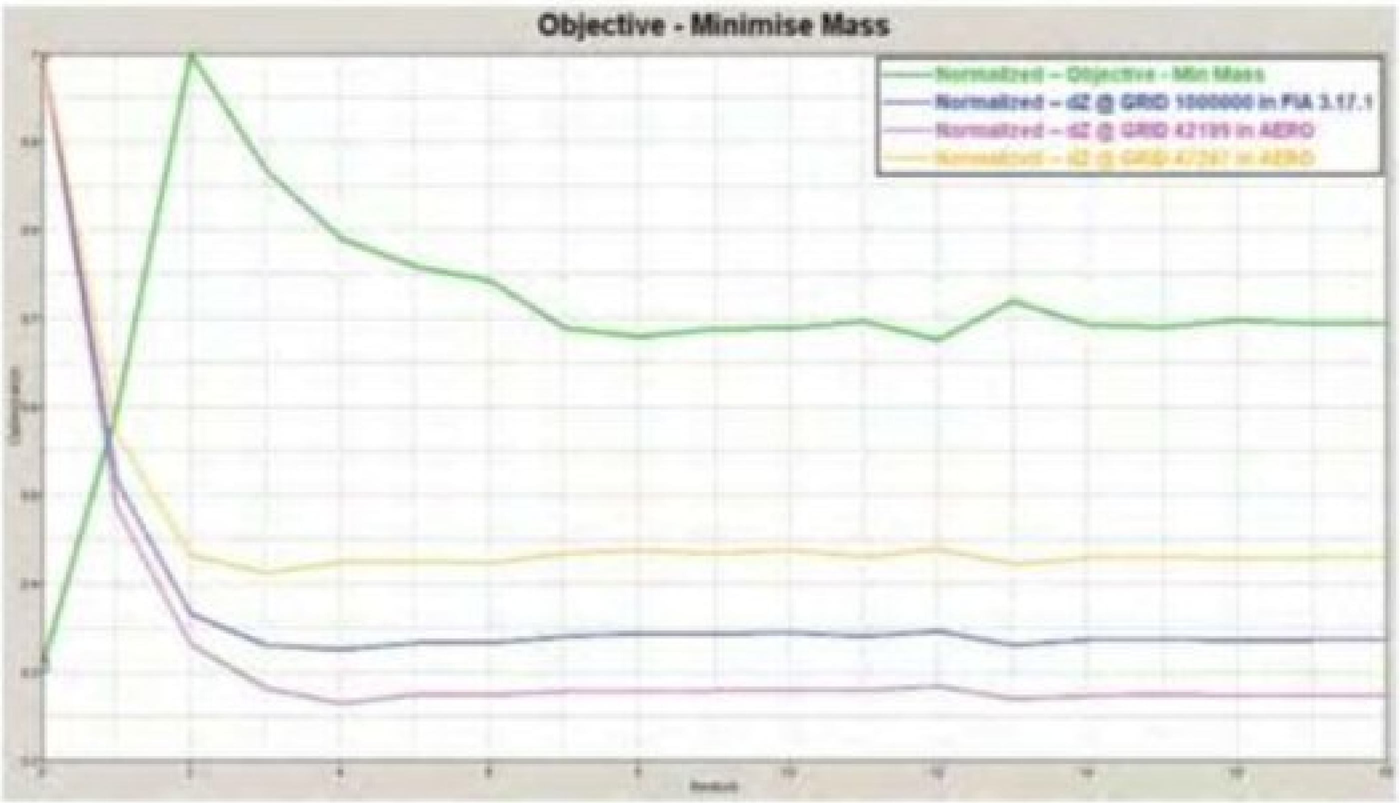


Figure 3: Normalised Convergence Curves

The traditional method of defining a laminate stack can be split into three discrete stages:

- **Define Ply Boundary (including ply orientations & differing materials)**
- **Vary numbers of individual plies**
- **Organise the stack to ensure structural integrity is achieved**

Even with this simplified process, the number of design variables and required manual iterations would be significant and very time consuming to perform. Particularly at the first stage, where different materials and orientations must also be considered for each individual ply.

The use of OptiStruct can simplify this process, and uses the same 3-stage approach

In order to yield the best results for composite lay-up optimisation it is necessary to first define the individual ply boundaries. Free sizing is used to size each ply of each individual element allowing the designer to see the best distribution of material, thus aiding in the definition of the ply boundaries. A global laminate is defined using a variety of materials and orientations with various thicknesses ranging from 0 to t_{max}. The free size optimisation aids in screening out inefficient materials and orientations.

Once the ply boundaries have been defined (by the previous step), the number of each individual ply is optimised. Move limits can be set according to individual manufacturable ply thicknesses and force the optimiser to reach discrete values for thickness, highlighting the total number of plies required.

The position of each individual ply in the stack sequence is optimised to ensure all design and manufacturing requirements are met and in some cases exceeded.

As previously mentioned, the first stage to a composite optimisation problem is the Free Size stage. With the results from the geometric study showing the significant requirement for extra stiffness, the study was limited to the use of one material as this would significantly decrease the problem size and yield a result in a much shorter time frame. Therefore the composite stack was modelled with two cloths at 45 degrees (orientation set from previous experience) covering unidirectional material

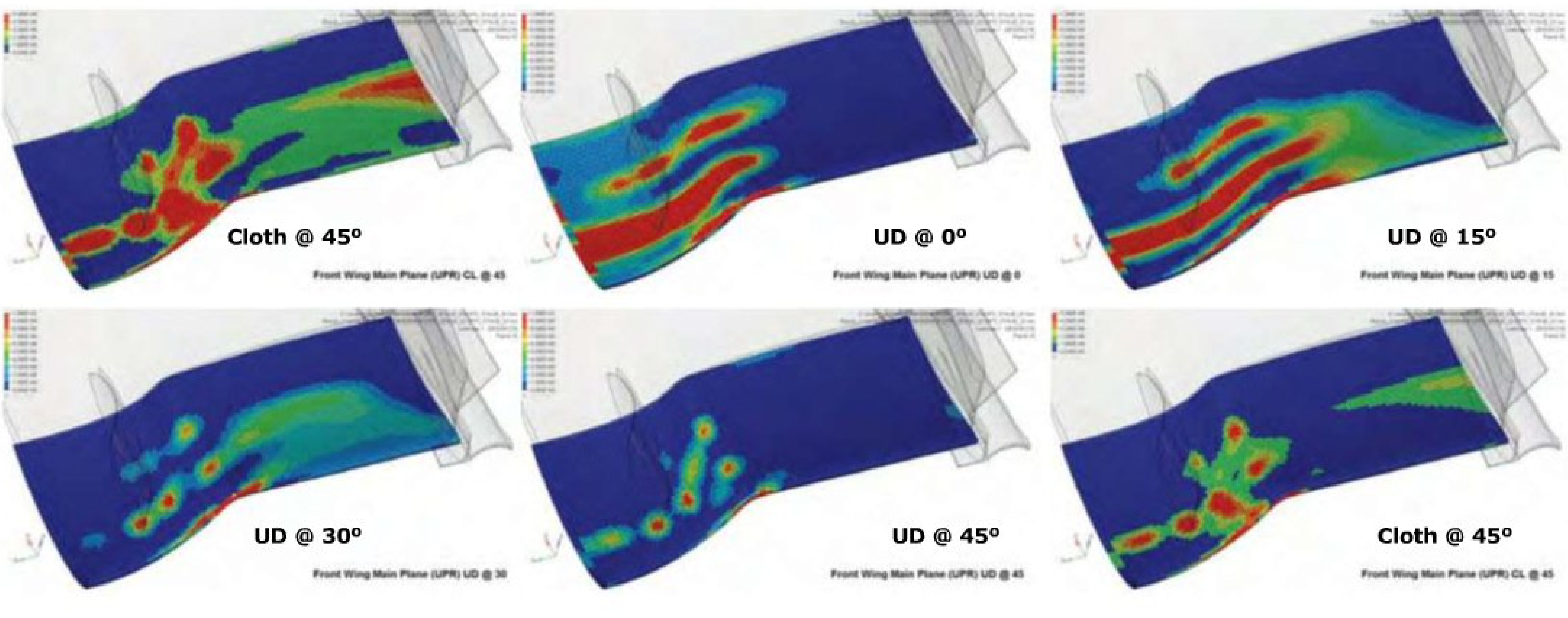


Figure 4: Element Thickness Results from Free Size Optimisation

set at 4 different orientations; 0 degrees,15 degrees, 30 degrees and 45 degrees. Each ply orientation was also given a maximum total thickness which results in 1,317,184 design variables (equivalent to the number of free size elements multiplied by number of composite layers).

Manufacturing constraints can also be set at this stage, so to avoid small patches and aid final manufacture, a minimum member size was utilised. It is also pertinent to note that SMEAR was used in order to remove any effect of stacking sequence, as this first stage is used to define efficient ply boundaries.

For the front wing, two load cases were considered using the Altair software and optimisation responses defined such that displacements due to the FIA load and aerodynamic loads were constrained, with the objective to minimise mass.

- **The analysis converged in 14 iterations (see Figure 3)**
- **Analysis time: 22mins on a standard windows desktop.**
- **Memory used 1.4Gb(in core)**
- **Mass reduced by 57 per cent compared to 2007 wing**
- **all Displacement constraints were met**

The free sizing results **(Figure 4)** show that the cloth at 45 degrees, UD at 0 degrees and 15 degrees are working hardest. This is not surprising as these orientations are directed along the load path and would help prevent bending for the FIA load case and resist twisting due to the aerodynamic loads.

As expected the UD at 30 degrees and 45 degrees are not being worked and as such require very little in the way of thickness. This result is also present on the lower wing surfaces.

THICKNESS AND STACKING

The second stage of the process involved calculating the discrete ply thickness. Again the Altair software was used. Initial calculations use ideal ply boundaries with no restrictions, later updated with rationalised and realistic ply boundaries.

Interpretation and visualisation of results for discrete ply optimisation can sometimes be complicated and

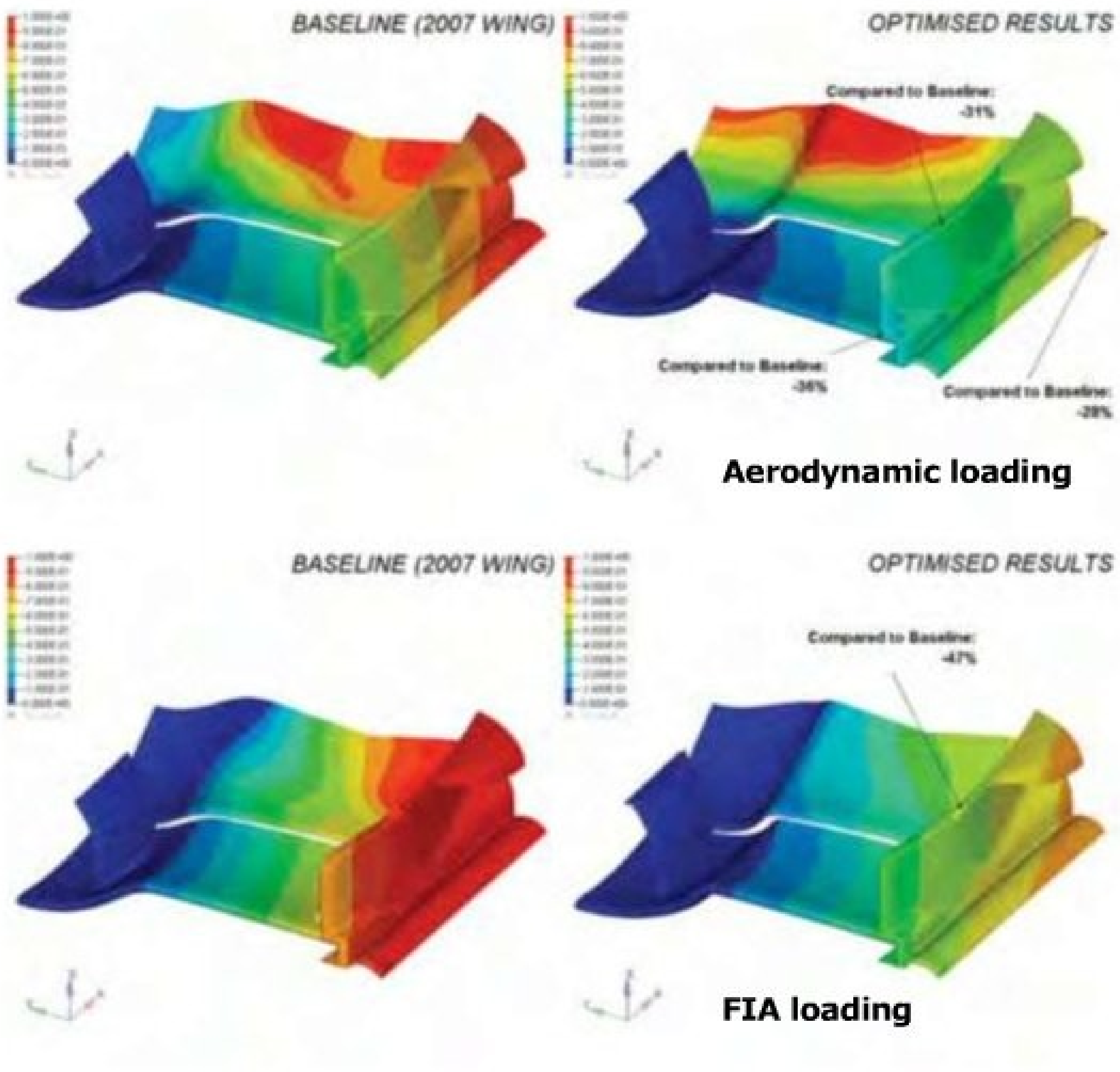


Figure 5: 2007 vs. Optimised 2008 Wing Displacements

as such an easy way to review the results is to produce a chart illustrating the number of required individual plies.

The most influential plies are the 0 degree and 15 degree unidirectional plies, which is not surprising as these directions lie on the load path, and will provide the majority of the support for vertical bending and torsion.

The third and final stage of the composite optimisation process was defining the stacking sequence. A basic lay-up has been defined, which comprises all the optimum ply boundaries, and optimum number of discrete plies. This is further optimised by re-ordering the stacking sequence while considering manufacturing details, improving the structural performance of the wing.

The process of element free size and discrete optimisation, means that the laminate stack will already satisfy all constraints previously set in the earlier stages of optimisation.

As such, the shuffle of plies only applies desired manufacturing constraints, and should improve on the previous stages. Therefore optimisation responses and objectives for the final optimisation stage were altered slightly such that the minimum mass which had already been achieved during stage 2 was no longer required. Instead, it was decided to constrain the composite failure indices only and the objective was altered to minimise a weighted compliance. The optimisation converged in 2 iterations taking 18mins using 1.5Gb to run in core.

Figure 5 shows displacement results for the fully optimised shuffled lay-up vs the 2007 model for both the aerodynamic and FIA loading regimes.

The process has produced a wing structure which meets and exceeds all design criteria

As can be seen from the displacement results, the optimisation process has produced a fully finished wing structure which meets and exceeds all design criteria set at the start of the analysis. The composite failure indices were not violated, and the largest improvement was achieved for the FIA loading showing a reduction in displacement of 47 per cent. The aerodynamic results also showed a marked improvement and exhibited deflections ~30 per cent lower than the 2007 baseline.

Despite the mass reduction being less than originally anticipated, the significant increase in stiffness compared to the baseline 2007 model justifies the optimisation given the large geometric differences between the two wings.

The original objective of the Force India optimisation study was to produce a lightweight wing structure which performed as well if not better than the baseline 2007 wing. However even before any optimisation was started the pre-optimisation geometry studies showed that the structural differences between the two wings were large and the ability to generate a lighter stiffer solution for the 2008 wing was likely to be a difficult task.

AN ADAPTABLE PROCESS

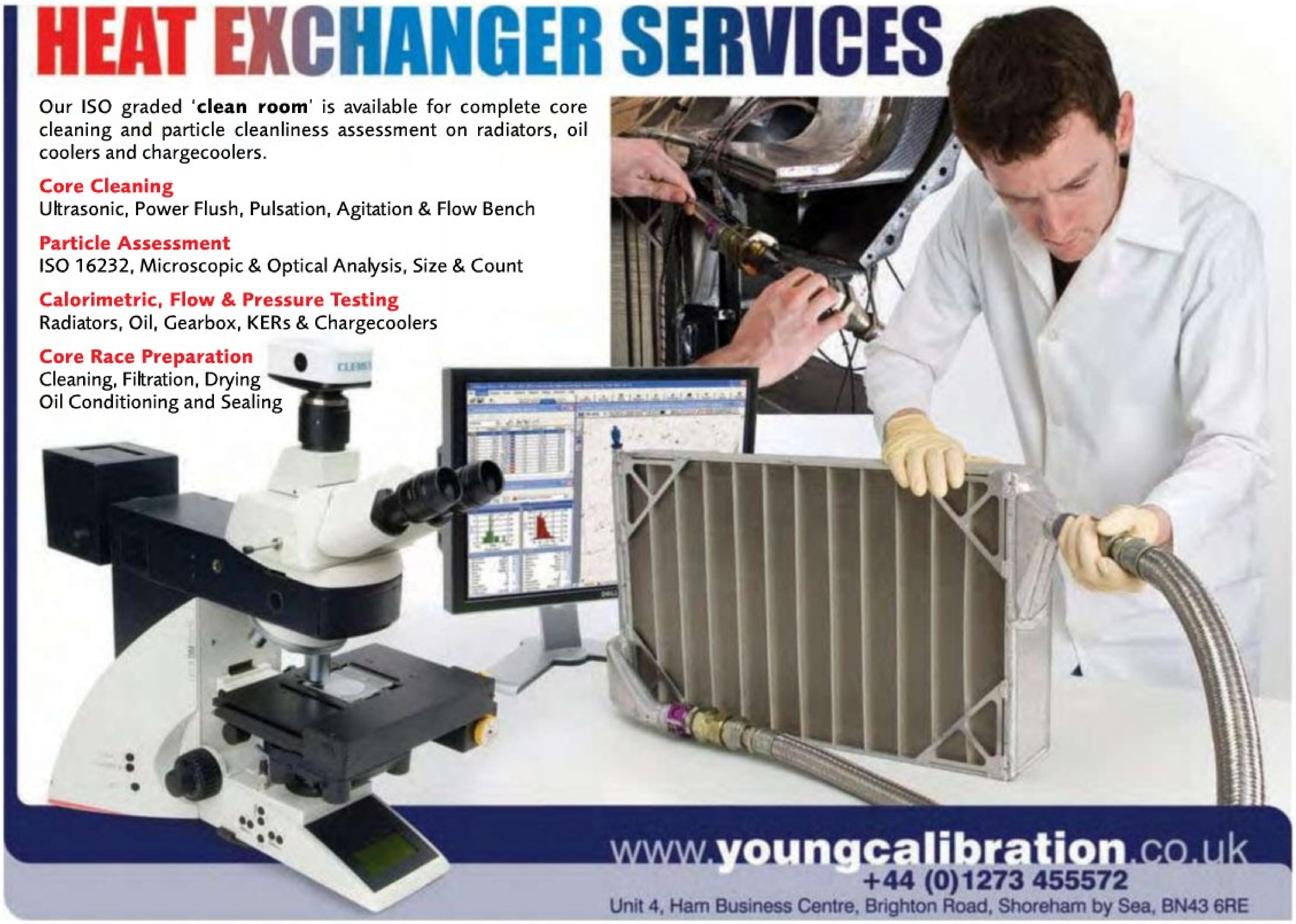
Stage 1 was able to demonstrate the effectiveness of free size optimisation in order to screen out inefficient plies and orientations, while automatically identifying efficient ply boundaries, all within a minimal time frame compared to traditional analysis methods.

