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Red Bull RB8

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CONTENTS JANUARY 2013 VOLUME 23 NUMBER 1

COVER STORY

COLUMNS

FEATURES

TECHNICAL

BUSINESS NEWS

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It's all a matter of time

Massive in racing. See also: that which flies by as deadlines approach

Time has been described as that which avoids everything happening at once (although sometimes I feel it has failed, looking at my schedule), but it is also intrinsic to motor racing.

It is famously used to determine one's grid position, as in the result of qualifying performance. It always amuses me to see the report of a boring race, when the pole-sitter disappears into the distance. What did you expect?

The smallest unit of time in this universe is 10^{-43} secs (Planck time, equivalent to how long it takes for a blonde to notice an unmarried billionaire). This is somewhat smaller than the units we use in racing, which are several orders of magnitude bigger: one 1000th of a second (although NASCAR and Indy have now graduated to one 10,000th of a second, to cater for the closeness of racing.

The unit used can be put in perspective by noting the biblical three score and 10 years allotted to the life length can be notated as 2.1 gigaseconds, and the life of the universe can be put at 430 petaseconds (10^{15} sec). Le Mans, on the other hand, only lasts 86.4 kiloseconds.

It is famously used to denote the advantage of one car to another, by giving the difference between the winner and second place, but one could also give the difference in inches, or metres, or centimetres. On a lap average of 205kph, a one second advantage is equivalent to 52m (although strictly speaking the vehicle is probably faster on the straight past the finishing line, say 270kph, wherefore the distance will be roughly 72.22 recurring meters, but we won't be pedantic about it.)

A 10th at the start finish line is equivalent to 7.2m, slightly more than a car length, which puts a length of 3.6m for a 0.050s – a proper way of seeing the difference in performance, but not so big as to cause the team manager to exclaim 'O aching time! O moments big as years!' as Keats quoted in Hyperion: A Fragment.

Time is a fundamental part of daily life, and more importantly, racing

If measured over the entire race distance of 300km, a one second difference is equivalent to 0.0189 per cent in distance. If 10 seconds behind, it is less than two-tenths of one per cent. Gives a different perspective on winning, eh? Also in defining the difference between a good car and an also-ran, not that much, and certainly not enough for the tifoso to elevate or denigrate a given car.

One of the things that amused me in days of yore was to see the lap times during qualifying for a GP, with times falling until the chequered flag, but at the sharp end of the grid cars would be separated by a few hundredths. This with cars in their most diverse form, F1 with wide noses, tea-tray wings, six wheels, short wheelbase, long wheelbase etc.

Fundamentally it was the time on the bottom of the pit board being waved at the driver which defined the time he had to achieve, and then the driver did make a difference, or the cars were so bad that putting it on the grid was a measure of how close to the edge he was prepared to go – to go faster than the number shown on said board.

These parameters are so fixed now, that cars usually line up side-by-side, being locked into their performance levels, and the grid is used more to judge between team mates performance, proof further that the car is now more important than the driver. It demands a whole lot more research and design, by an army of engineers, and a supply chain far bigger than the halcyon days of one DFV, one Hewland gearbox, a set of discs and calipers from Lockheed, add water, stir. Voila! One F1 car...

"Planck time is equivalent to how long it takes for a blonde to notice an unmarried billionaire"