Stage 2 demonstrated the ability of OptiStruct to vary the number of discrete plies while keeping to design constraints. Note that this stage significantly increased the mass of the model compared to stage 1. The difference in geometric stiffness compared to the baseline would mean larger displacements and hence larger strains. As a result the composite failure index became the significant factor in this optimisation stage.

Stage 3 further improved the laminate stack, by ensuring the stack complied with manufacturing constraints and also improved the stiffness of the model further.

The final design was able to meet all regulation displacement limits, minimise composite failure, meet manufacturing demands and mass constraints, with all being achieved in a significantly reduced time frame.

This process could also be used to ensure that a wing could demonstrate just the right amount of aero elasticity to pass the FIA tests but still deform at speed – something that has become particularly relevant in the light of events at Le Mans this year (see tech update).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Record breaker!

The Nissan ZEOD achieved a 300km/h top speed and a full lap of Le Mans in EV only mode. Here's how they did it

BY ANDREW COTTON

Nissan's ZEOD programme was unarguably the most challenging at Le Mans this year. Merely stating the bald fact the car completed 23 minutes of the race is an unfair assessment of such a milestone programme, all accomplished on a tight budget and with a small, dedicated engineering team at RML and NISMO.

Led by Frenchman Arnaud Martin, RML's head of powertrain, battery development took priority once the three cylinder, 1.5-litre, 40kg and 400bhp engine was proven. Also on Martin's plate was e-motor development and gearbox development, while RML's Software Designer got to work writing more than 250,000 lines of code for the MoTec ECU which controls many of the car's key functions.

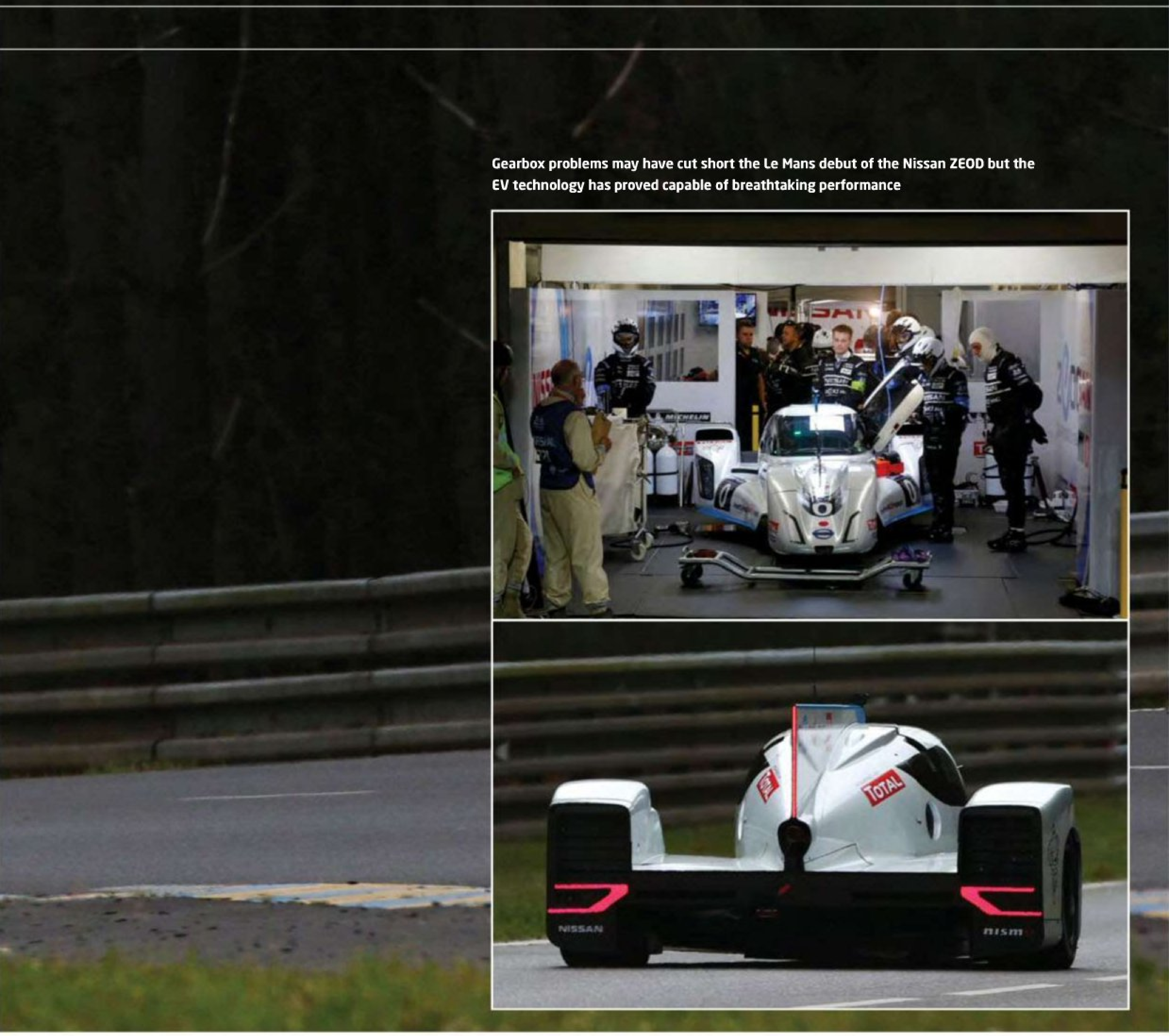
'Basically, on the battery side, lithium technology is reasonably well known, but the context that we were planning to use it was very different because of this one lap [on EV alone],' said Martin at Le Mans after the car had completed the all-electric lap, reaching a top speed of 300km/h on the Mulsanne Straight on Thursday evening.

'We had to develop the technology to be able to do this very high charging in the car, close to 100 per cent state of charge down to 10 per cent charge in four minutes. As a result, the lithium technology is being challenged. It is a very extreme case. You have to control this discharge, keep the temperature in check, cool the battery, have enough information from each cell to make sure that you prevent issues with the battery, that you know the voltage in all 672 cells, and react to your control based on the state of charge and temperature of each individual cell. When you have 8000 components in the battery, just getting a system that will be reliable is already a massive task. That is over 2800 electrical connections which all behave as one. It is a huge project.'

"Just getting a system that will be reliable is already a massive task"

RML had to practically start from zero with its battery knowledge, but quickly built up not only the best practices for working with high voltage (see sidebar), but also managed to quickly get into a development phase with the help of Warwick University, which conducted individual cell tests for charge and discharge cycles, according to a power cycle provided by RML.

It was no minor task, but the knowledge gained proved



Gearbox problems may have cut short the Le Mans debut of the Nissan ZEOD but the EV technology has proved capable of breathtaking performance

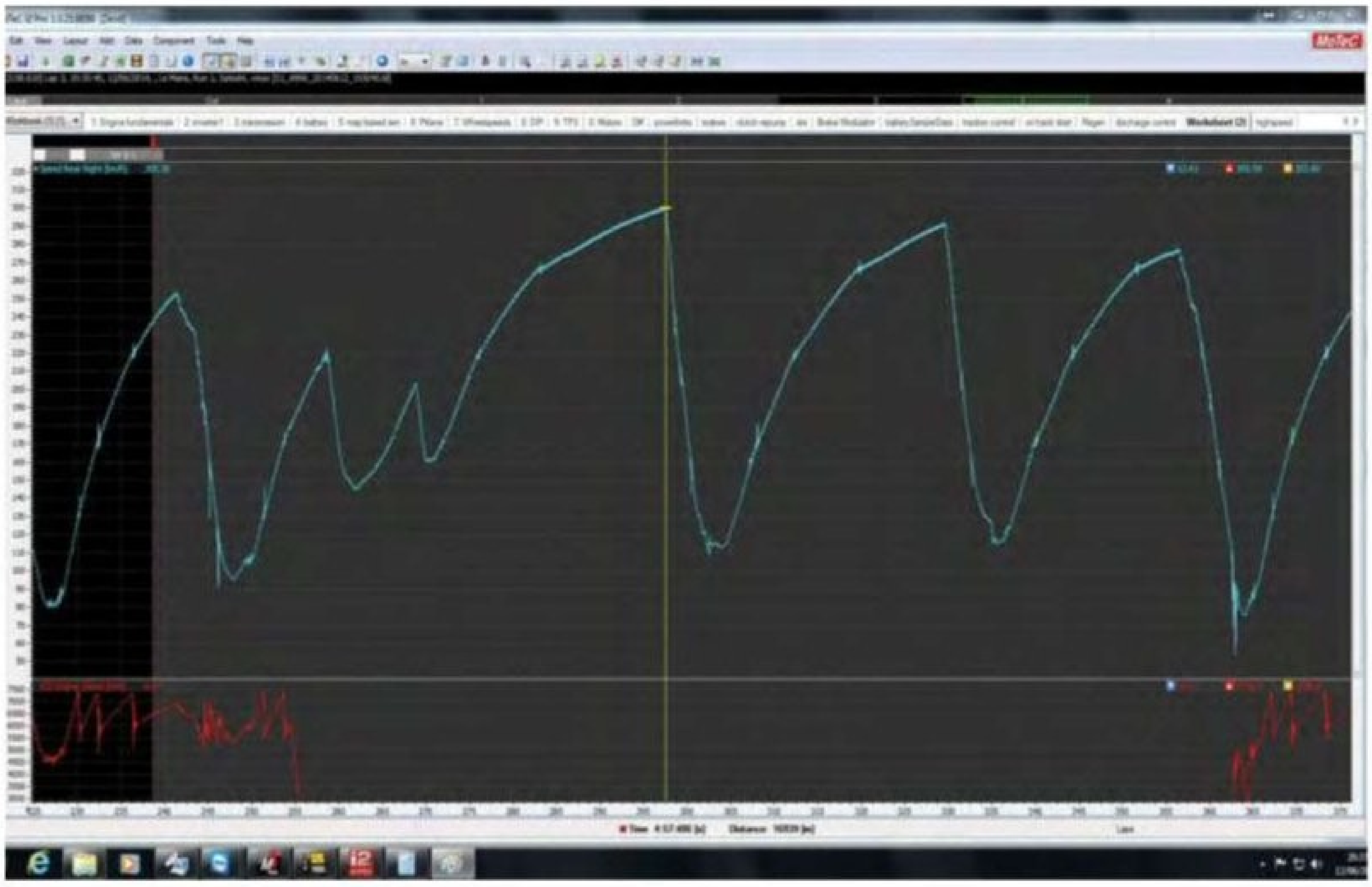
invaluable as the team prepared for Le Mans in a short space of time. 'We started by making a simulation of what we needed to achieve in order to do that lap in terms of car speed,' says Martin. 'Then we looked at the cell technology, the one that was more suited within the minimum amount of weight, energy and power density. Then we took some sample cells that we submitted to the same cycle that the full 672 would be submitted to in the car, so that we could validate what the temperature rise was going to be in the battery, whether we could draw the energy out, how many times and how fast we could do the cycle. That was all done at Warwick University. That's how we gained the confidence that we were not aiming for an impossible task.'

The team was faced with something of a dilemma – does it run a fast portion of a lap at Le Mans at LMP2 pace and use the energy more quickly causing the cells to reach their temperature limits, or aim for a plus four minute lap, GTE-Am pace, and reduce the load on the battery. The team went for the longer lap time, managing the temperature of the batteries at below 60degC.

'We are trying to keep the cells below 60 degrees, by choosing to generate a maximum of 253Nm of IC equivalent torque,' said Martin. 'The idea [of limiting the lap speed] is that you have to consider that in the internal combustion engine we are running 360Nm of torque, but on batteries we are looking at 253Nm. By reducing the straight line speed, you are reducing the amount of energy required to complete the lap significantly. If you draw any more than this torque, you end up with the cells heating up to the limit. If this was the case you would have to shut down the battery to avoid thermal runaway, which is not a good advertisement!'

"You have to shutdown to avoid thermal runaway, which is not a good advertisement for lithium"

The team partnered with MoTec for the ECU, and with Minnesota-based MTS for the e-motors that delivered the required power on EV and which helped to make the records possible. The ECU is an off the shelf MoTeC product on which RML wrote its own code to control the entire car, but more specifically on the battery side to control the power reduction based on cell temperature and energy, the battery shutdown based on temperature, and maximum and minimum voltage.



The data capture shows speeds in EV only mode with the record-breaking peak of over 300km/h. The red trace at the bottom shows the petrol engine shut off and restart points

Controlling the battery itself is like controlling an engine. The ECU also controls more fundamental parts of the car, including the brake balance system, the clutch, DRS, internal combustion engine, and the e-motors. When setting up the project, Martin had pinpointed the ECU as one of the key points in order for the project to be remotely feasible.

HEAT BUILD-UP

'We struggled in the early days with battery leaks because it is dielectrically cooled, with poor sealing methods,' says Martin of the development process behind the batteries. 'The inter-connection between the cells is a very important parameter in terms of battery behaviour and efficiency – if you don't do it properly you have a build-up of heat due to resistance – so there was a steep learning curve in that area.

'The main thing was how to calibrate the ECU parameters to control it. What voltage can you go to without damaging the battery? What are the temperatures that are acceptable? This is very difficult to establish, because technically the only way that you find out is when you encounter a thermal runaway… and you are trying not to burn the car.' says Martin, wryly. 'With hindsight we needed to set up a test where a small number of cells got submitted to extreme temperature in order to define what is safe and what is not. At the moment we are within what we believe to be a safe limit, but the car is still not fully developed.

'We would like to get to a point where we can literally kill a battery, where we know exactly where we can get to. You can do it out of the car, but you want it to be representative [of racing conditions]. Then you can learn.'

The car was first presented to the public in Fuji for the World Endurance Championship, and the roll out was something of a disappointment. The car swept past the press box at low speed, and then didn't come back. It was not the full lap of the track that had been promised, and was not even what the engineers had hoped to achieve. Although observers were disappointed, it demonstrated just how far the programme had to go before it was ready to tackle Le Mans, and a full EV lap.

'We ended up not using the right battery, because we had some issues with it,' said Martin of the Japan debut. 'The battery development required was underestimated originally. We are now on evolution six of the battery, and the first was built in September last year, so it was a very fast development phase. We never lost an entire pack, but through the validation process you always ended up losing a few cells. If you lose a cell, for example by reaching a state of charge that is too low, you would not only lose this one cell, but in effect your entire battery. From the time you cannot see one of the 672 cells you cannot control the battery.

"We are now on evolution six of the battery, and the first battery was built in September last year"

'Alongside that was the development of the e-motor. We were developing multiple systems in parallel. We were effectively developing the e-motor side, the battery side, the ICE and the gearbox all at the same time. Any one of those would stop you from running. None of them were simple.'

The gearbox was built by Hewland to a set of specifications provided by RML, and it was RML which undertook the development work. The car stopped at Le Mans on Wednesday night with a gearbox issue, and it was this same part that stopped them running during the race, in the first hour. This was the first time the failure had been encountered and there was not enough time to remanufacture and validate parts before the race.

However, by then, the team had achieved its stated goals; to run at 300km/h on electric power only, and complete a full lap at Le Mans on battery power alone. The team never had the chance to complete a full lap of Le Mans once each stint, which was the ultimate goal, but by then the car had already sealed its place in the history books. That was, says Martin, in no small part thanks to e-motor supplier MTS.

'It is essentially a motor with much lower inertia than the one we had started the project with and a much better control system. As a result, the way we control the motor from the ECU has been improved massively. We have managed to get a motor that produced the power, which behaved as we wanted it to. So between the MTS knowledge and software writing, and ours, we have been able to develop at an incredible pace.'

ECU SOLUTIONS

'On Wednesday we were still fixing a problem with the e-motors on the rolling road at Le Mans. Mike Newton and RML developed a system to log into a MoTec ECU to see what was happening to the phases inside the motor, so we were able to analyse on the fly what is happening. Which is why the software side of things, and Mike's system for logging these things, meant we could solve the problems very quickly.

'With the earlier motors I had learned enough to know that what MTS was proposing was the solution. We even designed our own controller in order to support the MTS. MTS is an e-motor specialist and software specialist, and they use RMS based controllers. We effectively re-installed an RMS controller in a dual inverter package with our own implementation, our own

chassis implementation and so on. It was achieved in combination between our electronics and our mechanical powertrain designers.'

The team's upgrade battery for the race was held up in customs in the US and never made it to the track, leaving RML to run the battery used in crash testing. 'The new battery has better cell interconnection and an indirect cooling system using water as the coolant. Although the orginal battery concept we used at the test was not far off.'

Armed with all the learning of RML in battery technology, Nissan will embark on an LMP1 programme that will utilise the knowledge and carry the technology forward. With another year to develop the concept RML believes it could have had a reliable car.

Rarely seen view of the engine in situ with rear suspension and radiators

As it is, the immaturity of the technology meant that the car didn't even complete the first hour of the race, although it was conventional components that let it down.

'If you are planning to do batteries in LMP1, the control side is similar, cell technology is similar, you just have to downsize it,' says Martin. 'As you use the cells for 20 second bursts, it makes the control much more straightforward and allows you time to cool the cells down.'

Having gone through the pain, RML is capable of driving an EV programme forward.

HIGH VOLTAGE HAZARDS

Dealing with high voltage technology is no work of the moment. As Audi's Ulrich Baretzky pointed out, a hot engine will burn your fingers, an electrical failure could kill you. RML developed up a system of working to ensure the safety of its workers when dealing with high voltage systems.

'We have learned from a company point of view how to deal with the safety side with the high voltage hybrid cars,' says RML's head of powertrain development, Arnaud Martin. 'When we set off on the project, we quickly looked at health and safety, what was best practice in terms of HV systems. We worked with a company called Sterling Power to setting up an HV management system within the company. We trained up the employees in a basic level of HV knowledge. No one can come to the area that is HV without this basic level of training.

INVESTING IN SAFETY

'Then, everyone who is able to work on the project has another level of training, they become 'competant'. Then we have a third level, HV supervisors like mechanics, who manage people working with HV systems. They are called 'SAP', and then we have this super type of employees, who were live trained, who were allowed to sort out problems on a live 400V system.

'Everything has been defined beforehand, you have documentation that you follow to ensure you do the work safely. It was a massive investment in 110 employees, but it was necessary. It was all developed specifically for RML, based on a recommended set of instructions from Sterling Power.

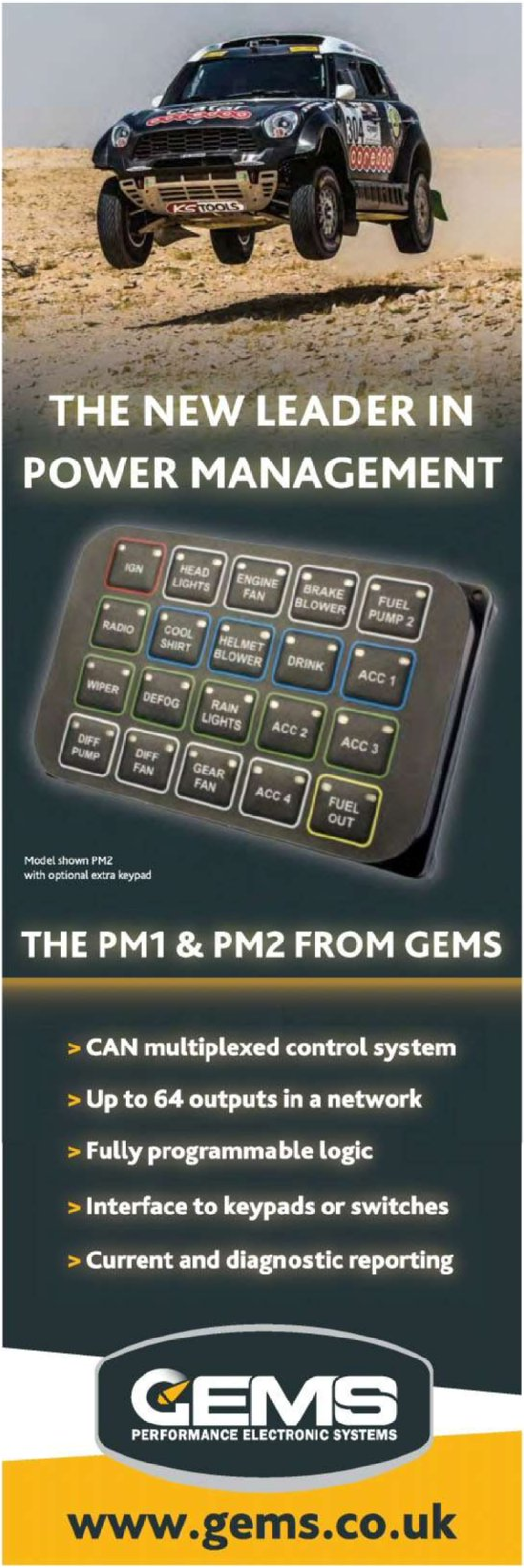
'It is a process that you can reapply to any project. Take the example of putting the battery in and out of the car. There is a specific set of documentation that needs to be filled in before you start it. You have to be sure that the people doing the work, despite being asked to do the work, have witnessed that the battery they have been given is safe, so that they know that they are not put at risk. When the battery has been proved safe a mechanical key is locked in a multikey safe, and all of the people in the work party are given one of these keys. That way until all of the people have returned their keys, there is no way that the car can be powered up. The battery is being monitored by the ECU, the insulation of the battery is known, so if anything is going wrong, it will tell you that it has all gone wrong.

'When the battery is in the main RML building it is always connected to an extractor winch to ensure that it can automatically be removed if things take a turn for the worse. As we developed the system, we gained knowledge of the car, and found that the ECU does a very good job. The ECU controls the green safety light system. When you are in the garage and the battery is in (and it is only rarely in, an hour before the session and an hour after the session), it is brought in from a container where it is stored safely and is monitored by the ECU. The period when the car is live is kept to a minimum; the area is cordoned off, and only those who have signed to the work are the ones that are allowed in the area. That is how you keep the safety at that point.

"It is not the size of the battery that will kill you, it is the voltage"

'When we were at the test day, we were going through scrutineering, I spent half an hour explaining to marshals what the car was and how the safety systems worked. They started to ask questions so we were there for a long time before the test. I was explaining how the car works, how the system works, how to make it safe, and although they initially thought that it was a big battery, they realized that it is not the size of the battery that will kill you, it is the voltage, and you look at the capacitors in the Toyota, the battery in the Porsche, they are just as dangerous as our bigger battery. The safety systems are the same, and the way we check things is the same. We probably spent more time explaining the safety side of the Porsche and the Toyota than our car. The only reason they were worried was that the battery was bigger, but it is still as dangerous. It is the same. The perception is very different.

'Out on track, you can have a loss of insulation, and a part of the HV system might have made a connection to the chassis. Nothing happens, because the driver at that point is insulated from the ground. He is not under any risk. The problem is for the marshals. If there is any is a break of insulation, the car will show it with the red light, and that means that from the time you have a red light, the marshals know that to touch the car they need the right personal protective equipment. The drivers know that to be safe they need to jump out of the car, so at no point are touching both the ground and the car. The major risk on track is if you have thermal runaway by internal shortage, and at that point you really have a problem. The risk is not shock, it's fire. You will have a short, a massive release of energy very instantaneously and the cell will go into thermal runaway. The fuse will hopefully save things, but the short can be before the fuse in the system. The battery is designed to make sure that doesn't happen, but you never know.'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XADO's Revitalizant technology is utilised in motorsport applications such as UK Formula Renault, the Paris to Dakar Rally, and in the Mazda MX-5 Supercup by current 2014 Champions Michael Comber Racing

The power of protection

Friction and heat are two of the engineer's most insidious enemies in the extreme environments created by motorsport. Coatings technology is coming to the rescue

BY GEMMA HATTON

If an F1 car was assembled 99.9 per cent correctly, 80 components would be in the wrong place. Its deceleration under braking is similar to a road car driving through a brick wall at 300mph. At maximum speed the engine ingests 0.4kg of air per second - equivalent to inflating 600 balloons in one minute. Welcome to the extremities of motorsport. The consequent stress, heat and durability demands placed on components exposed to these punishing environments are astronomical, and the hunt for materials with the lowest wear and thus, highest efficiency, will forever continue. In the meantime, current materials used need protecting which is where the technology of coatings and surface treatments comes into the limelight.

2014 TAKES THE HEAT

This year's Formula One ERS (Energy Recovery System) stores ten times the amount of energy of the 2013 KERS; doubling the power generated to 160bhp for 33 seconds per lap. Of course, the laws of thermal efficiency ensure that there is plenty of wasted heat energy, and units such as the MGU-K now generate three times the amount of heat created by the 2013 KERS, requiring materials to withstand even higher temperatures.

Avoiding thermal damage is an issue throughout the car with brake temperatures reaching 1500degC, exhaust gases at 1000degC and cockpit temperatures of 50degC. However, with the innovative coatings that world-renowned firm Zircotec has developed since 1994, protecting materials from heat has never been easier.

'We believe coatings offer a performance gain not yet exploited and we are working with teams in every category of sportscar racing,' explains Peter Whyman, Zircotec's sales director. As well as doubling the amount of coating work Zircotec does for F1 (due to 2014's new turbochargers and ERS demands), 60 per cent of the BTCC grid utilises one of their technologies, while the WEC and GT racing sectors use more Zircotec products than ever before. Teams in NASCAR, BriSCA F1 Stockcars, classic racing and Formula Student all use its exhaust coatings.

Units such as the MGU-K now generate three times the amount of heat created by the 2013 KERS

PLASMA-SPRAYING

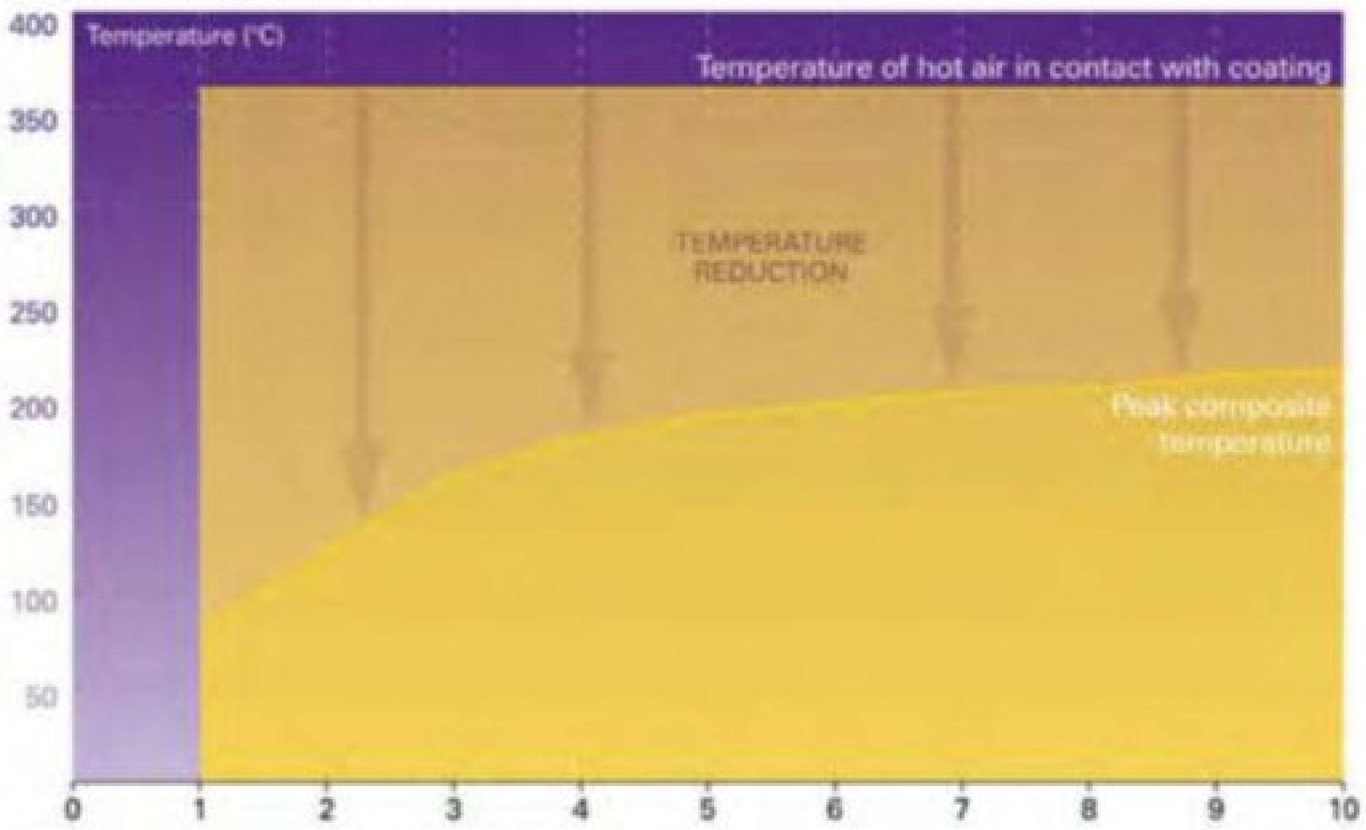
One of the major benefits to Zircotec's coatings is the fact that it is effectively 'welded' to the surface of the component by a plasma-spraying process, yet is flexible enough to cope with vibrations. Plasma-spraying is a specialised high temperature industrial process which uses electrically generated plasma (ionised conductive gas) to melt the feedstock material (the materials being plasma-sprayed) at 10,000degC which is usually in the form of powder or a wire within the plasma torch. The small molten droplets are then propelled towards the target material via a carrier gas, where they flatten and rapidly solidify; adhering to the material. These flattened deposits are only micrometres thick and hundreds of micrometres laterally. The nanoscale structure of the coating is determined by the small voids that occur between the deposits which either trap air or the carrier gas as they cool, leading to rapid crystallisation and large grain size. Small micro-cracks and regions of incomplete bonding also affect the structure and can occur under particular plasma-spray conditions resulting in the deposited material exhibiting different characteristics to that of the feedstock. Parameters such as nozzle design, plasma gas composition and feed rate all influence the interaction between the feedstock with the plasma jet and substrate. Zircotec have exploited these variations in parameters to develop their own in house method of plasma-spraying which was first developed within the UK nuclear

Zircotec's Performance White coating utilised on the exhaust system of historic cars

industry when Zircotec formed part of the UK Atomic Energy Authority. This enables them to tightly control the parameter variations to achieve the desired material structure for specific applications. Plasma-spraying can also be used to generate free standing parts made just from the plasma-sprayed material in the form of plates, tubes and shells as well as powder processing. Parameters such as nozzle design, plasma gas composition and feed rate all influence the interaction between the feedstock with the plasma jet and substrate.

One type of coating unique to Zircotec is the ThermoHold GOLD, which is a high performance heat shield material designed specifically on use of carbon composite, fibreglass and plastic parts. It offers high levels of radiant and conductive heat protection through the use of real 24 carat gold on the surface for up to 98 per cent infrared radiation reflectivity, whilst the underlying ceramic-based insulation layers minimise heat conduction to the substrate. As the coating itself is only 0.2mm thick and adds a minimal 750g/m² to the surface, it allows carbon composites to now withstand harsher environments and be used in new areas of the car.

Typical Application



Exposure time in minutes

A graph showing the effectiveness of how the coating deals with heat

EXHAUST COATINGS

Turbocharged engines experience higher temperatures due to the hot turbo housing and increased pipework to direct the exhaust gas through the turbocharger. To reduce the amount of heat dissipating into the engine compartment, the exhaust and hot side of the turbo can be ceramically coated, which results in reductions of over 50degC in the engine bay. Not only does this lead to increased reliability and safety, but sensitive electrical components can be protected, and the risk of fuel vaporisation is reduced. 'Coating the turbo not only traps the heat inside, but also helps it to spool up quicker, reducing lag and improving throttle response,' points out Whyman. This performance gain may not be achieved so effectively with other methods such as wrap solutions which often become brittle over time and can soak up oil. Wrap technologies also require more space, restricting the airflow.

For the exhaust, Zircotec's Performance White is often used, as pictured on Nick Mason's 512 Ferrari, and Lola. 'We have coated parts for a number of Nick Mason's Ferraris. They like the blend of a period look for both texture and colour and a technology that is fit-and-forget,' explains Whyman. In addition to withstanding temperatures up to 1,400degC, being only 0.3mm thick and increasing component life, the surface temperature of the coating cools dramatically when the engine is switched off; making pit stops easier, safer and faster.

'GT3 racing is a category where our coatings help to manage heat within the tighter confines of the production-based class,' says Whyman. An example is David Appleby Engineering, which runs a Bentley Continental GT3 under the Generation Bentley banner and uses Zircotec coatings for composite parts protection. 'The exhaust is in very close proximity to the bodywork on the Bentley,' explains James Appleby 'especially the sidepipes which, in common with many cars of this type, run through the composite sills. Without the Zircotec ceramic coating, we found that the resin cooks, resulting in delamination and discolouring. Heat also found its way into the cabin. The coating has prevented discolouration and is an effective thermal barrier.'

The effectiveness of Zircotec's coatings is displayed in the pictured graph, which illustrates how the temperature of a carbon composite coating varies over time when in contact with hot air. There is a large temperature reduction which equates to a 33 per cent drop in surface temperature in some cases. In fact these coatings are so effective that coated parts can now withstand temperatures higher than the original materials melting point allowing them to be used in even harsher environments in the car.

"Coating the turbo not only traps the heat inside, but also helps it to spool up quicker"

SCIENCE FRICTION

Tribology is defined as the 'science and technology of interacting surfaces in relative motion,' and in 1966 Dr Peter Jost published a report highlighting that the effects of friction, wear and corrosion were costing the UK approximately £515 million per annum. 'For every $1,000 invested in tribology research and development, savings of $50,000 per year could be reasonably expected in two years time - not a bad investment, one might say,' explained Jost in a recent interview. From separate surveys conducted in Germany, USA, Canada, China, UK and Japan, each country concluded that investing in tribology could save up to 1.4 per cent GDP (Gross Domestic Product). This led to several national tribology centres set-up around the UK which formed the driving force behind the progress in technical understanding over the last few decades of the effects of friction in engineering.

In motorsport, the phenomenon of friction can be utilised to be a hero (for example the principle behind braking) or the enemy (the cause of tyre wear). However, it is most

XADO's extensive range of products includes engine treatments, fuel treatments, flushes, greases, metal conditioners and much more

often the latter, and engineers work tirelessly to innovate new materials and technologies that beat the effects of friction. 'However it is now possible not simply to mitigate these effects, but to actually reverse them,' explains Nicholas Buckle, sales director at XADO which markets a range of products which recondition any friction exposed surface, particularly in the engine. 'We do not simply add a layer of new material on top of the existing structure, instead we create a new CERMET (ceramic metal) surface, bonded at the molecular-level on the worn substrate, which gives the components a much smoother and therefore lower friction surface, and an incredibly tough finish (with a Rockwell rating of 320) which means that future wear is significantly reduced.'

ATOMIC BOND

XADO-patented Revitalizant is completely unique in the sense that it is not a lubricant additive because it does not change the viscosity or characteristics of the lubricant, it simply uses the lubricant to initially deliver XADO to the moving parts of the engine. As the Revitalizant passes over friction points and surfaces, the heat and pressure in these areas triggers a nano level reaction, which removes and cleanses any non-metallic matter present on the friction surfaces. The revitalizant then acts as a catalyst to activate the process of carbon absorption by the surface layer and results in the formation of metal carbides. The continued heat and friction causes the carbides to atomically bond with the microscopic metal particles suspended in the lubricant and so incorporates these particles back into the main metallic structure, creating a CERMET coating, which is three times harder and stronger than the original surface. The reaction itself reduces friction and thus heat between the surfaces and as the heat diminishes the reaction stops and the required depth of CERMET is left on both surfaces.

XADO's Revitalizant is unique because rather than simply adding a new layer on top of the original surface for protection, a new CERMET (ceramic and metal) surface is created and bonded at the molecular level

'The creation of CERMET has three primary effects on an engine,' explains Buckle. 'It significantly reduces internal friction in the cylinders, increasing compression and making the engine more fuel efficient, simply because less fuel is required to counter the friction forces. This also means a reduction in vibration and the level of harmful emissions. The XADO technology further improves the longevity of the engine, because not only is existing wear refinished, but the new surface is much harder than the original metal and will wear more slowly. It has been shown possible for the CERMET coating to last up to 60,000 miles.'

The Continental GT3 uses Zircotec's composite coatings to protect parts

XADO products have been used and proven in severe environments, such as the Paris to Dakar Rally, American Hot Rod Circuit and European Rally Cross, as well as UK Formula Renault and the Mazda MX-5 Supercup series raced by Michael Comber Racing, who are currently leading the 2014 championship. 'Rather than hone the engine or even complete a rebore we decided to try the XADO treatment,' explains Michael Comber. 'You warm the engine, pour it in and tick over for five minutes. We checked the engine compression before and after and on both engines they raised by at least 10 per cent.'

Whyman concludes; 'Ceramic coatings have been around for a while but the application process requires the parts to be individually coated using a laborious heat process, whereas XADO is unique in that it can do this in situ, dramatically reducing engineering costs. Mazda has used CERMET engine coating technology in endurance racing, winning in their class. We would like to think that Formula 1 and other motor racing championships would also embrace this technology.'

"The new surface is much harder than the original metal and will wear more slowly"

AMARI TRACKING

Amari Aerospace is a division of Amari Metals, and specialises in the supply of semi-finished metal products such as bar, sheet, plate and forgings to the Aerospace, Defence, Motorsport and High Tech industries. To maintain its position as market leader, the company has recently invested in enhancing its part-marking capabilities to enable the traceability of parts as the demand for processed Aluminium Plate and Bar rapidly increases. 'Accurate and efficient part marking is essential in order to maintain identification on all processed materials,' explains Dave Enright, General Manager of Amari Aerospace. 'Every single cut bar or plate billet produced by Amari is individually etched with critical information necessary to ensure the material reaches its machining centre with complete traceability'.

To achieve this, Amari has purchased a variety of machines from Telesis that etch flat surfaces. The necessary data required on each part is translated into bar code by Amari's main operating system; this is then printed on each customer's order and is scanned into the marking system at the point of processing, eliminating the risk of operator read or typing errors. All Amari's marking systems are fully capable of marking not only alphanumeric characters but also company logos. Information can be translated into 2D data matrix or QR codes. This allows for the storage of significantly more information on cut billets, no matter how big or small.

'Amari is currently working with customers to implement suitable scanners and software, again eliminating human error in reading the data and allowing customers to utilise the 2D code marking to book material into 'Direct to Line' feed processes.'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On the rebound

Damping Ratios and State Space Analysis revisited

BY DANNY NOWLAN

One of the really great things about what I do is that from time to time I get asked some good questions about vehicle dynamics. In particular I had a customer ask me about how to tie damping ratios and state space analysis together to specify a damper curve. I have written about both of these disciplines extensively. However I was somewhat remiss in not tying them together. Well, thanks to that customer, I'll be spending this article tying them together because it's something we can all learn from.

Firstly, we'll discuss the origins of damping ratios and what state space analysis is and where this all comes from. We'll then apply it to a quarter car model based on F3 numbers. The reason we are discussing the quarter car model is to keep things simple. However the techniques and insights we'll bring to light are applicable to the bicycle and full car model. Also to make things simple we'll be talking wheel rates and linear damping rates. We are doing this to make the analysis easier so you get the point about how to use this.