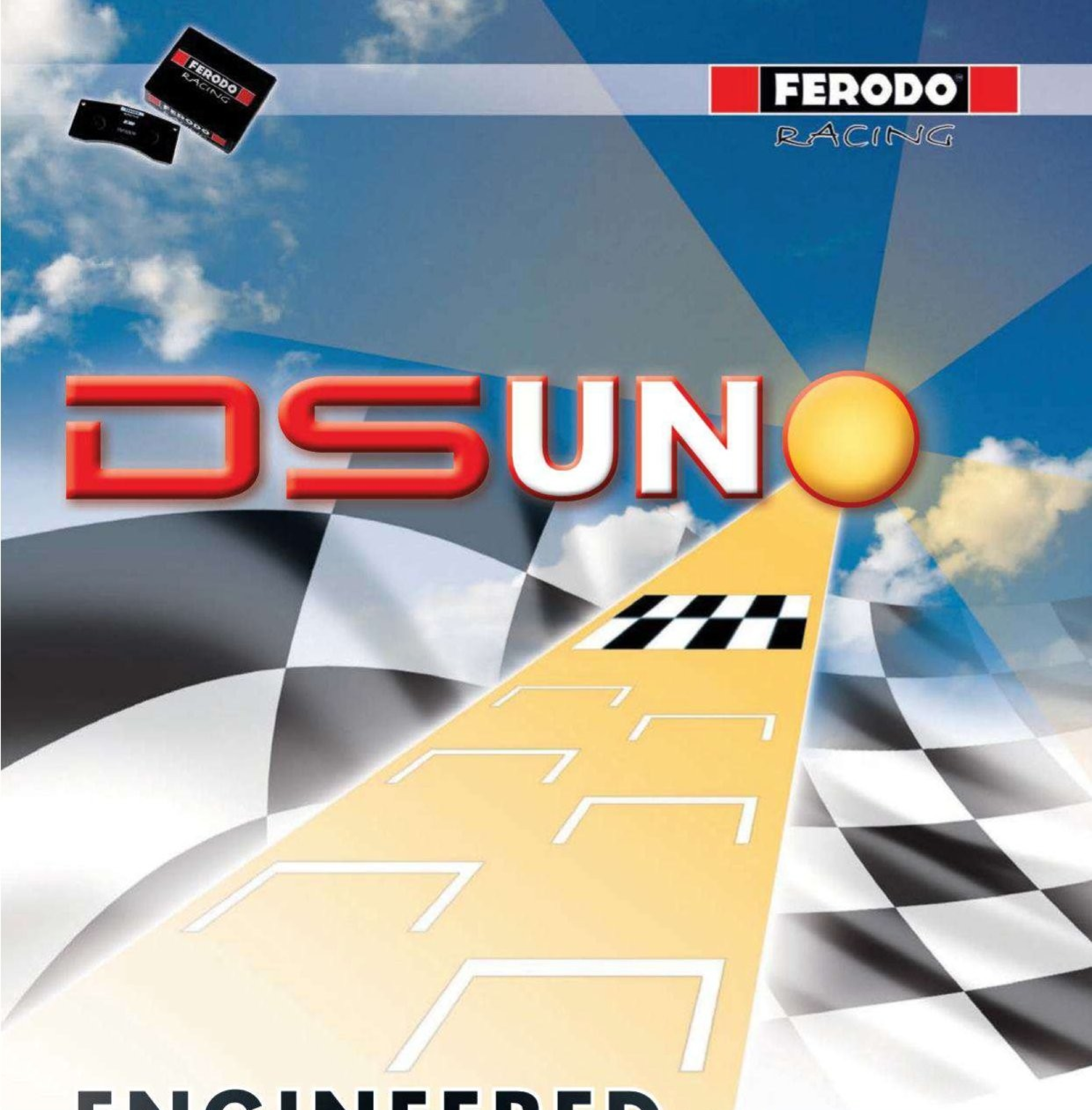
Likewise, coming back to the time theme, design and development are not the punctuation at the end of the season, but a never-ending continuous affair, as in the Bard's words: 'Tomorrow, and tomorrow, and tomorrow, Creeps in this petty pace from day to day.'

The driver's side, however, is being reduced more and more by the reduction of testing time, in the name of the great god Mammon, also known as money. In all formulae, track time and tyres available make experience a valuable commodity, and the arrival of new drivers from the yearly crop of youngsters leave them on the shores while the F1 ship sails away, with the hoary usual crowd of veterans. As they are not culled by accidents, as one Bernard Ecclestone once said, they will stay on as long as they produce acceptable lap times. So much for the selection of the best.

Time itself in racing is quite elastic, and in the preparation and design phase seems to rush along to the point that it should have a large red note: 'Warning – dates in calendar are closer than they appear!'