To kick off this discussion, let's discuss the origins and the applications of damping ratios. To start, consider the classic ¼ car model of a suspension system. This is shown in **Figure 1**.

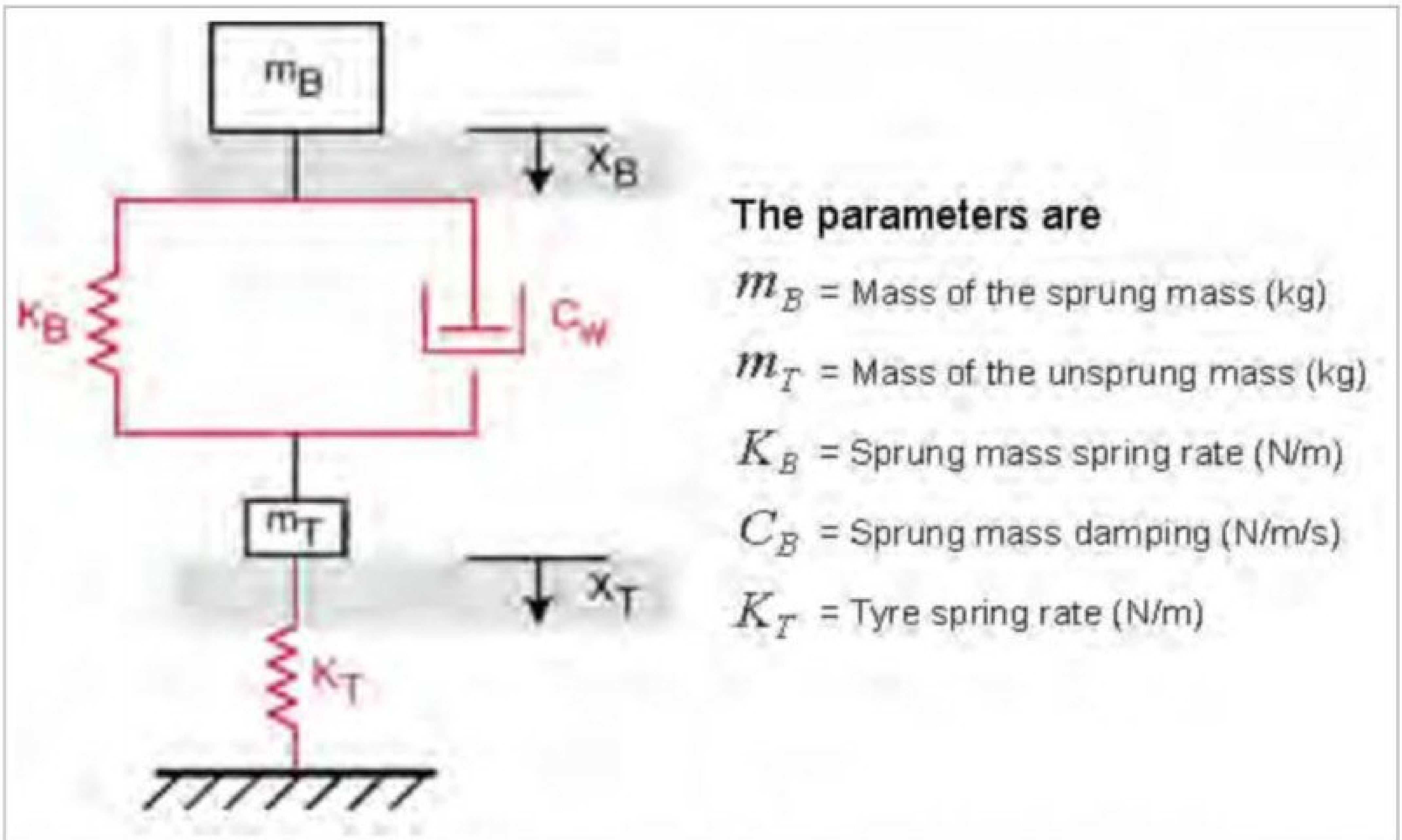

Fig - 1: Standard ¼ car model

The power of the ¼ car model is that, while it doesn't represent the full physics of the car, it non-the-less provides a powerful tool for understanding what is going on with the suspension. As a further simplification let's assume **Equation 1**. In this case the governing equations of the sprung mass reduce to **Equation 2**

The power of **Equation 2** is that a Laplace transform can be applied to describe the spring damper system by a natural frequency and a damping ratio. Applying the Laplace transformation to the spring damper system shows **Equation 3**.

It is useful to compare this equation to the ideal second order system with natural frequency and damping ratio, as shown in **Equation 4**.

When **Equations 3 to 4** are compared, we now have the tools to specify our desired damping rate in terms of damping ratios and natural frequency **Equations 5 and 6**. This is the first point of the analysis. **Equation 5** specifies the natural frequency in rad/s of the system, and **Equation 6** means a damper rate based on the damping ratio that is desired can be specified. Please note the spring rate is specified in N/m and the mass is specified in kg. What this means is that we can now specify a damping rate based on what we want the system to do as opposed to guessing. Also because of the form of **Equation 6**, this can be readily applied for both the front and the rear.

Now that damping rates can be specified the next step is to choose the desired damping ratio. To consider this, let's consider a typical second order system response to a step input. This would be equivalent to a driver giving the steering wheel a sudden jolt. See **Figure 2**.

EQUATIONS

Equation 1

$$K_B << K_T$$

$$m_t << m_B$$

Equation 2

$$m_B \cdot x_B'' = -K_B \cdot x_B - C_B \cdot x_B'$$

Equation 3

$$0 = s^2 + \frac{C_B}{m_B} \cdot s + \frac{K_B}{m_B}$$

Equation 4

$$0 = s^2 + 2\zeta \cdot \omega_0 \cdot s + \omega_0$$

Equation 5

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

Equation 6

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

It goes without saying that the results we have presented show you what a big impact dampers have on the behaviour of the race car

What this shows is that the higher the damping ratio the better controlled our system will be to a sudden input. However as the damping ratio drops the sprung mass will oscillate. This isn't ideal for body control but it is the behaviour that is needed to absorb shock loadings like traversing bumps or kerbs. From this, two very important relations can be shown,

$\zeta \geq 0.5$ **Is ideal for body control.**

$0.3 \leq \zeta \leq 0.4$ **Is ideal for bump control**

Armed with this information the damper ratio selection guide can be shown and this is illustrated in **Figure 3.**

What is presented is what the ideal damping force vs peak velocity curve would look like.

The damping curve is broken up in to the traditional low speed and high speed regions. In low speed bump body control is critical. Consequently the ideal damping ratios are 0.5 to 0.7. If the tyres really need to be worked hard then 1.2 is chosen. As always tune the damper to the conditions that are appropriate. If the circuit is bumpy then the low end of the damper guide in Fig 3 is applied. If the circuit is smooth then larger damping ratios can be used. As always remember this is a tool. Consequently it must be used appropriately.

There are pros and cons to the damping ratio we have just discussed. The big plus of what we have just discussed is that this is a great hand calculation to add to any excel setup sheet.

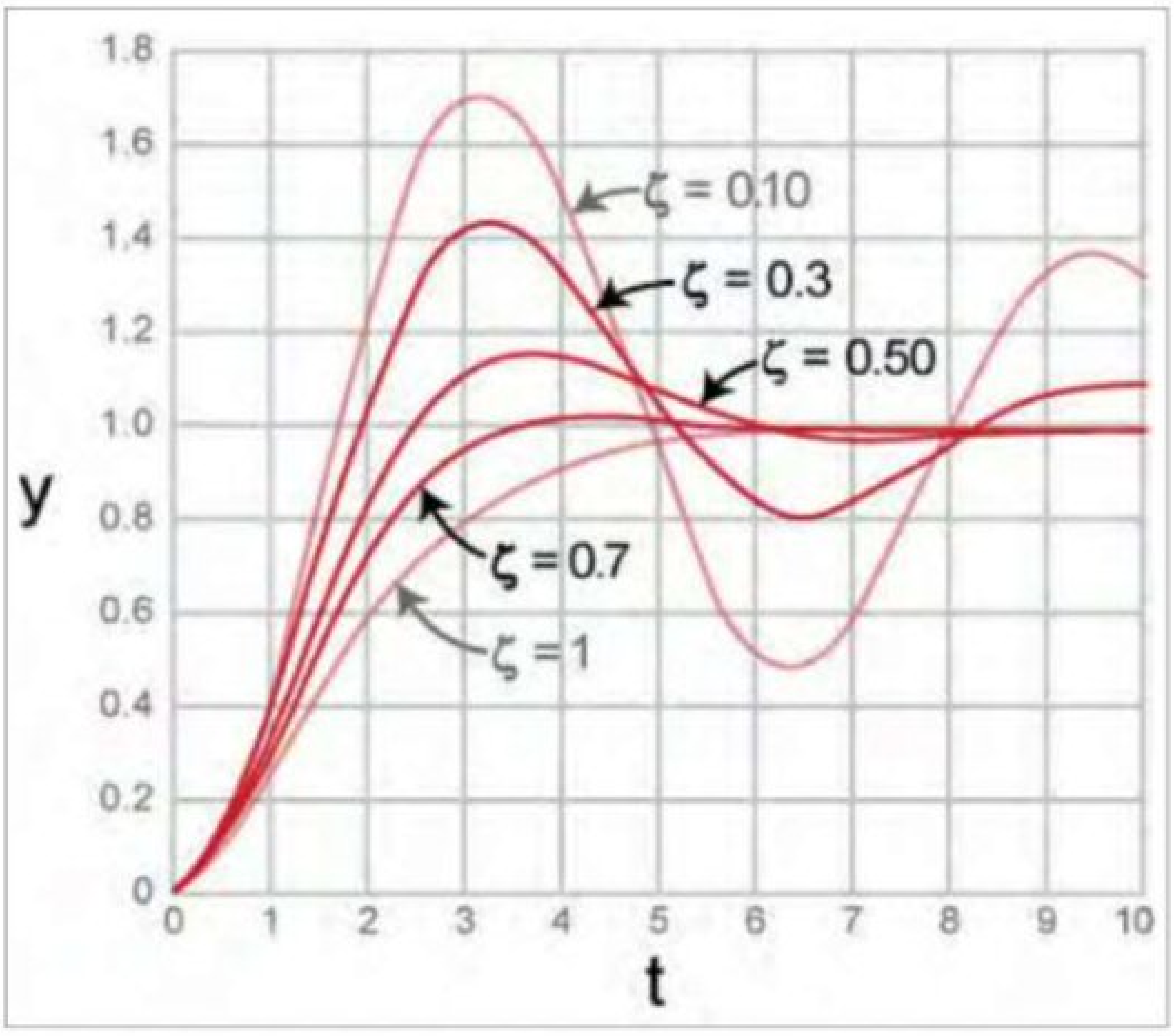

Fig-2: Idealised second order system response to a step input

Region	Value
$\zeta_{LS-Bump}$	This is body control so, if it is a bumpy circuit the ratio is 0.5. If the circuit is smooth choose 0.7. If the tyres need to be worked hard then choose 1.2.
$\zeta_{LS-Rebound}$	This will be dependant on a number of factors. Where body control is not significant use 0.3. However where body control is significant use 0.5 to 0.7.
$\zeta_{HS-Bump}$ $\zeta_{HS-Rebound}$	This is the high pass area of the damping curve. The values here should be 0.3 to 0.4

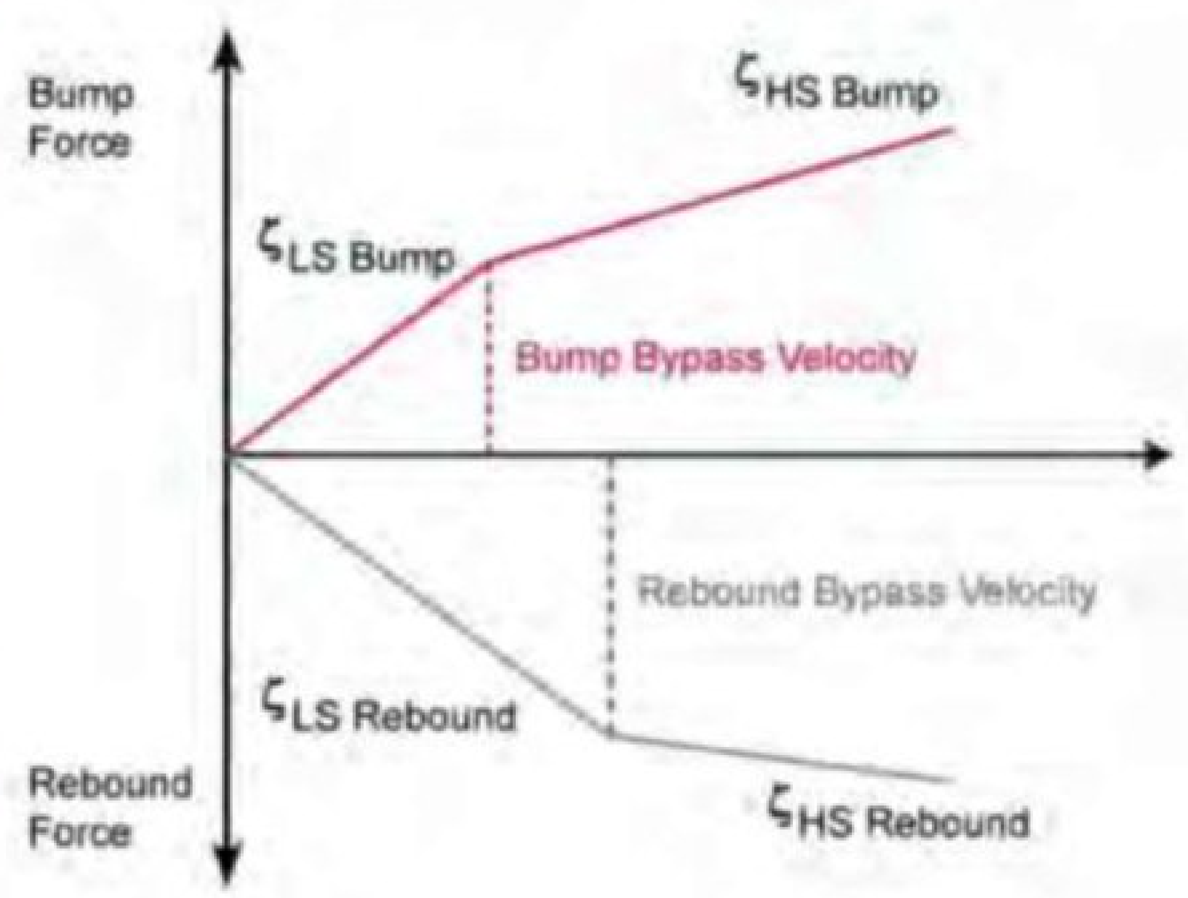

Fig-3: Damping ratio selection guide

Consequently given any damping curve we have a great metric to get our heads around what the damper is doing. Where it falls down is the assumption we have made in that the tyre spring rate is significantly greater than the body spring rate. You might get away with it with a touring car but you'll struggle on a sportscar/ open wheeler. It doesn't mean it's useless you just have to take a bit more care.

STATE SPACE ANALYSIS

To get us the rest of the way we need state space analysis. In particular we'll be evaluating the eigenvalues and eigenvectors of the system so we'll know how the car responds to an input. What these bring to the party is it gives us the full view of what the damping ratios are since we haven't needed to make any short cuts.

To kick this discussion off we need to review what state space analysis is and where eigenvalues and eigenvectors come from. Bear with me; it will be slightly long winded but it will be worth it. Let's review our quarter car model in **Equation 7**.

The terms of this equation are,
m_b = Mass of the body (kg)
m_w = Mass of the wheel (kg)
x_b = Body position (m)
x_w = Tyre/Wheel position (m)
K_B = Body wheel rate (N/m)
C_B = Body damping rate (N/m/s)
K_T = Tyre spring rate (N/m)

The dots above the wheel and body positions represent velocities. So at this point you might be thinking so what? This is where we pull our first rabbit out of the hat. The trick comes from looking at the mathematically obvious in **Equation 8**.

What this says is the acceleration of the body is the time derivative of the velocity. Ditto for the unsprung mass. So to make our life a bit easier let's down the following vector x as **Equation 9**. We can now express **Equation 7** as the following. See **Equation 10**.

The subscripts refer to the individual elements of the vector x. What this means is that we can represent **Equation 5** as a matrix. This matrix looks like this in **Equation 11**.

Equation 11 is what is referred to as the state space matrix and the construction of this matrix is the first step in using state space analysis.

The next step is to determine the eigenvalues and eigenvectors of the state space matrix because it will tell you everything you'll ever need to know about the way this system responds to the world. The eigenvalues determine the time response of the system, and the eigenvectors determine in what ratios the various states move in relation to each other and these are associated with the corresponding eigenvalue. Mathematically eigenvalues are determined by **Equation 12.**

In this case we are finding the solution for a big polynomial that is equal to 0. The number of eigenvalues is dictated too by the size of the state space matrix. This reflects the fact that if we have 4 variables that we are modelling, then that will represent 4 time responses. The eigenvectors are given by the **Equation 13**.

You have two options to solve this. You can do it by hand, which beyond 4 variables can get quite tricky, or you can use programs such as Matlab, Maple or Mathematica. My personal preference is Matlab but that's just me. I realise that we are now pushing into some pretty advanced stuff, but we are doing this because this is the most effective way we have of seeing

EQUATIONS

Equation 7

$$m_B \cdot \ddot{x}_B = -K_B \cdot (x_B - x_w) - C_B \cdot (\dot{x}_B - \dot{x}_w)$$
$$m_w \cdot \ddot{x}_w = K_B \cdot (x_B - x_w) + C_B \cdot (\dot{x}_B - \dot{x}_w) - K_T \cdot x_w$$

Equation 8

$$\ddot{x}_b = \frac{\partial \dot{x}_b}{\partial t}$$

Equation 9

$$\mathbf{x} = \begin{bmatrix} \dot{x}_b \\ x_b \\ \dot{x}_w \\ x_w \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$$

Equation 10

$$m_B \cdot \dot{x}_1 = -K_B \cdot (x_2 - x_4) - C_B \cdot (x_1 - x_3)$$
$$\dot{x}_2 = x_1$$
$$m_w \cdot \dot{x}_3 = K_B \cdot (x_2 - x_4) + C_B \cdot (x_1 - x_3) - K_T \cdot x_4$$
$$\dot{x}_4 = x_3$$

Equation 11

$$\mathbf{x}' = \begin{bmatrix} -\frac{C_B}{m_B} & -\frac{K_B}{m_B} & \frac{C_B}{m_B} & \frac{K_B}{m_B} \\ 1 & 0 & 0 & 0 \\ \frac{C_B}{m_w} & \frac{K_B}{m_w} & -\frac{C_B}{m_w} & -\frac{K_B + K_T}{m_w} \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \mathbf{x}$$
$$= \mathbf{A} \cdot \mathbf{x}$$

Equation 12 $$\det(\mathbf{A} - \lambda \mathbf{I}) = 0$$

Equation 13 $$(\mathbf{A} - \lambda_i \mathbf{I}) \cdot \mathbf{x}_i = 0$$

Equation 14

$$y = A_1 e^{-\sigma_1 \cdot t} + A_2 e^{-\sigma_2 \cdot t} + A_3 e^{-\sigma \cdot t} \cdot \sin(\omega_d \cdot t + \phi)$$

Table 1: F3 parameters

Parameter	Value
Sprung mass	100 kg
Unsprung mass	20kg
Wheel Rate	120 N/mm
Tyre Spring Rate	240 N/mm

Table 2: Damping ratio numbers for different damping numbers

Damper Value (N/m/s)	Damper ratio
2100	0.3
6000	0.87
12000	1.73

Table 3: Underdamped Eigenvalues/Eigenvectors

Mode	1	2	3	4
Eigenvalues	-4.46 + 28.4i	-4.46 - 28.4i	-58.5 + 117.9i	-58.5 - 117.9i
Eigenvectors				
x_b'	0.93	0.93	-0.11 - 0.11i	-0.11 + 0.11i
x_b	-0.005 - 0.032i	-0.005 + 0.032i	0	0
x_w'	0.33 + 0.11i	0.33 - 0.11i	0.98736	0.98736
x_w	0.002 - 0.012i	0.002 + 0.012i	0	0

Table 4: Critically damped Eigenvalues/Eigenvectors

Mode	1	2	3	4
Eigenvalues	-304.14	-11.6 + 36.3i	-11.6 - 36.3i	-32.579
Eigenvectors				
x_b'	-0.22	0.83	0.83	0.926
x_b	0	0	0	0
x_w'	0.975	0.42	0.42	-0.37
x_w	0	0	0	0.01

Table 5: Over damped Eigenvalues/Eigenvectors

Mode	1	2	3	4
Eigenvalues	-695.3	-6.86 + 42.9i	-6.86 - 42.9i	-10.953
Eigenvectors				
x_b'	-0.22	0.73	0.73	0.99
x_b	0	0	0	0.09
x_w'	0.975	0.63	0.63	0
x_w	0	0	0	0

what our system is actually up to. I do realise here we are talking strong language, violence and that most dreaded thing of all, complex numbers. However we are going to all this trouble because every eigenvalue will tell you how the system responds to an input and the corresponding eigenvector will show what this will look like in the real world. This is absolutely vital in nailing down what the system is going to do. Getting into the detail will reveal a wealth of information about what the car is going to do, which we'll see shortly.

To further quantify this, let's just say for the sake of the argument that with our state space model we have eigenvalues of values $-\sigma_1$, $-\sigma_2$ and a complex conjugate pair $\sigma \pm \omega_d i$. Then depending on the eigenvectors the response of say the sprung mass to a step input (such as body acceleration etc) can be represented by **Equation 14**.

We can put this into practice using some typical F3 numbers. The numbers we'll be using are illustrated in **Table 1.** These are all pretty run of the mill F3 values. Let's now play with the different damping numbers. These are presented with their damping ratios in **Table 2.** These damper values are standard settings for an F3 car. The first configuration represents damping rates in the high speed region of the damper – when it is going over bumps. The second is when you want a bit of body control, and the third configuration is when you want from sharp response from the car.

Where things get really interesting is when you evaluate the eigenvalues and eigenvectors.

Studying the first damping case doesn't yield any great surprises. The numbers are presented in **Table 3**. Given our very low damping ratio, **Table 3** doesn't present anything earth shattering. We have two primary modes acting here. The first mode illustrated in modes 1 and 2 acts primarily on the body velocity. Not surprisingly the damping ratio is much smaller than predicted by the quarter car model. The ratio here is 0.155 as opposed to 0.3. Note that the second mode, acting on the tyre velocity, is again underdamped and we are talking a ratio of 0.44. Again nothing surprising but at least the quarter car got us going in the right direction.

Let's now talk about the second case which was the ¼ car damping ratio of 0.87. The numbers presented in **Table 4** present an interesting story.

The first mode acts primarily on the tyre. Given that we now have proper damping, this mode dies off very quickly and, given the high value of -304.14 it's the mode in which load is transferred to the chassis. Modes 2 - 4 tell a fascinating story. Both of them act primarily on the sprung mass. However the devil here is in the detail. The mode that will dominate the response is the -11.6 +/- 36.i mode. This has a damping ratio of 0.306. However we have another mode that is real that has a frequency of -32.579 rad/s. Response will resemble critical damping but will have an oscillatory response to it. It also has significant spill over to the tyre - given the equivalence of the spring rates of the tyre and the body, this is to be expected.

Where things get interesting is the over damped case. The results are presented in **Table 5.** As per the critically damped case mode, the first mode acts on the tyre. However with a time constant of -695.3 rad/s the impact on bumps will be much more severe. Where things get really interesting is comparing modes 2 - 4.

You might get away with it with a touring car but you'll struggle on a sportscar/open wheeler

Again, as per the critically damped case, we have an oscillating mode and a critically damped mode. There is one key difference. In terms of time constant Mode 4, the critically damped mode will take the dominant response. So if you are looking at this on a damper plot on paper it would look fantastic. However the price you pay for it is in modes 2 and 3. If we look at the eigenvector in comparison to **Table 4** we know have almost equal response in wheel and body velocity. If you had a ride height sensor and you where logging something like this what it would look like is the dampers would be locked solid but the ride heights would be oscillating out of control. I experienced this with an LMP2 team at Le Mans back in 2007. The car had weird understeer over the Porsche Curves. What we see in **Table 5** explains why.

When you are tuning your dampers, what you are looking for is the halfway house between **Table 3** and **4**. What you see in **Table 3** represents what you want in high speed damping. You are deliberately underdamped so you can ride the kerbs. However for body control you want something like **Table 4. Table 5** represents the case where you go too far. This data can be readily incorporated into your existing engineering tools. This is what I would be doing if I where you:

- **Use damping ratios to get yourself into the ball park.**
- **Validate using state space analysis by calculating the eigenvalues and eigenvectors.**
- **Refine with simulation.**
- **Test on track.**

Start on existing setups so you can understand what they did and then move on to setups you want to try. It goes without saying that the results we have presented show you what a big impact dampers have on the behaviour of the racecar.

We have now closed the loop between damping ratios and state space analysis. While the damping ratios didn't give us the complete picture, they gave us a starting point. Eigenvalues and eigenvectors which come from state space analysis really allow us to nail this down and this is why this is such a powerful technique. Achieving the ideal damping balance is within your grasp. Throw some mud at the wall and see for yourself what it can do for you. You are not going to be disappointed.


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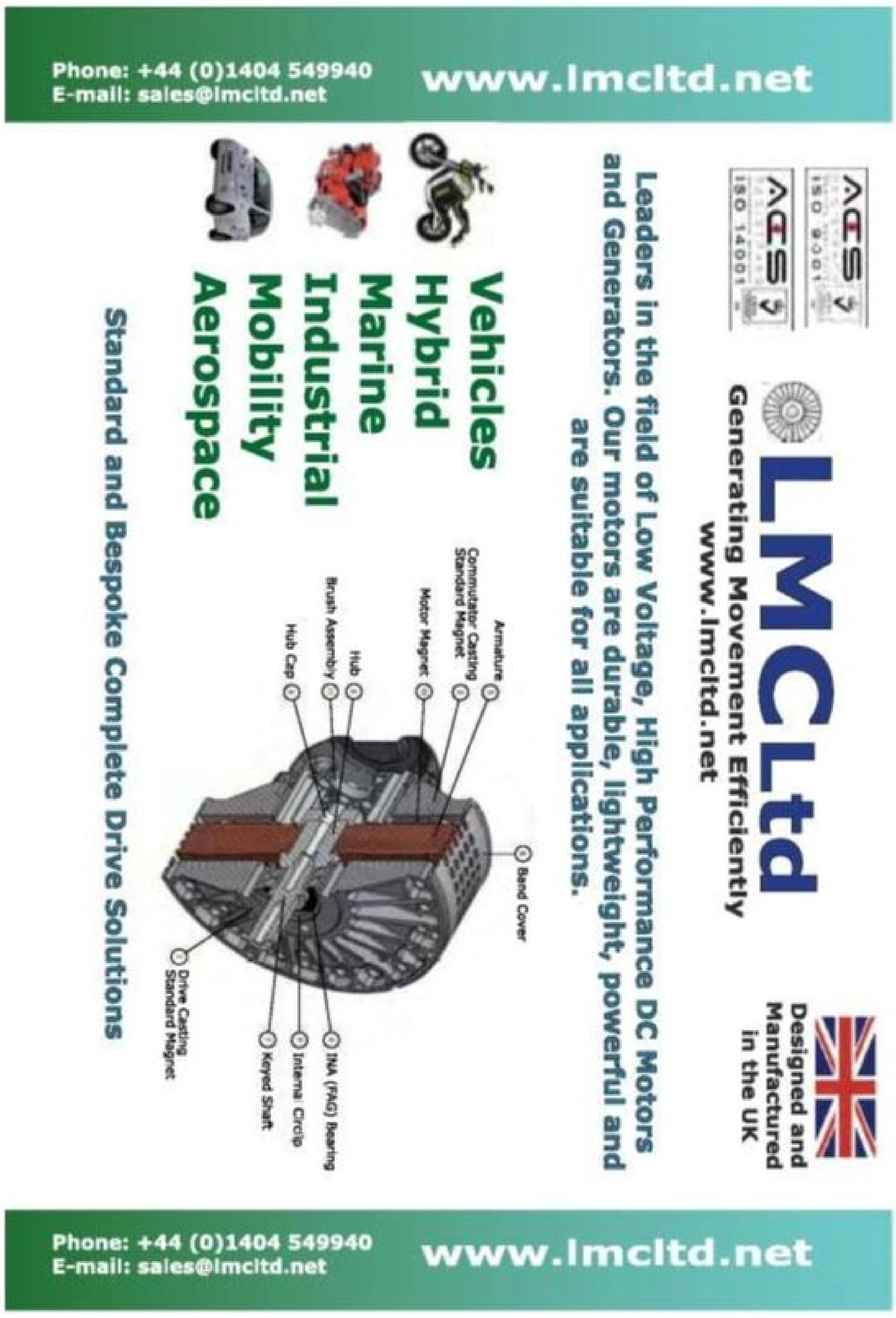
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The world's fastest office

There's a lot more to Andy Green's office in the Bloodhound SSC Land Speed Record car than just a steering wheel and a speedometer that reads up to 1,100mph

Screens display data from the hydraulic and braking systems (left) and jet, rocket and F1 engine-driven oxidiser pump (right). Analogue instruments from Rolex provide back-up

STEFAN MARJORAM

This is the space-age cockpit of Bloodhound SSC, the 1,000mph (1,609km/h) Land Speed Racing car, unveiled by the team in June. The state-of-the-art carbon fibre monocoque has been tailored to the needs of driver Andy Green and will be his supersonic office during record attempts in the South African desert in 2015 and 2016.

Hand crafted by URT Group using five different types of carbon fibre weave and two different resins, the monocoque has taken more than 10,000 hours to design and manufacture. Sandwiched between the layers of carbon fibre are three different thicknesses of aluminium honeycomb core (8, 12 and 20mm), which provide additional strength. At its thickest point the monocoque comprises of 13 individual layers but is just 25mm in cross section.

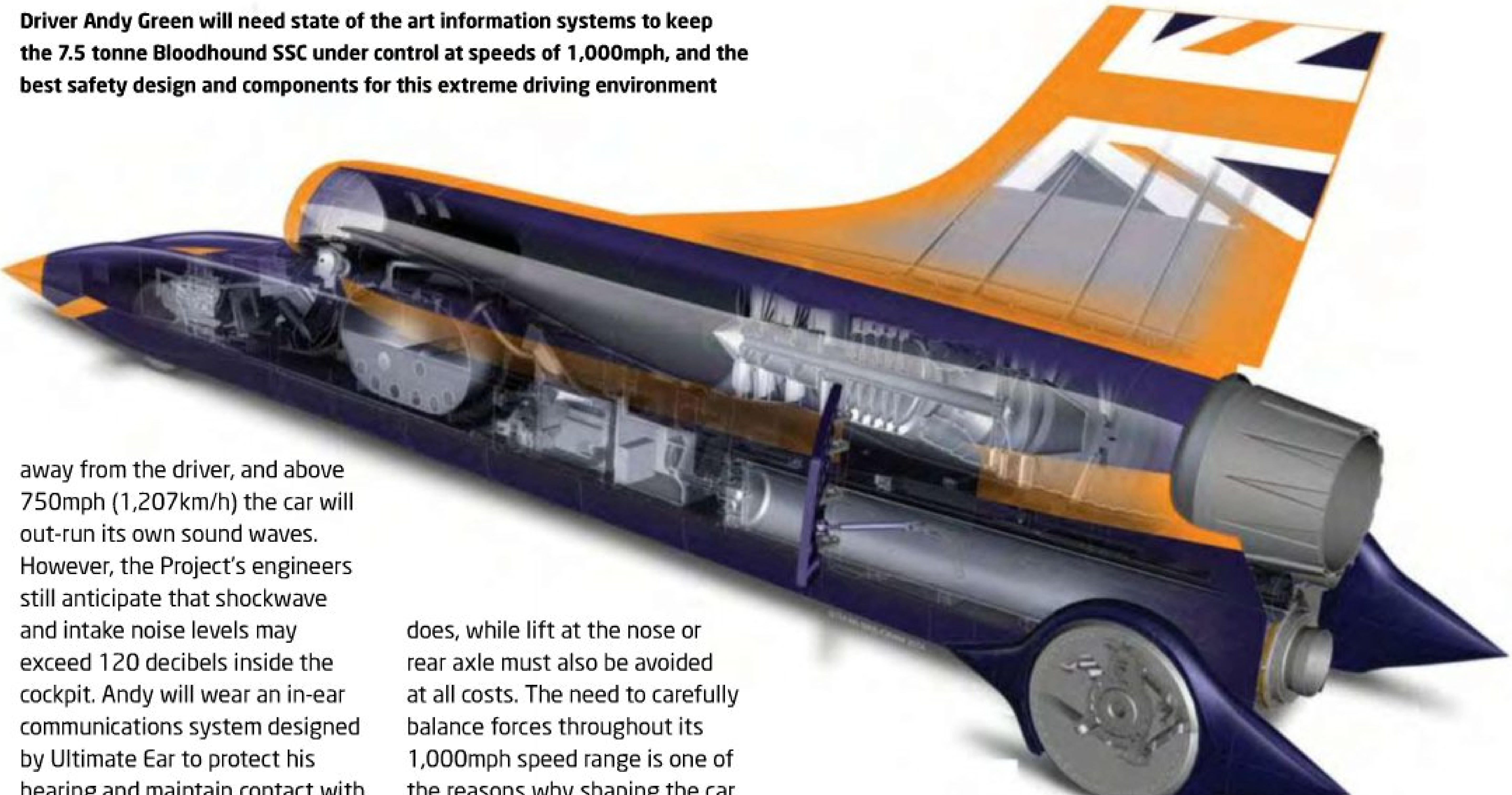
The structure weighs 200kg and bolts directly to the metallic rear chassis carrying the jet, rocket and racing car engine. The carbon front section will have to endure peak aerodynamic loads of up to three tonnes per square metre at 1,000mph, as well the considerable forces generated by the front wheels and suspension. It will also carry ballistic armour to protect the driver should a stone be thrown up by the front wheels at very high speeds.

The roof of the cockpit has been designed to create a series of shockwaves that will channel the air into the Eurojet EJ200 jet engine. If supersonic air reaches the jet engine fan blades, the airflow will break down and the engine will 'choke' (known as a 'surge'). This can generate huge changes in pressure that could damage both the jet engine and car, hence Bloodhound SSC using shockwaves over the canopy to slow the airflow from over 1,000mph to just 600mph (643km/h) in a distance of around one metre. Deflecting winds travelling five times faster than a hurricane will, however, cause additional noise and vibration to be transmitted into the cockpit.

SONIC BOOM

The sound levels expected in and around Bloodhound SSC are being carefully evaluated. The cockpit is positioned in front of three incredibly loud motors: the jet, a cluster of hybrid rockets and the 750hp Cosworth V8 that drives the rocket's oxidiser pump. Collectively they will generate a noise level estimated at 140 decibels. Much of the noise will be directed backwards,

Driver Andy Green will need state of the art information systems to keep the 7.5 tonne Bloodhound SSC under control at speeds of 1,000mph, and the best safety design and components for this extreme driving environment



away from the driver, and above 750mph (1,207km/h) the car will out-run its own sound waves. However, the Project's engineers still anticipate that shockwave and intake noise levels may exceed 120 decibels inside the cockpit. Andy will wear an in-ear communications system designed by Ultimate Ear to protect his hearing and maintain contact with Mission Control.

Bloodhound has a highly specialised windscreen custom-made by PPA Group from acrylic. The plastic is heated, stretched and then two layers are bonded together to create a 25mm section, thicker than a fighter jet's windscreen and sufficient to withstand an impact with a 1kg bird at 900mph (1,448km/h). Due to the oblique angle of the windscreen, the driver will in fact be looking through 50mm of curved plastic. The key challenge has therefore been to make the screen robust while maintaining absolute visual clarity.

AEROSPACE TECHNOLOGY

Andy has drawn on his experience of flying fast jets and driving World Land Speed Record winners Thrust SSC and JCB Dieselmax to design the dashboard and cockpit layout. Good ergonomics are vital, given that Bloodhound SSC will cover a mile in 3.6 seconds, or 150m in the (300 millisecond) blink of an eye.

The central screen shows the speed in miles per hour and Mach number (Mach 1 being the speed of sound), calculated by GPS, plus jet engine and rocket outputs. Dynamic speed indicators help Andy to judge when to fire the rocket and deploy the braking systems. Wheel loads are also given prominence. Bloodhound does not use aerodynamic downforce, as a Formula 1 car does, while lift at the nose or rear axle must also be avoided at all costs. The need to carefully balance forces throughout its 1,000mph speed range is one of the reasons why shaping the car has taken 30 design-years.

The left-hand screen shows hydraulic pressures and temperatures in the braking and airbrake systems, while the one to Andy's right provides data on the three engines, including temperatures, pressures and fuel levels. Together, the EJ200 jet engine and Nammo hybrid rockets produce around 210 kN (21 tonnes) of thrust, equivalent to 135,000 thrust hp, or 180 F1 cars, and Andy will monitor their status at key points on each run.

Bloodhound's dash also features two precision-engineered analogue Rolex instruments: a chronograph with built-in stopwatch, and a speedometer graduated up to 1,100mph (1,770km/h). The speedometer is a vital back-up to allow the car to be stopped safely should the digital dashboard fail, while the chronograph will help to time the start-up and cool-down of the jet, and help to monitor the performance of other systems. Tested to withstand the severe vibration at 1,000mph and the desert heat, these bespoke Rolex instruments are unique to Bloodhound SSC.

Good ergonomics are vital, given that Bloodhound SSC will cover a mile in 3.6 seconds

Andy enters his office via a carbon fibre hatch, 500mm in diameter, just below the jet air intake. At full power, the EJ200 fan sucks in 65m3 of air per second, so the hatch will be fastened using latches able to withstand loads of 2.5kN (quarter of a tonne) to prevent it from getting ingested into the engine.

The instrument panels have been coated with a special non-reflective grey paint to provide the optimum background colour against which to see the gauges and controls, while the cockpit walls are white to maximise the available light during the potentially blackout-inducing 3G deceleration on Andy. This long-duration G force is another issue unique to Bloodhound: an F1 driver may experience higher G forces, but they only do so for a few seconds at a time. Andy will be sat in a carbon fibre seat, moulded to his body shape by Real Equip, and manufactured by URT Group. This seat installation will provide unparalleled levels of support and safety for the driver who will be angled back and strapped in using a Willans five point harness. Andy will also wear a Pro Ultra HANS device, to protect his neck from sudden, violent movements or decelerations, and an Arai helmet.

The cockpit also carries a Camlock air supply, feeding clean breathing air to Andy through the 'Adom' mask used by RAF Typhoon pilots. The full-face race spec helmet, mated to a jet fighter-style breathing system, is again unique to Bloodhound and combines the best driver protection features from both motorsport and aerospace. A Willans fire suppression system has also been specified, which will douse the cockpit in foam should built-in infrared sensors detect naked flames.