But then those last couple of laps before the flag when you are leading trickle along with the speed of molasses at sub-zero temperatures. Relativity at its best.

Which explains why life in the fast-lane gets a bit confusing sometimes. Something to do with time slowing down with speed, as you whizz by different time zones, that zombie feel from continuous jet-lag, that whoosh of deadlines flying by, the postponing of essential tasks... being a procrastinator is the belief that if something is done at the last minute, means it can be done in a minute, a bit like this column. Cheers. I must now be off to reduce the blood level in the caffeine system.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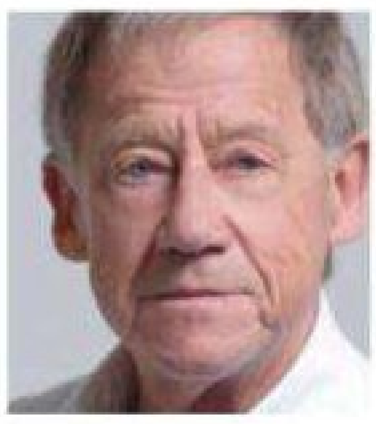


An enduring dilemma

Technology improves reliability, but is it making long-haul racing irrelevant?

Walking the Silverstone WEC paddock in September, I wondered whether the sport and business of motor racing has become too top-heavy in regard to the equipment, personnel and all the ancillary goings-on that accompany the main activity – man and car competing on the race track.

Is the tail wagging the dog and taking relevance and cost with it? Endurance racing, as typified by Le Mans 24 hours, is surely where the link between race track and road should be at its closest. Even the exotic LMP cars are not so far removed from the supercars of tomorrow, and with the successful advent of diesel and hybrid powertrains and the ACO's forward-looking 2014 regulations, the technological and engineering link with ordinary passenger cars has become even stronger.

So isn't it a bit misleading for a manufacturer to widely advertise its success in winning endurance championships and events such as Le Mans and Sebring? The inference being how reliable, as well as fast, their machinery is, when every inch and every second of its running is being monitored and nursed from outside the vehicle, with constant adjustments being made. I'm talking, of course, about telemetry, and the small army of engineers/technicians monitoring each car constantly whenever it's on-track, via the array of computers and their attendant servers, aerial masts and communications equipment.

Moto GP racing doesn't even allow radio communication, let alone telemetry. Of course, races are much shorter, but these bikes have complex systems and high-revving, close-to-destruction engines with restricted fuel allowance, and still manage to perform with great reliability. By far the most common DNF's are due to the riders falling off.

So why not the same for the endurance racecar? Materials, manufacturing processes and quality control procedures are far in advance of the time when cars ran and finished 24-hour races without any off-car aids at all. And, so is the level of preparation and accumulated knowledge, and generally the fitness and professionalism of the drivers.

It seems to me that the best use and function of digital technology is being misdirected. Shouldn't one of the aims of technology be to reduce the human element in repetitive tasks? The endurance racing technical challenge should be to design and make chassis, powertrains and transmissions that can run competitively for the whole duration of events with the minimum of human monitoring from outside. No telemetry permitted, just the onboard data logger manually downloaded at every pit-stop by simply plugging in a laptop for a few seconds.

Any critical faults not able to be 'intelligently' handled in this way can instead be instantly flashed up as a warning message from the on-board sensors to the dash display. The driver can then radio this information to the race engineer for them to work out the best response. As for the ever-critical fuel consumption figures, these are routinely displayed on the dash and can be radioed to the pit each time the car passes.

I am not dismissing the workload of the driver in current LMP projectiles, and the concentration required in driving them, especially in traffic and in poor conditions, but compared to previous generations of racing they have the advantage of power steering, paddle shifting and a variety of driver aids including far superior lights for night driving, all reducing driver fatigue and concentration-loss.