Driver safety has been the prime design and engineering objective throughout Bloodhound's gestation and the team has worked closely with motor racing's governing world body, the Fédération Internationale de L'Automobile (FIA) to create the best safety cell in the history of motor sport.

The cockpit is something of a showcase for the extraordinary skills of UK manufacturing. The Bloodhound Project has enlisted the support of a raft of world-class companies in the fields of science, engineering, motorsport and aerospace in order to devise, build and race what is almost certainly the most extraordinary car in the world.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Volkswagen commits long term future to WRC as it confirms entry to 2019

Volkswagen has committed itself to its longest ever motorsport programme by announcing it's to stay in the World Rally Championship for at least five more years.

The German car giant, which is currently dominating the championship with its Polo R WRC, signed up until the end of 2015 and is into its second year, but will now stay until 2019. The announcement also means the manufacturer is committed to building a car to the new regulations, in 2017.

XPB

'Huge potential for marketing' sealed the WRC deal for Volkswagen

VW said that being able to compete against its market rivals with cars relevant to its customer base is part of the reason for the decision. Dr Heinz-Jakob Neuser, VW's board member for technical development and the man responsible for its motorsport programme, said: 'The WRC is a very good platform for Volkswagen to demonstrate the efficiency, dynamics and reliability of its cars to a global public. The series is more closely oriented towards the technology used in the latest production vehicles than any other world championship, and based on the kind of real conditions that our customers all over the world experience on a daily basis.'

Neuser added: 'The close interaction between the production and motorsport development departments at Volkswagen, the sporting contest with our direct rivals in various markets, and the huge potential for marketing in the media led to our decision to commit to a long-term involvement.'

VW currently competes against market rivals Ford, Citroën and Hyundai in WRC, while its biggest competitor for global sales, Toyota, has said it's waiting on the new-for-2017 regulations to be announced before it makes its decision on entering the championship.

Jost Capito, VW motorsport director, said: 'Volkswagen has never implemented a long-term motorsport programme on this scale before. This faith is a huge motivation for our entire team not to rest on its laurels for a single second.'

However, Capito also said the WRC promoter needs to do more to ensure there is adequate TV coverage, which has been a major issue for manufacturers in the WRC recently. 'A prerequisite for the success of the championship itself is a format optimised for TV, in order to make rallying even more attractive for the general public,' he said. 'We call upon the promoters to work together with the manufacturers to significantly increase the media coverage of the series.'

WRC teams talk technical regulations for 2017

World Rally Car technical rules will change for 2017; there will be initial official discussions on the topic later this year, but existing top team people stress the need to err on the side of caution, *says our rally correspondent, Martin Sharp.*

Volkswagen Motorsport engineer François-Xavier 'FX' Demaison would like a bigger restrictor for a bit more power and a bit more aero to make the sport more spectacular for the spectator, but: 'We don't want to frighten anybody; for sure we want as many manufacturers as possible. So we are more than happy to stay where we are.'

The FIA is considering C-segment models to replace the existing B-segment WRC cars. Malcolm Wilson doesn't see a problem with this for M-Sport: 'As long as there's a set of technical regulations that stay the same, then you could use a lot of your carry-over parts.' FX points out that bigger cars would improve safety by having more structure to deform, although the decision would depend on Volkswagen's marketing plans.

It's a different matter for Hyundai. The team is developing an entirely new WRC homologation of an as-yet unnamed model for 2015. Team boss Michel Nandan stresses that if C-segment became mandatory, for the car to be competitive would demand a complete re-design, not carry-over assemblies. He also points out that C-segment-based WRC cars are not forbidden today, but nobody uses one because it would be less competitive.

Toyota has already built a Yaris to WRC regulations and tested it. Yet if Toyota comes to a future World Rally Championship it will be with a different model, and it is possible TMG might lobby for hybrid powertrains in the 2017 technical rules. Existing teams consider this a no-no. While Hyundai's Nandan agrees that while hybrid technology would be technically interesting, he feels the concept goes far away from the aim to reduce the cost of WR cars. He is also concerned about the safety of hybrid rally cars: '[It's] easy to control on a circuit; a bit more difficult on a special stage.'

Devoid of Ford support M-Sport doesn't have the money to develop a privateer hybrid: 'For me, if we still had Ford and Ford was interested... but at the moment it's the last thing I would need.'

Demaison is also certain: 'The costs would go ballistic. Maybe you could interest one manufacturer, but scare off four or five others. Just to test this solution will be expensive in terms of parts and development, so I don't think [it wise] at the moment to put a lot of money or energy into the technical part of rallying. I think more of the promotional aspect has to be looked at first.'

Marussia set to rake in millions after scoring first points

XPB

Jules Bianchi's fine Monaco drive looks set to earn his team big bucks

F1 team Marussia stands to pocket an extra $50m from the F1 prize pot following its ninth place finish at the Monaco Grand Prix.

The team, which up until Monaco had not scored a point since entering F1 at the start of 2010, now finds itself in ninth place in the championship (at the time of writing), ahead of both Sauber and Caterham.

If Marussia can hold on to its ninth place, or even if it slips to 10th by season's end, it will be in line for a massive hike in its prize money - which Formula 1 pays out on results over consecutive seasons, rather than a single year.

Marussia collected $10m for finishing 10th last year - this is known as a Column 2 payment - but if it can repeat or better that this year it will pick up an additional Column 1 payment. If the team finishes the season in 10th it should collect an extra $30m, on top of the Column 2 payment of $10m. However, if it keeps hold of its ninth place - which largely depends on Sauber's poor form continuing - it could pocket $50m, which totals $40m for Column 1 and the $10m for Column 2. Either of these results will be a massive boost for the team, which operates on a budget of $85m, according to the latest available figures.

Yet while the Monaco result was great news for Marussia, it could spell disaster for its perennial rival Caterham, which could lose eligibilty for Column 1 payments if it does not finish the season in the top 10.

Meanwhile, Caterham has been forced to deny the group has been put up for sale. 'The reports circulating are factually incorrect,' it said. 'It is, however, true that the Group is actively searching for additional investment as it seeks to fulfil ambitious plans to develop.'

Caterham Group boss Tony Fernandes, who also owns the QPR football team that gained promotion to the Premier League, which also requires investment, said: 'Caterham Group is not for sale. We love what we build and we are always looking for further investment. This is no different to how we started AirAsia. Yes, we are constantly challenging ourselves and making decisions on everything from the structure to projects within the group. That is normal business.'

Smaller F1 teams say scrapping FP1 could cut income

XPB

Running young drivers in FP1 can be a useful income stream for smaller teams like Force India

A planned move to do away with Free Practice 1 (FP1) on the Friday morning of a grand prix weekend has received criticism from some of the smaller teams in the sport.

The move to ditch FP1 has been agreed by the Strategy Group - made up of five of the bigger teams plus the FIA and Bernie Ecclestone - and it is intended to cut costs.

The Strategy Group believes money can be saved as less running will mean less wear and tear on parts, particularly engines, which are a major expense for teams. They also argue that teams will not need to spend as much on accommodation, as personnel can arrive at the track one day later.

However, the smaller teams say the cutting of FP1 will mean the loss of a vital revenue stream for them, as often pay drivers are run in this session. Andrew Green, technical director at Force India, said: 'From Force India's perspective, we don't see this as cost-saving at all. For us, we've always looked to use the FP1 session to blood in some new drivers and that was an income stream for us. If we lose that, that's going to be a relatively severe blow, which, in turn, will have an impact on our technical ability so in that respect, I don't think it's cost-saving.'

The reduction in track time could also decrease the teams' opportunities to develop their cars. Sauber's head of track engineering, Giampaolo Dall'Ara, said: 'For a team like ours, the time at the track is very precious. Obviously we are more limited than other teams in simulation... so time on track is extremely important for us.'

But Paddy Lowe, the executive director of Strategy Group member Mercedes, believes the move could actually help the smaller teams in other ways: 'I think the rationale is to reduce the workload on the cars significantly through the weekend and also to reduce the consumption of parts, particularly power units, which is one of the major costs for all the teams, but that's a particular burden for the smaller teams.'

Lowe also said the decision, although agreed by the Strategy Group, has yet to be finalised.

SEEN: ZYTEK LMP2

Zytek has released images of the LMP2 coupe it intends to launch in 2016. The design work on the new car, which has not been given a type number as yet, has already started and it will be built to the cost-capped LMP2 regulations that were introduced in 2011. Zytek says the car is to be designed to accommodate a wide range of engines and will begin its test programme at the end of 2015. The new coupe will replace the existing Z11SN open LMP2, which is a modified version of the 07S introduced in 2007.

Company founder and Zytek chairman Bill Gibson said: 'The level of interest in the Zytek chassis has been tremendous of late, due to its continued on-track success, its driveability and renowned safety record. The chassis business brings the Zytek brand to the fore and showcases our engines and electronics perfectly. We want this to continue and flourish and have made this important decision to go ahead with a coupe that will maintain our presence in the sportscar scene for many years to come.'

Drayson to stay connected with Formula E

Drayson Racing has dismissed suggestions that it is to turn its back on the new Formula E Championship for electric racecars, despite June's announcement that Jarno Trulli will manage a new team that has taken over the Drayson entry into the series.

Drayson Technologies will be entering into a supply and sponsorship arrangement with TrulliGP to be the squad's principal partner, and will continue to develop the wireless charging system, and introduce the technology to the whole grid.

'We're delighted to welcome Jarno to the FIA Formula E Championship as both a team manager and a driver,' said FE CEO Alejandro Agag. 'Drayson very much remains a part of the Formula E family, focusing on developing their wireless charging technology, which they couldn't have done as a team.'

A spokesperson for Lord Drayson, CEO of Drayson Technologies, added that the deal is purely business driven: 'He's certainly looking at his options. He has wider business interests than just Formula E. The other thing to bear in mind is that the buzz for Formula E has really ramped up, and all the teams were locked down a long time ago. There's a real surge in demand to be partners and players, from car companies to suppliers, major sponsors or clean-tec companies, who were a bit late to the party.

'He's still a technical adviser to Formula E as a championship, so he's very close to the organisers and that is not something that's going to end. Our ambition is to supply all the teams with wireless charging and we are delighted that TrulliGP is the first team to adopt this exciting technology,' said Drayson of the announcement.

McLaren road car division rakes in £12m

McLaren Automotive, the McLaren Group's supercar division, raced into the black chalking up an operating profit of £12.4m.

Other headline figures for Automotive include a turnover of £285.4m (up from £266.6m in 2012), while the company delivered 1359 12Cs and 36 examples of the McLaren P1. It also tells us it invested some £70.6m in future models during the period. It is the first time that the supercar division has turned a profit, and will undoubtedly provide a boost to the company.

McLaren Automotive has also confirmed that its all-new carbon sportscar, codenamed P13, will be available before the end of 2015 and will extend its range into a lower price market, pitching it squarely against Porsche. The P13 will increase McLaren Automotive's total production to around 4000 cars per year.

The company has also said it will produce a limited run of track-only editions of its McLaren P1. These will only be made available to customers who have ordered one of the 375 road legal versions and the car will be the company's most powerful model yet.

Commenting on the results, Ron Dennis, chief executive and chairman of the McLaren Group and chairman of McLaren Automotive, said: 'Since launch, McLaren Automotive has outperformed predictions and rivals, setting new benchmarks in the sportscar market with a range of models that push boundaries through innovation and technology, while remaining true to the core values of the brand. The latest financial results, and returning a profit so early in the life of the company, are a real credit to the tremendous team within McLaren Automotive, and reflect their hard efforts.'

In 2013 McLaren Automotive also expanded its geographical reach, opening 13 new showrooms, including four in China, and growing its global network to 50 retailers in 28 international markets. There are plans to open another 20 outlets in 2014 and exceed 100 locations in its global network by 2018.

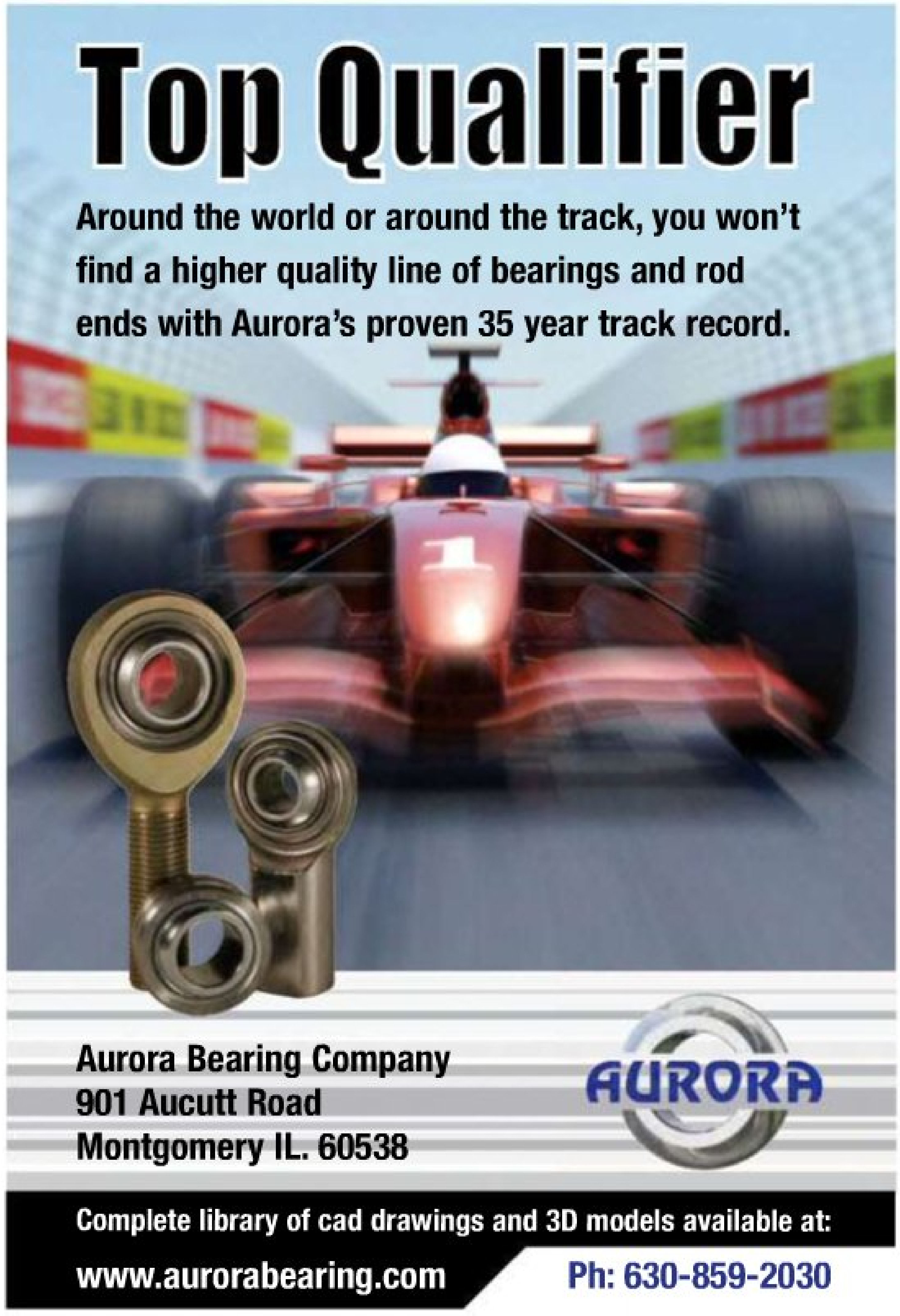
Sales of the P1 helped put McLaren Automotive into profit for the first time

CAUGHT

The Penske IndyCar team has been hit with a $5000 fine after its Juan Pablo Montoya-driven Dallara was found to be under the minimum weight limit after qualifying for the first of the two Detroit races at the end of May.

FINE: $5000

Honda has been docked 50 points in the IndyCar manufacturer standings after five of the engine supplier's cars were found to be in violation of IndyCar's minimum engine mileage rule at the Indianapolis 500. The manufacturer was penalised 10 points for each infraction of the rule, which states that each of the 2.2-litre twin-turbo V6 engines must clock up 2500 miles before it is changed. Chevrolet was also docked 10 points for the same infringement with one of its cars. Both manufacturers have the right to appeal the ruling.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SEEN: LOTUS T129

The much-delayed Lotus T129 LMP1 car has been revealed at Le Mans. Originally designed to accept the NBE built Audi DTM V8, the rear of the car has had to be extensively reworked to accept the new AER P60 twin turbo V6 engine. The car could be seen as part of the HRT family line with the Holzer Group in Germany playing a key role. A solitary example of the T129 will contest some of the remaining World Endurance Championship races in 2014.

BRIEFLY

Because E's Wirth it

Wirth Research is to be a technical partner to Andretti Autosport in the Formula E electric racecar championship, the inaugural race for which is in China in September. The two organisations – headed by Nick Wirth and Michael Andretti – have collaborated in the past, with the Wirth-designed Acura LMP2 that Andretti ran in the ALMS for two seasons from 2007, while they have also worked together in IndyCar. Wirth ran the Simtek F1 squad in the mid-90s and was also the technical head at Benetton. The company was then responsible for building the first Marussia F1 cars for 2010 (the team then known as Virgin).

Kyalami sale

The legendary Kyalami race track, for many years home to the South African Grand Prix, is to be sold to the highest bidder in what's being described as South Africa's biggest ever no-reserve auction. The circuit, which is close to Johannesburg, has been beset with legal problems – chiefly involving disputes between the track operator and its owners over recent years, and it has seen very little use since 2011. The track was the venue for the South African Grand Prix, off and on, between 1967 and 1993, although the 1990s incarnation bore little resemblance to the original classic layout, after the track was completely redesigned and rebuilt in 1985.

Eco Beach

The Formula E championship is to race at Long Beach as part of its inaugural season, the iconic Californian street circuit to be round seven of 10. The race will be held in April of next year – the championship kicks off in September 2014 and runs over the winter. California is the number one market for plug-in electric vehicle sales with around 12 per cent of US sales alone occurring in the South California area. Long Beach hosted F1 from 1976 until 1983, before switching to IndyCar (then known as CART) in 1984. The Formula E cars will use a modified configuration of the regular IndyCar circuit, which will be 1.6 miles (2.1km) in length with seven corners.

Entries for manufacturing awards invited

UK motorsport manufacturing companies could be well placed to clean up in the annual Future Manufacturing Awards, for which entries are now being sought.

The free-to-enter awards, which are run by the manufacturers' organisation EEF and business banker Aldermore, are designed to find the best of British manufacturing, and among the categories are a number which might appeal to motorsport companies.

The competition is open to all manufacturers and supply chain businesses, regardless of size, and there are seven different categories. These are: success in strategic growth, smart products, health and safety initiatives, investment in skills and training, operational excellence, reducing environmental impact, and exporting. Entries will be judged regionally, with winners going on to compete for national awards. One company will then be crowned as EEF/Aldermore's 'Winner of Winners'.

Terry Scuoler, CEO of EEF – which once stood for Engineering Employers' Federation, but now we are told is a name in its own right, said: 'Manufacturers have a great story to tell and these awards give them the opportunity to demonstrate what they do so well. Collectively, our sector is a powerhouse driving the economic recovery, employing 2.6 million people and accounting for 11 per cent of GDP. However, these awards look behind the facts and figures and showcase talented, hard-working individuals.'

Entries should be made before 3 October 2014. To find out more visit: www.eef.org.uk/awards/

Nashville back on track as tech firm takes control

A Tennessee-based technology company has signed a deal to buy the Nashville Superspeedway for a total of $27m.

NeXovation Inc, which earlier this year had its bid to buy the Nurburgring rejected, has agreed the cash deal with the track's current owner Dover Motorsports. The sale includes all the related equipment and assets plus an assumption of $18.8m of the circuit's debts.