Live time telemetry is interesting, but fundamentally an expensive luxury

'Hang on!' I hear you say. Doesn't the ACO demand instantaneous information from the cars, regarding matters such as fuel flow metering and a number of other data inputs, hence the statement 'an FIA telemetry system will be imposed' being included in the 2014 LMP rules?.

As yet, the ACO has not fully investigated whether this will mean that every team has to adopt identical mandated systems, or whether a central system will receive the necessary signals from every car independent of the teams' data. Could this be the ideal time to implement the second option, ie ban any teams' telemetry altogether, saving teams having to spend yet more money and simultaneously meeting the objectives I have outlined? After all, pit-to-car telemetry was banned – including in F1 – a number of years ago and the world didn't end.

"Telemetry can add up to half of a private team's budget"

Probably the most noticeable change in endurance racing in recent years is in the number of personnel involved, largely because of the sophisticated technology being employed. Twenty to 25 people, excluding the drivers, to run two cars is not unusual. Multiply this by about five for the manufacturer teams. Given that one of the largest race team budget items is personnel – including global travel expenses – every additional person, even if employed part-time, adds significantly to this burden, as does the cost of the telemetry equipment and transporting it to every race and test. Not a big issue for manufacturer teams, but a headache for privateers when this telemetry expense can easily add up to half – or more – of the budget that a paying driver can bring to a private team, many of which are scratching to compete at all.

OK, teams don't have to use telemetry, but even for privateers it is practically forced on them by their engineers and engine suppliers, and the perception that they can't seriously go racing without it.

Austerity is upon us, is continuing to bite ever deeper and is very dangerous to ignore. Time to start cutting back, because at some stage the straw will break the camel's back. Anyway, part of the challenge of endurance racing should surely be to operate cars and systems that are closer to mainstream vehicles and proving technology that can later be incorporated in them. I don't see a bunch of guys staring at computer screens 24/7 ever being a part of everyday motoring, do you?

Development of a champion

The heritage of the Red Bull RB8 stretches back further than you might think. Adrian Newey takes us right back to the start

BY SAM COLLINS

'I think the result today or the result last week or whenever, the results in the last two years are not just thanks to me, or thanks to any particular person in the team, I think it's thanks to all of us. Everyone is pushing hard, there are lots of bright guys with good ideas. Obviously some guys are really important but all in all, that's the spirit we share and it's just nice to be a big part of it.' These the words of an elated Sebastian Vettel following yet another dominant win. His team Red Bull Racing has essentially dominated Formula 1 ever since it adopted a new design concept at the start of the 2009 season.

The man heading up the team behind that concept is used to life at the front of the grid. Indeed, in the last two decades Adrian Newey-designed cars have won eight World Constructors Championships and nine drivers titles. His philosophy is not one of aggressive revolutions in design, but instead gradual steps in a particular direction.

'The way I have always tried to work is that if you can get the concept right in the first place then, within stable regulations, I think it is good to evolve a car from there,' says Newey. 'That's what I did at Williams with the FW14 through to the FW16. That concept stopped when at the end of 1994 when there was a big regulation change. The Williams FW17 as a result was a brand new car that had nothing to do with the FW16 due to the rule changes. From then the FW17 to FW19 were very much evolutions of each other. It was the same during my time at McLaren, the MP4/13, MP4/14 and MP4/15 were all very similar.' Newey admits however that this approach has not always worked as it should. 'At the end of the MP4/15 I felt that while there was no big regulation change, the concept we were using had reached its limits,' he says. 'So we went a new way with the MP4/16 and MP4/17, but I didn't get the DNA quite right with those.'

In 2006 Newey joined Red Bull Technology, the company that develops the cars raced by Red Bull Racing, and which in the past has looked after designs for Toro Rosso as well.

LEARNING CURVE

'Continuity is hugely important,' Newey explains. 'Really, Red Bull Racing is a team that first raced in 2005, and in truth that was a Jaguar painted blue. Then it had a steep learning curve of developing the culture – there were quite a lot of new people joining, and some people from the Jaguar days choosing to leave. So it was a period of quite rapid change and that took time to settle down, and to develop a way of working – a culture, an ethos – to develop some of the bigger tools, be it developing the wind tunnel, developing simulation, things that you can't just go to Argos and buy. It takes some time to develop those from scratch which is what we were doing and to learn how to use them and how to work with them. Once you got to that stage, continuity becomes very important. People have learned to work with each other and it's

then making that an ever tighter-knit group and trying to maintain it as the team continues to grow. It's been flat for the last couple of years in numbers as a result of the RRA, which I think is very good. But it's an evolutionary thing which took us three or four years to settle down into. The big regulation change in 2009 was good timing for us, because that coincided with the point where we had started to gel together.'

This is one of the reasons for the strong form of Red Bull's cars. When the new rulebook was introduced, Newey's new concept hit the sweet spot almost straight away. If it had not been for the Brawn team's innovative double diffuser, the new Red Bull concept would have won every championship since the rule change.

Mating a Renault RS27 engine, an in-house seven speed transmission, and pull rod rear suspension with Newey's trademark, very tight aerodynamic packaging, the overall car concept introduced in 2009 still remains one of the strongest on the grid, and much of the DNA remains the same.

'The concept started with RB5 in 2009 so I guess this makes the RB8 the great-great-grandson of that design, the RB5, RB6, RB7 and this year's car are all

"The regulation change in 2009 was good timing for us, because it coincided with the point where we had started to gel together"

Exhaust layout was a strength of the Red Bulls until the regulation change for the 2012 season, which hurt the team more than most

evolutions of each other. If you sat an RB5 next to an RB8 there would be a clear and obvious resemblance,' says Newey. 'Generally speaking if a car is an evolution, which the RB8 was, its kind of a gradual process. The knowledge from the development of the RB7 was constantly fed into RB8. You have to get the big bits out of the way, though, to hit the time scales, and the longest lead items on the RB8 were the chassis and gear case as well as the internals. The initial research will centre on what is needed for those long-lead time items and it will progress on from there.'

Red Bull supplies one of those long-lead time items, its transmission, to a customer team, Caterham. On the RB8 the layout is little changed from the RB7 and the unit found in the CT-01. 'With the gearbox everybody now has instant shift, which means that you're engaging the new gear before you come out of the old gear, and you're using the backlash to get out of the original gear before you have the two gears fighting against each other. After that it is just reliability and packaging. On the RB8 the gearbox internals are the same as on the RB7, and quite a few of the assemblies carried over too. Wheel bearings, pedals and that sort of thing are the same, so we have only changed parts where there was a reason to do so,' he continues.

'That regulation puts an emphasis on light drivers, as long as we're in a situation where we don't have ballasted seats,' says Newey. 'For instance, with Mark Webber we have a driver who's on the heavier end, compared to Sebastian. That means he has less freedom on weight distribution. The obvious solution to that would be that

"With the RB8 It was about damage limitation from losing the exhaust technology"

The car's monocoque is another of the long-lead time items and as was the case with all of the Red Bulls since 2009 it had to accommodate the 64kg of Sebastian Vettel who is 174cm tall and the larger 75kg frame of Mark Webber, who stands at 184cm. A regulation limits all cars on the grid to a very small window for weight distribution and this is certainly a challenge where the latter is concerned.