The Lebanon, Tennessee track – unused since 2011 – will be developed into a year-round venue by NeXovation, and the company has made it clear it intends to invest in the circuit.

'We intend to turn it into a 52-week-a-year venue dedicated not only to motorsports, but other experiential events,' NeXovation CEO Robert Sexton said. 'We're going to be adding a lot more infrastructure and opportunities for different events.'

Dover Motorsports has previously tried to attract the NASCAR Sprint Cup to the speedway but lost out because the circuit, which opened in 2001, did not have the required seating capacity. But Sexton has said he believes the facility could be expanded out to 150,000 seats.

Denis McGlynn, Dover Motorports' CEO, said of the agreement: 'This is a great deal for all concerned...as we can transfer an under-utilised, high-quality asset to NeXovation, who will create and implement a new business model and reactivate Nashville Superspeedway for the benefit of everyone in the area.'

NeXovation will take over the speedway in the autumn. It has no experience of running race circuits, although it did make a $150m bid for the Nurburgring, only to be beaten by The Capricorn Group. The technology company is best known for its patented FlatWire technology, a surface-mounted wiring system.

Nashville Superspeedway is located on nearly 1400 acres of land near Lebanon. The 1.33-mile concrete track hosted NASCAR Nationwide Series and Truck Series races between 2001 and 2011, and IndyCar races from 2001 to 2008.


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INTERVIEW – RAY MALLOCK

Racing unlimited

RML has now been in the business of winning races and championships for 30 years. Racecar Engineering talked to its founder about the group's past, present and future

When you have 30 years of recollections to sift through the question 'what memories stick out?' can be a difficult one, especially if those three decades have been crammed with countless race wins and five world championship crowns. So it's no surprise that Ray Mallock, founder and boss of RML (Ray Mallock Ltd) – which celebrates its 30th anniversary this year – thinks long and hard before giving his answers. It's also no surprise that one of his replies involves one of RML's many manufacturer tie-ups, because in the final analysis working with car makers is what this outfit is all about.

'Winning the World Touring Car Championship with Chevrolet in 2010 was particularly sweet,' says Mallock. 'We were up against the works BMWs and SEATs; we were normally aspirated, the SEATs were turbo diesel, and at the time the front-wheel-drive/rear-wheel-drive balance was in favour of BMW, to our mind. So it was a real battle every inch of the way.'

RML chief executive Ray Mallock

WINNING WAYS

This was actually the second world title for RML, as it had also scooped the Group C2 crown with Ecurie Ecosse in 1986, two years after RML was formed – although it was preceded by Ray Mallock Atlantic Racing (which operated from 1979 to 1984). RML went on to claim three more titles in WTCC in 2011, '12, and '13, and on top of that there's a bevy of BTCC triumphs (1995 with Vauxhall, 1998 and '99 with Nissan, and 2010 with Chevrolet) and many wins in everything from GT to rallying, including a hat trick of LMP2 victories at Le Mans.

The relationship with Chevrolet finished in 2012, although RML won in 2013 fielding the same cars, and then went on to build race-winning customer Chevrolet Cruzes for this year's new regulations, while it also leases out RML Powertrain designed and built engines to Chevy-running teams. But while it lasted, the Chevrolet tie-up was actually the perfect example of how RML operates: 'We're here to look after the motorsport marketing needs of manufacturers,' Mallock says. 'So what we did for Chevrolet; starting in 2005, getting to a winning position fairly rapidly, and then a championship-winning position not too long afterwards, that's what we're about.'

RML likes to say it offers 'turnkey packages' to manufacturers, but how do you get a car maker on board? It's a mix of pitching the opportunity to them, and manufacturers actually approaching RML, says Mallock. He also adds: 'Having a good reputation in the business is hugely important. And a lot of it is to do with building relationships with manufacturers and manufacturers' representatives; people move around. Someone might be with GM one year, and then VAG another.'

The most recent manufacturer tie-up has been with Nissan and its ZEOD experimental racecar at Le Mans. RML has had ties with the Japanese manufacturer since 1990, but now Nissan has said that it will not be entrusting RML – or any other such organisation – with next season's LMP1 campaign. 'There are no plans for RML to be involved in the LMP1 programme,' says Mallock. 'We still have a very strong relationship with Nissan on a number of other projects, but not LMP1. It would be wrong to say I'm not disappointed. Le Mans is always on our radar, so we would have loved to have been involved.'

Yet while Nissan hasn't given RML the P1 gig, it has given it a wealth of experience with the likely future of motorsport: electric. 'It will be part of our future. We've learnt a huge amount about EV systems in the last nine months [with ZEOD], and we certainly know more than most (see Nissan ZEOD feature p56). We are one of the experts now, so Formula E would suit us well, but to compete you need a commercial partner either through a manufacturer or a sponsor. We've been in discussions with a number of people but it hasn't happened yet, but it would be a good place for us to be, what with the rules opening up on powertrains for next year.'

If RML were to race FE then it would be a first. For despite Mallock's Formula Atlantic and F3 past as a driver and entrant, RML itself has not done anything close to a full season of single seaters – only a one-off ChampCar race at Rockingham (UK) in 2002, in fact. Mallock says this is because manufacturers are often attracted to categories with more relevance to their products, such as touring cars and GTs. The exception, of course, is F1. And for a little while back in 2009 RML was tempted...

'We were seriously interested when the [then planned] cost cap was at its original figure [£40m],' Mallock says. 'I don't want to

say who it was, but we had a manufacturer – it would have only worked with a manufacturer – and we had one seriously interested. But then the goalposts were shifting rapidly away from that [cost cap figure].'

Missing out on this F1 opportunity is not something Mallock regrets, though. 'Formula 1's a very difficult area to be in, for all sorts of reasons, and I'm certainly pleased we didn't commit ourselves when we thought there was going to be a cost cap and then it turned out there wasn't. That would have been horrendous.'

While F1 is certainly not on the RML radar right now, it's fair to say that just about everything else is. For instance, with its experience of both racing and rallying (it developed and ran the multiple-championship-winning Vauxhall Astra F2 rally car in the '90s, for example) rallycross could be the perfect arena. 'I think rallycross is a fantastic offering for manufacturers. It's very much on our radar, but in the same way that touring cars, GT and many other things are.'

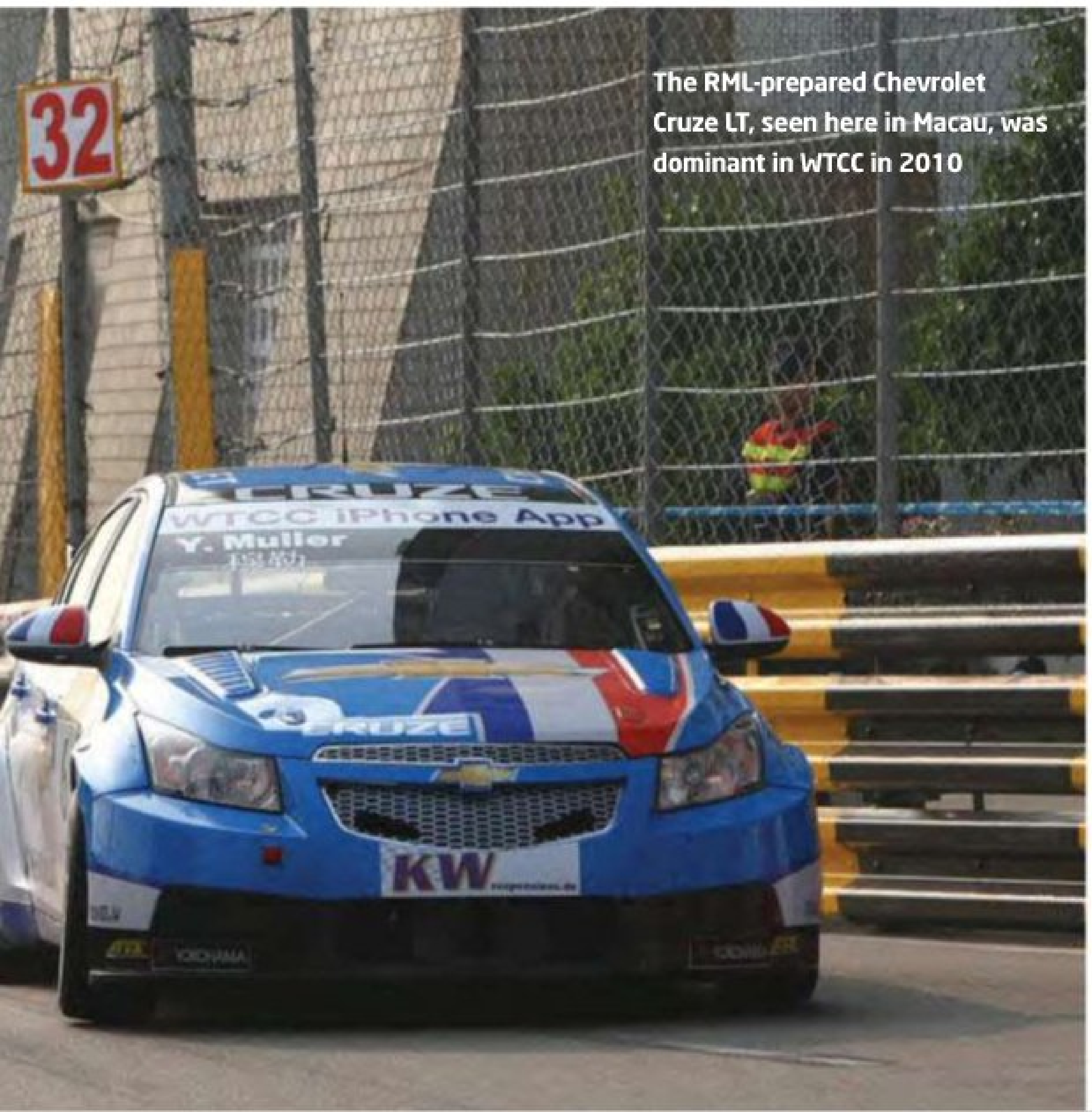
It's not all about motorsport, though, RML also does a great deal of automotive business. In fact Mallock says around 30 per cent of its work is non-motorsport, including building one-off specials such as Nissan's Juke-R 'super-crossover', and secret development work for car makers. But the heart of the business is still racing, preferably with a manufacturer.

Mallock is under no illusions about just how tough it is to persuade manufacturers to go racing these days, though. 'At the end of the day, motorsport is a marketing platform, and there are plenty of other ways manufacturers can spend their money, through the internet or TV or football, and as these different avenues become more global it does put more pressure on budget availability for motorsport.'

So, what do the next 30 years have in store for RML? 'Who knows? In this business you can't have a five year strategy because the world changes, the market changes, you've got to be light on your feet, and keep your eyes open for the direction the market is going all the time.' That's the sort of attitude that comes with 30 years of experience in top class motorsport – and one that should ensure RML's around for another three decades, too.

Mike Breslin

"You can't have a five year strategy because the world changes, the market changes"



The RML-prepared Chevrolet Cruze LT, seen here in Macau, was dominant in WTCC in 2010

RACE MOVES

Dave Price is no longer the team manager at the DeltaWing United SportsCar Championship outfit. **Tim Keene**, formerly the sportcar team manager at Ganassi, has taken his place. The change has been made because DeltaWing boss **Don Panoz** wanted his team manager to be based near the team's HQ in Braselton, near Road Atlanta. Price is based in Europe.

The Chip Ganassi Racing pit crew of **Scott Dixon** won the Tag Heuer Indy 500 Pit Stop Competition in the run-up to the great race. The crew members were: **Blair Julian** (chief mechanic and right-front tyre); **Adam Rovazzini** (left-front tyre); **Greg Shuker** (right-rear tyre); **Tyler Rees** (left-rear tyre); **Andy Schneider** (air-jack) and **Todd DeNeve** (fuel). They picked up $50,000 for their efforts.

Nissan Australia has appointed **Mitchell Wiley** as its full-time 'motorsport activation manager', a new post conceived to promote the Japanese manufacturer's involvement in the V8 Supercars series more effectively. Wiley was formerly the national retail communications manager for Mitsubishi Australia.

Andrea Tosa, head of research and development and US racing leader at Dallara, has been presented with the BorgWarner Louis Schwitzer Award – which recognises those associated with the Indy 500 for their innovation and engineering excellence. The $10,000 award is presented by the Indiana section of SAE International and was given to Tosa for his work developing Dallara's US simulator, now in operation at Indianapolis Motor Speedway.

Yas Marina Circuit, the home of the Abu Dhabi Grand Prix, has appointed a new CEO. **Al Tareq Al Ameri** previously ran the commercial division at the circuit and was part of the team that has developed the United Arab Emirates track and leisure complex since its inception in 2009.

Julie Conlin, who works at motorsport PR and consulting firm Sunday Group Management, is now the account manager for United SportsCar team Action Express Racing. Conlin joined Sunday Group in 2010 after a spell at Team Ganassi.


XPB

Ferrari has assigned normally factory-based test engineer **David Lloyd** to a back-up race engineer role. He will assist Kimi Raikkonen's regular engineer **Antonio Spagnolo** – the Finnish driver has struggled for performance so far this season. The Scuderia has not said whether the move will be temporary or permanent.

Former sportscar racer **James Weaver** is the new chief engineer at BTCC outfit Rob Austin Racing. Weaver, who raced in BTCC and IMSA in the '80s, will engineer one of its two Audi A4s, allowing team owner/driver and regular engineer **Rob Austin** to concentrate on the other car and his driving.

David Stuart is now the sporting and technical director for Australia's top motorsport series, V8 Supercars. Stuart comes to the post from the Mercedes-running Erebus Motorsport team, formerly known as Stone Brothers Racing (SBR). Stuart was at SBR for seven years and he started his racecar engineering career at Dick Johnson Racing in 2000, having worked in motorcycle sport before that.

The Erebus Motorsport V8 Supercars team has restructured its operation following the departure of **David Stuart** (see above). Head of performance engineering Wes McDougall and crew chief Ben Croke will now fill the void left by Stuart, working alongside the team's general manager, **Ross Stone**.

Adrian Newey to step back from Formula 1 work

Adrian Newey is to cut back on his involvement with the Red Bull Formula 1 operation to allow him to concentrate on other technical projects for the energy drinks giant.

A new multi-year contract with Red Bull brings to an end mounting speculation that he was about to defect to Ferrari.

Newey will still have a role with the Formula 1 team, although Red Bull tells us this will be: 'Advising and mentoring Infiniti Red Bull Racing as it develops its Formula 1 cars over the next few seasons.'

It is not known what other projects Newey will work on, although he has been in talks with Ben Ainslie around the yachtsman's $130m bid for the America's Cup. Road car projects and even a Red Bull aeroplane have also been mentioned.

Newey was also recently seen at the Silverstone WEC round, sparking rumours that Red Bull were looking at an involvement in LMP1, possibly in partnership with engine sponsor Infiniti.

It's been reported that Red Bull is building a new technology centre close to its Milton Keynes F1 base and it's thought that the new projects would be developed here under Newey's direction.

Red Bull team principal Christian Horner said: 'It's great we've come to an agreement and that Adrian's going to continue to be advising and mentoring the team. Some exciting new projects will be announced in due course.'

Horner didn't think the team's performance would suffer as a result of the move: 'We've got tremendous strength in depth. [And] it's not like he's not going to be about any more,' he said.

Newey joined Austrian-owned Red Bull for the 2006 season as chief technical officer. In 2010 the team won its first drivers' and constructors' world championships and it has retained the titles ever since, winning both championships again in 2011, 2012 and 2013.

Before joining Red Bull, Newey also enjoyed great success at McLaren and at Williams.

OBITUARY

John Bishop, one of the most influential people in the history of US sportscar racing, has died at the age of 87.

Bishop was best known for his role in founding IMSA (International Motor Sports Association) but before this he was also executive director of the Sports Car Club of America (SCCA). IMSA was created in 1969 after NASCAR boss Bill France Sr. contacted Bishop with the idea of starting a road racing sanctioning body which could run parallel to NASCAR.

The IMSA GT championship started in 1971 and this grew to become a major US championship, encompassing the classic American races at Sebring and Daytona, and with manufacturers such as Porsche, Ford, Nissan, Jaguar and Toyota competing while Bishop, and his wife Peggy – who died last year – were in charge.

Bishop had to have heart surgery in 1987 and then he sold IMSA at the end of 1989, but he stayed involved in sportscar racing and was a commissioner of the GrandAm series in the 2000s.

NASCAR boss Jim France, son of Bill Sr. and current chairman of IMSA – which is now the sanctioning body of United SportsCar – said on the news of Bishop's death: 'John's passing evokes grand memories of another era of sportscar racing in North America. We have lost a man who, once upon a time, was a sportscar pioneer. Over the years, he became a giant in our industry.'

John Bishop 1926-2014

RACE MOVES

The nominees for the 2015 NASCAR Hall of Fame have been announced. The shortlist of figures from the business and engineering side of the sport will include team owners **Richard Childress, Rick Hendrick, Raymond Parks, Robert Yates** and **Ray Fox** (the latter two also renowned as engine builders) and track owner and promoter **O Bruton Smith**.

NASCAR also announced the five nominees for its inaugural Landmark Award: **H Clay Earles** (Martinsville Speedway); **Anne Blesdoe** France (helped found NASCAR); **Raymond Parks** (team owner); **Ralph Seagraves** (architect of NASCAR's Winston sponsorship deal) and **Ken Squier** (media).

The British Automobile Racing Club (BARC) has announced it has voted three new members to its Council: **Dennis Carter, Rhodri Jenkins** and **Bruce Grant-Braham. Martin Hunt** has also been re-elected to the Council.

Former NASCAR owner/driver **Ed Negre**, the man credited with giving **Dale Earnhardt** his first chance at Cup level, has died at the age of 86. Negre, a WW2 veteran who saw service in the Pacific, gave Earnhardt his opportunity in a second car at Charlotte in 1975.

BTCC team principal **Christian Dick** was injured in a racing accident at Zandvoort at the end of May. The Speedworks boss broke two ribs, his sternum and left fibia, and also punctured a lung. Doctors told him his recovery could take three months, but he attended the BTCC round at Oulton Park just a week after the heavy shunt.

Well-known IndyCar engineer **Jim McGee** has come out of retirement to help out with the race strategy on the Chip Ganassi Racing car of **Ryan Briscoe**. McGee, who says the arrangement is for weekends only, first came to IndyCar in 1960, working for **Clint Brawner** on the Dean Van Lines team.

V8 Supercar squad Red Bull Racing Australia has brought in its technical head to back up Jamie Whincup's race engineer **David Cauchi**. Frenchman **Ludo Lacroix** will now support Cauchi at the track. Cauchi took over from **Mark Dutton**, who was promoted to team manager at the start of this season. Dutton engineered Whincup to all five of his championship wins.

Former NASCAR team boss **Charles Everett 'Hoss' Ellington** has died at the age of 79. Ellington-owned cars won five times in top level stock car competition and earned 52 top-five finishes in 264 starts in the 1970s. Ellington never actually run the full season, preferring to pick and choose the races his team took part in.

IndyCar has placed **Don Oldenburg** – the crew chief for **Simon Pagenaud** at Schmidt Peterson Motorsports – on probation until the end of August for breaking its social media policy. It's not clear what the transgression actually was.

Former NASCAR team owner **Junie Donlavey**, who ran cars for 45 seasons, has died at the age of 90. 'Chief', as he was known in the paddock, started off as an owner/driver in 1950 before switching fully to team ownership, where he gained a reputation for bringing on new driving talent.

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

SPONSORSHIP

Malaysian fuel and oil company **Petronas** is to stay on as sponsor and supplier to the **Mercedes** F1 squad, signing what's been described as a multi-year extension with 2014's Formula 1 World Championship-dominating team. Petronas has been a sponsor of Mercedes since the German car maker re-entered F1 in 2010.