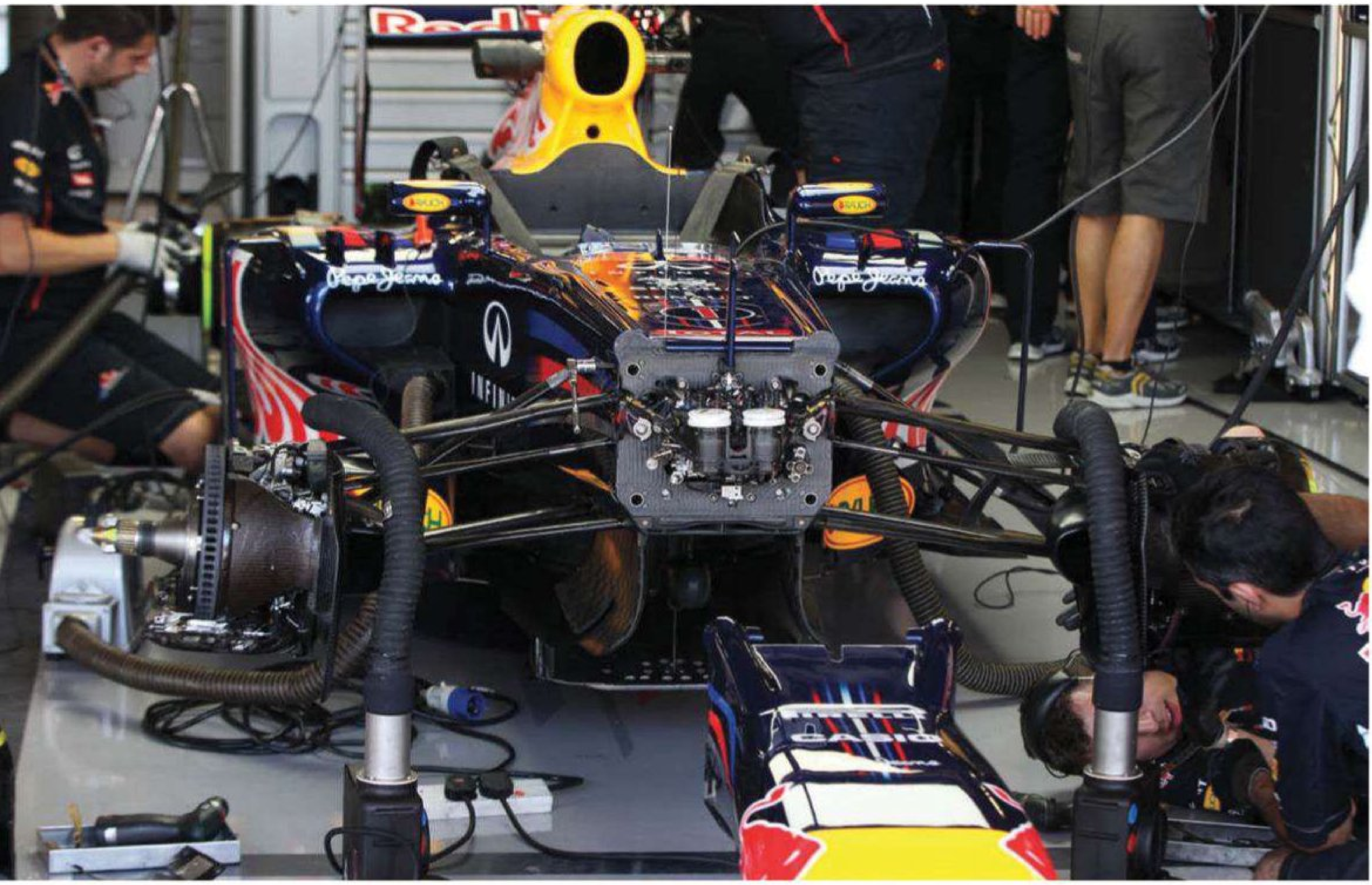
drivers have to carry ballast on the side of their seat, but that's something that has been discussed and it hasn't happened so far. It really means that if you make the wrong move, you're locked into it for a while. It's one less variable, but one that's the same for everyone.'

While the gearbox itself is little changed, the area around it is key to understanding not only the RB8's design but also that of the RB7 and earlier cars.

'The RB5 was designed as a single diffuser car,' says Newey, 'but when double diffusers were deemed legal we put one on RB5 as best we could, but it had not been designed for it and was not as effective as it could have been. So the main focus of the RB6 was to redesign the back end of the car to maximise the double diffuser effect - that dominated the packaging of the rear suspension and so forth.

'The RB7 was different. With the double diffuser gone again it was about maximising the exhaust technology which we started to do with the RB6. It was really taken a step further with RB7, the way to recover much of the downforce lost with double diffusers was with the exhaust. It was a remarkably effective system to the point where RB7 was very close in terms of downforce to where the double diffuser car had been.'

The major change for the 2012 season was the outlawing of that exhaust technology, the so called 'hot blown' diffusers, which again meant that Red



The RB8 is a clear evolution of the RB5 to the RB7 as Newey concerns himself with evolution, rather than revolution each season

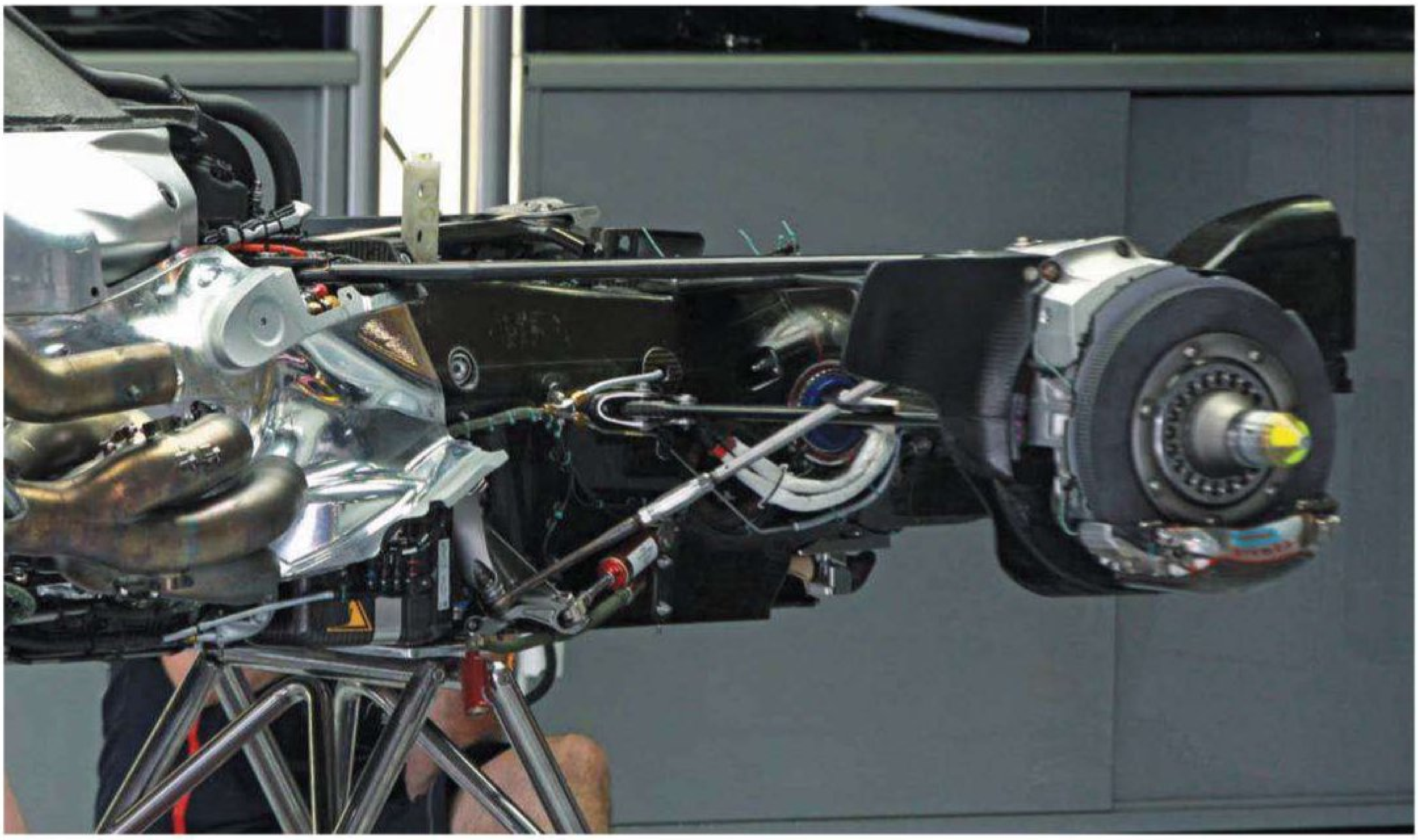
Bull had to rework its rear-end concept. 'With the RB8 it was about damage limitation from the cut in downforce from losing that exhaust technology. We have suffered more than our competitors in terms of the exhausts. We were the first to do it in 2010, so we have been on that track for two years and had probably taken it further than other people. It's been difficult to get the car to work properly again with that missing – we've had to re-learn the baseline,' Newey admits. 'The RB7 was designed around the exhaust. This year, knowing that the exhaust position from last year would be taken away we've had to go back and look at how we developed the car through the two years with the side exit exhaust. The routes we'd taken that were only suitable for that exhaust position now had to be re-evaluated. Probably one of the key things there is the rear ride height. The exhaust allowed us to run a high rear ride height – it's much more difficult without that, so we have to go back down and redevelop the car around that lower ride height.'