The **Force India** F1 team has announced a technical partnership with Univa, which is described as a leading provider of automation data management software for large scale computer projects.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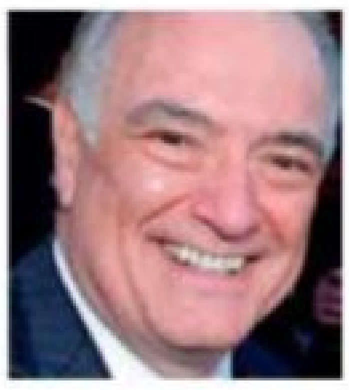


Ahead of the game

Technology is moving fast, but motorsport is always faster

What an exciting Le Mans – great looking cars, close racing, drama and plenty of lead changes, just like the "old days" – but was it really? Were the thousands of spectators just as enthralled as in the past, and did the TV audience stay glued to their screens?

F1 this year has seen Rosberg and Hamilton dicing for victory, and Audi at Le Mans provided great entertainment, fighting off the new challenges from Porsche and Toyota. A professional eye could pick holes in the reality of such entertainment, but most fans won't. Most significantly, the new technologies haven't damaged the racing in the way many expected.

From a business perspective, paying spectators and TV audiences must be entertained, as it's their numbers which attract sponsors and technology partners to keep the show on the road. I wonder if, without the new technologies, "old style" racing would have seen the audience dwindle away. Nothing remains static for very long, particularly in motorsport.

PACE OF CHANGE

The sheer scale and breadth of the regulation changes in Formula One is breathtaking. The confidence shown by the F1 teams and their engineering suppliers in creating the new 2014 cars, within such a short lead is exceptional. You are all experienced engineers and you know just how many major changes were demanded. Yet a full grid of cars turned up at the first race and the audience were enthralled by close racing. This was a stunning showcase of the capabilities of motorsport engineering to meet the technology challenges, and is a credit to all involved.

The same is true of Le Mans. In LMP1 alone, close racing was delivered from a normally aspirated V8, racing a 2-litre V4 turbo and a diesel V6, each with entirely different performance patterns. Fans were entertained by seeing the futuristic Nissan ZEOD complete a lap entirely on electric power at a top speed of 180mph. Just five years ago, this would have been unbelievable, such is the rate of progress.

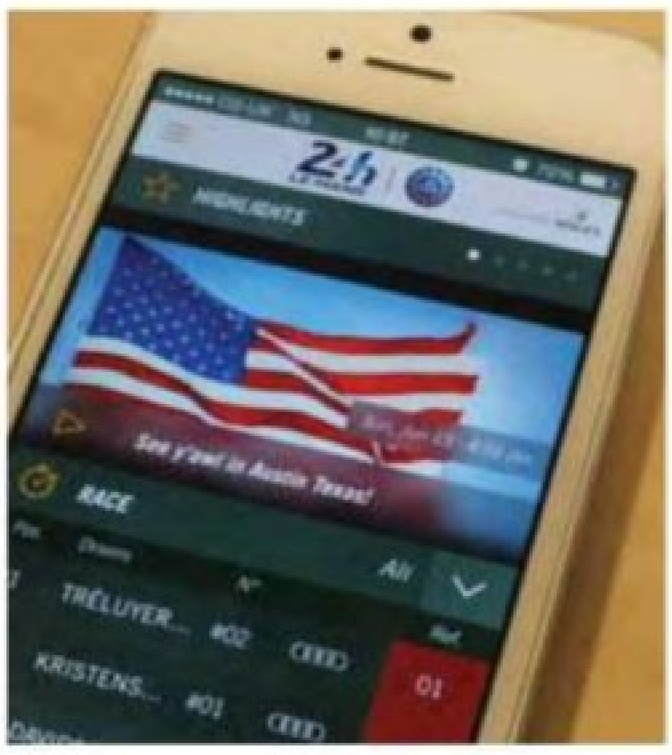
The Corvette employed a new Collision Avoidance developed to avoid the horrendous rear-end crashes we have seen in endurance racing. This seems certain to appear on road cars in the near future as Corvette has worked with Cosworth on other electric systems, already seen on their road cars.

So in reply to the question whether these developments are good for business, I would give a resounding 'Yes!'. It is easy to criticise those with courage, vision and a plan for the future, but look back and consider where we would be without embracing innovation. The world is changing fast and never more so than in the area of human transport.

The way we will travel in the next few decades will bear no relationship to where we are now. Electric vehicles will be essential to urban travel, different fuels will power a variety of hybrid cars for those who enjoy speed and the full driving experience away from the city landscape. The cost of enjoyable driving will remain in focus as fossil fuels decline, and alternatives come forward.

Just think how other transport has changed dramatically in recent decades yet the stalwart internal combustion engine has powered our cars throughout the same period – so it is time for a change. Of course, the I/C engine will be a significant power source for many years – it's now clear how much more efficient these can become with more investment. Each time a new, super efficient I/C engine is produced, the global lifetime of this fabulous power unit will be extended, often linking to other sources of energy.

Each of these technological advances brings new business opportunities for our motorsport supply chain. To operate in the motorsport market you must be nimble, open-minded and enjoy the challenge of innovation, but understand that technology change must be delivered fast. Motorsport has no time for slow moving adoption of innovations. Our delivery times leave the automotive engineering industry stunned – highly complex engineering, breaking new ground, always delivered fit for purpose and on time.


COTTON/COLLINS

WEC app, launched this year

This unique fast response ability is, in itself, proving to be a business opportunity as other sectors seek ever faster delivery of engineering solutions and they know those from the cauldron of motorsport have been race proven in tough competition. The hugely successful business development initiatives of the MIA, introducing their members to the defence, marine and automotive sectors, has already secured millions of pounds of new business for this reason.

NEW PARTNERSHIPS

I am sure others from our world class supply chain will profit from the demand created by this new world of motorsport. It will drive them into new areas of business with new partners. Change will bring exciting new rewards for those who rise to the challenge.

The greatest asset of motorsport is the quality of the people we employ. We need them to be motivated, excited and challenged by the technologies of motorsport. The new generation of engineers won't want to be involved with yesterday's solutions. They are thrilled by the variety of technology the future holds for motorsport. To a young mind, these are not new technologies, simply the right technologies. The use of an iPhone or iPad is now second nature to them, and immediacy is considered a right.

Motorsport has always attracted bright young minds and the rules are going to have to keep pace with them. Their new ideas will shake up the establishment, as engineering has done for a century, but at a faster pace than ever.

I am sure that the new materials, new products, new approaches and thinking needed to meet these challenges will bring growth to motorsport businesses, and that the best motorsport suppliers are going to enjoy the most exciting decade of their engineering lives.

The ZEOD completed a lap entirely on electric power at a top speed of 180mph. Just five years ago, this would have been unbelievable

HOSES

Five million users for Aflex

Aflex has passed a milestone with deliveries of their patented Hyperline FX. More than 5 million engines now rely on their hoses.

Hyperline FX is a flexible 'hybrid' PTFE hose with a smoothbore inner and convoluted outer liner providing engineers with an exceptional opportunity to package not only turbocharger lubrication hoses, but oil, fuel and coolant lines where space is limited. Offered in cut lengths as well as bulk, Hyperline FX has been fitted on over 5 million engines without a single failure. The added flexibility of Aflex's FX hose allows easy assembly, reduced installation times and increasing efficiency. Hyperline FX excels where high temperatures and space restrictive environments demand a high performance PTFE hose.

UK-based Aflex has pioneered the development of flexible PTFE hoses since 1973. From their modern facilities in West Yorkshire and with a distribution network around the world, Aflex can support automotive manufacturers wherever needed and being TS: 16949 registered, are well placed to serve the needs of this industry.

www.aflex-hose.com

RACING FUEL

New blends for vintage racing

VP Racing Fuels announced that Vital Equipment, a UK distributor of racing fuels and global logistics fuel provider for international racing series, has added the VP Racing Fuels brand. With the partnership, VP's fuel blends formulated for Historic Cars

and Motorbikes will be available throughout the UK and Europe.

'Vintage Leaded is a top quality leaded fuel without ethanol or other components known to attract moisture,' said Jim Kelly, regional manager at VP. 'The lead is needed to protect the valve train in older engines.'

'Vintage Unleaded, also marketed as C9, is a really special blend. It is 94 octane and also contains no ethanol,' Kelly added. 'This fuel is designed for cars, motorbikes, marine engines and others that sit for extended periods. It will not attract moisture, won't degrade plastic fuel lines and will start on command whether sitting for a day or a year.'

'Alistair Roberts and I have spoken many times over the last few years about joining up with VP. Our fuels for Historics gave him the edge he needed to provide a complete product line for his customers in the UK and around the world,' said Kelly.

Alistair Roberts commented, 'I'm delighted to enhance our range of fuels with these quality products from VP and look forward to helping the Historic world with fuel supply during the week and on request at track day and race events.'

Both blends, along with VP's complete product line of FIA, MSA and other fuels, are now available in 19-litre and 204-litre drums from Vital and VP's extensive European distributor network.

www.VPRacingFuels.com/Europe

SWITCHGEAR

New Cartek power control panel

Cartek now produce bespoke Power Control Panels for all motorsport applications. As the name suggests, these products are custom designed switch panels with integrated solid-state electronics offering high current switching, adjustable circuit protection and custom functionality in a single unit thereby replacing individual switches, relays, circuit breakers and complex, interconnecting wiring.

www.cartekmotorsport.com

BRAKES

Winning formula brake pads

Pagid RS racing brake pads have been successful in every major endurance and circuit race for decades. It has proven to be such a winning formula that Pagid has now developed a complete product range for historic cars: Pagid RSH. Using state-of-the-art compounds in shapes engineered to fit the brake calipers on your classic race cars, Pagid RSH is both for the distinguished gentleman racer and for the serious professional.

www.pagid.com

MACHINING

Mazak launches new heavy duty VTC 800 machine

Yamazaki Mazak has developed a new heavy duty version of its UK-built VTC 800 series of vertical travelling column machining centres.

The new VTC 800/30HD, which stands for 'heavy duty', is a 50 taper variant that provides an ideal platform for cutting hard-to-machine materials, such as Inconel and titanium, which can cause spindle vibration during the cutting process. Thirty-six tools are provided as standard.

The high performance machine structure has been designed to provide class-leading static and dynamic stiffness, enabling the HD to deliver the higher levels of spindle torque and vibration-free power demanded by 50 taper performance in industry sectors such as subcontract, aerospace, marine, heavy equipment and power generation.

The Mazak designed and manufactured 10,000rpm spindle delivers continuous power of 22kW and a short time torque of 302Nm. In production, the machine will deliver a rapid feed rate of 50m/min in the X-,Y- and Z-axes; 0.5G of acceleration and a 5.7 second chip-to-chip time.

www.mazak.eu

Haymarket introduces new Low Carbon Racing and Automotive Show for 2015

Haymarket Exhibitions is launching a Low Carbon Racing and Automotive Show (LCRA), held on January 8-11, 2015 at Birmingham's NEC in the UK. The event will showcase innovations, provide networking opportunities and cement the UK's position as a global hub for low carbon technologies in the motorsport and automotive industries.

With low and ultra-low carbon vehicle technologies vital for the growth of the UK automotive sector, the government is planning a £150bn investment over the next 20 years, expected to result in a 60 per cent share of the market by 2030. The UK has already witnessed rapid proliferation of hybrid and electric vehicles sales, up 17.4 per cent year-on-year, with the technology having been proven in global motorsport series, such as F1 and the Le Mans 24 hours.

LCRA will take place alongside Autosport International, Europe's largest motorsport show, which attracts over 82,000 visitors including 27,000 trade buyers from over 50 countries. The new show will further reinforce the event's presence as a catalyst for global automotive engineering opportunities in a year when Autosport International will celebrate its 25th anniversary.

Gavin Brown, managing director of Haymarket Exhibitions, commented; 'We have been greatly encouraged by the response received from various government trade bodies and organisations to our new initiative. LCRA will be co-located alongside Autosport Engineering, for specialist suppliers to the motorsport and automotive industry, and will showcase companies with the latest and most innovative low carbon technologies being used across both the motorsport and the mainstream automotive sectors.'

Chris Aylett, CEO of the Motorsport Industry Association (MIA), added; 'The motorsport industry has an exciting part to play in developing solutions and technologies to meet the demands of a low-carbon automotive and transport future. Successful new business partnerships have already been formed and more will, undoubtedly, follow. LCRA 2015 provides a timely and helpful opportunity for all relevant low carbon business communities to come together and is an excellent initiative from Haymarket, which we welcome.'

Alongside the MIA, Haymarket Exhibitions is actively discussing collaborations to showcase technology at the show and seminars from industry leaders. Among the first to sign-up are Greenpower and Emissions Analytics, 'As the leading organisation for educational and sustainable motorsport for young people worldwide, we are delighted to learn about the new Low Carbon Racing and Automotive Show. We feel there is great synergy between our organisation, industry and this exciting new event and were delighted to sign up as one of the first exhibitors,' said Jeremy Way, CEO of Greenpower.

Jane Thomas, global sales manager for Emissions Analytics added: 'The calibre of exhibitors and attendees at LCRA makes it an exciting prospect for us to promote our services to the low carbon sector. It is rare to have the chance to reach so many people at once and we hope to capitalise on the opportunity by demonstrating the benefits of real-world testing.'

For updates on the Low Carbon Racing and Automotive Show visit: www.autosportinternational.com. Tickets will be available in July from £27, with discounts for group bookings.

Q&A WITH DR GARETH B NEIGHBOUR, OXFORD BROOKES UNIVERSITY

Dr Gareth B Neighbour is Head of the Department of Mechanical Engineering and Mathematical Sciences at Oxford Brookes University. Here, he talks of the importance of inspiring the next generation of engineers.

Q. What are your thoughts on the need for the motorsport industry to continue to attract skilled talent and graduates?

A. It is vitally important that the industry maintains its position at the vanguard of high performance engineering and continues to attract high quality and talented engineers from around the world. If we are going to use motorsport as a technology accelerator with diffusion into other markets, it needs the best people.

Q. What are you doing to attract and inspire the next generation of automotive engineers?

A. Oxford Brookes University is uniquely placed in Motorsport Valley in the heart of Oxfordshire with access to teams, suppliers and the latest R&D. Our students travel from all corners of the globe to be with us given our track record and to be part of the authentic learning experience we provide in our leading facilities.

Q. Nissan has committed itself to attracting more female graduates into the industry. Do you agree that this is the right way forward?

A. Absolutely. The issue is a complex one with many problems centred on teaching STEM subjects and other subjects that show a gender imbalance. However, by creating demand, it should have a positive influence in the supply of female engineers. The important thing is the industry engaging with academia at all levels to align education with professional qualifications and enrichment activity. This work is already being undertaken by Oxford Brookes alongside the University Technical College in Swindon.

Q. How successful was Autosport International 2014 for Oxford Brookes University?

A. Very successful. We engaged with new partners within industry and have a number of projects on going. We also interacted with potential students and were able to describe the learning experience they would receive if they chose Oxford Brookes as their top university. In a more general sense, the university is proud of its Formula Student Team, considered by many as the leading team in the UK, and to be able to show the car to the general public is a thrill.

Q. Autosport International is celebrating its 25th anniversary in January 2015. What has been the most significant year for Oxford Brookes University so far?

A. Well, in 2015 we will celebrate 150 years since the creation of our founding institution. We have a long and proud history that has included notable alumni such as Lord Nuffield. It makes me smile when we have been named as the best modern university for the past 11 years when we have been around for so long!

Q. The motorsport industry has changed considerably over the past 25 years, what one element do you feel will change most over the next 25 years?

A. This is a difficult question since the pace of change is always fast and nothing stands still. However, it is evident that social responsibility and sustainability are influencing the sport more than ever, both from an engineering perspective with innovation unthinkable only a few years ago, as well as the spectator experience. Creativity has always been at the heart of motorsport in dealing with the engineering challenges and we need to be careful that we allow this to flourish.

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Exploring the solar system

Air conditioning systems in closed cockpit racing cars are nothing new – in 2007, the Automobile Club de l'Ouest decreed that the temperature inside the cockpit may not exceed 32degC with air con, or 10degC above ambient without. With heat soak and penalties to be applied for failing to meet these criteria, Peugeot opted for an aircon system, while Audi pushed for as long as possible to keep the open cockpit.

In GT racing, where in years gone by drivers had collapsed from the heat in the cockpit (particularly in the Dodge Viper, where the engine sat above the drivers' legs and the exhaust ran down the side of the cockpit), it was slightly easier to fit an aircon system as there was a bit more space. However, Porsche had a slightly different problem – the cabin of the 997 was so large that it needed to partition it off to cool the area around the driver only. The system would otherwise be so large that it would rob valuable horsepower.

After years of development, the systems have now got smaller and more efficient. The new C7R Le Mans car uses a system from the hybrid Chevrolet Volt. It takes only 1bhp to drive it and was welcomed by Corvette drivers at Le Mans, though the team had planned to run a new system. 'We are working to improve the condenser unit – that is the biggest struggle,' says programme manager Doug Fehan.

The panels weigh 3kg, and save a 3bhp draw from the engine

However, the Aston Martin team decided to take it a step further in France, with a concept using solar panels for its air conditioning system. The plan is to cover the roof of the V8 Vantage in solar panels, and then use the energy to run the aircon system. The basic figures are that the panels weigh 3kg, and save 3bhp from the engine required to run the aircon system.

The system is developed with Hanergy Global Solar, a Beijing-based global clean energy company. The company is best known, according to Aston Martin's press release, by its solar photovoltaic panels that are fitted to the roof of buildings, harnessing the sun's energy for powering homes and industry. The company is run by Jason Chow, who made his money in hydro-electric plants in China and who is now looking to increase the reach of 'green' technology.

'I think that it is very important to use more renewable energy in the car industry,' said Chow at Le Mans. 'Everything is about petrol, diesel and that causes a lot of the environment problems out there. In the future, the EV car is coming. We will try to put solar charge into the car. That can be very interesting and open a new way for the car industry. Petrol and diesel cars can save their energy, and EV cars can charge by themselves in the future. Potentially the technology can go there. Right now, we have already started to develop with manufacturers. The first step is to put [the system] on the racing car. If we develop an EV car together, it can potentially be charged by the panel on the rooftop. That is doable and is coming soon. It is not in two or three years, maybe just one year. Right now, we are developing with full size cars to integrate the technology. The racing car is easy. The road car will take a couple of years, but finally the car will come into the real market. Per square metre it is 208 Watt of power.'

Audi's Ulrich Baretzky would balk at the idea of this – as far as he is concerned, a good lightweight diesel engine is more energy efficient than a battery-powered EV car. But, as we have no real clue as to what the future propulsion method of our cars will be in future, Chow may have a point. Interestingly, however, Aston Martin was super quick to distance itself from the road car programme, although the Cygnet would be a logical place for Hanergy to start. Imagine, in hot countries or climates, where the car heats up naturally, being able to leave the air conditioning system on full time.

As with most things, using solar energy this sounds great – we are never going to run out of solar energy until the sun explodes, which would then give us a finite (short) amount of time to enjoy ourselves before we all die. However, what happens to the energy that we capture in these solar panels? Or rather, what doesn't happen? Would it lead to global cooling as light and heat is reflected back into the stratosphere rather than be soaked up in the earth? Would magpies fly around permanently confused? What happens to the reflective light? How much of a change would this technology make in the world? As I write, this is being debated in the *Racecar* offices. I doubt we will reach any kind of reasonable solution. Aston Martin, however, will, when it debuts this technology in the hot races of the WEC later this year.

EDITOR
Andrew Cotton


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