While television commentators are very keen to tell audiences that blown diffusers were banned at the end of 2011, a quick look at the development of the exhausts this season shows how clear it is still a benefit.

The RB8 was launched with a fairly conventional solution, but after initial testing, it was fitted with a Sauber-style solution, which differs from the Coanda layout, but achieves the same goal, reducing the disruption to air flow in the diffuser caused by the rear wheels.

'It is a combination of two things that hit at one time,' says Newey. 'One was the restriction on where we could physically put the exhaust exits and the other was the restriction on the

PERFORMANCE PERFECTED



Aerodynamic packaging is famously tight on Newey designs. A new chassis was introduced to accommodate the new exhaust layout

mapping of the engine. Those combined have hugely reduced the exhaust effect, but you will never reduce it to zero. Compared to the other teams, there are obviously two ways of skinning the cat in terms of getting the most out of the exhaust given the limitations in the regulations. The concepts are different in the philosophy and the way they achieve the effect.'

The ever-tightening rulebook is something that clearly concerns Newey, who feels that things are starting to get too restrictive. 'Regulation changes I enjoy,' he says. 'Regulation restrictions I rather lament. All of those changes of the concept from RB5 to RB8 about are always due to regulation restrictions. Ultimately if the regulations become tighter and tighter then you end up with Formula 1 becoming GP1. All the cars will converge to become more or less the same and I think that would be a great shame for the sport. For me, what differentiates F1 from tennis or golf is the fact that it is a combination of man and machine, and to win either the drivers or constructors titles you need a combination of good driver and good car. If the regulations mean that the cars are all more of less the same it would to me reduce the attraction of the sport.'

It is worth noting the RB8 has pushed the current restrictions hard in a couple of areas, resulting in two high-profile regulatory issues. First the team was forced to change the design of the rear floor of the car. A new floor used at the Spanish Grand Prix and the Monaco Grand Prix featured a small cutout ahead of the rear wheel, but this was questioned by rival teams who argued that it did not conform with the technical regulations. These state: 'All parts lying on the reference and step planes, in addition to the transition between the two planes, must produce uniform, solid, hard, continuous, rigid (no degree of freedom in relation to the body/chassis unit), impervious surfaces under all circumstances. Forward of a line 450mm forward of the rear face of the cockpit entry template, fully enclosed holes are permitted in the surfaces lying on the reference and step planes provided no part of the car is visible through them when viewed from directly below.'

To circumvent this, other teams, such as Ferrari, fit a tiny slit between the hole and the outer edge of the floor meaning that the hole is not 'fully enclosed'. The FIA technical department said that in its opinion the floor did not meet the rules as it interpreted them, and for the next race in Canada Red Bull changed the design.

MAP WRAP

Another run in with the FIA Technical department took place at the German Grand Prix. This time it centred on the torque map loaded on to the car's McLaren ECU. The FIA's technical delegate, Jo Bauer, discovered the code ahead of the German Grand Prix and issued the following statement: 'Having examined the engine base torque map, it became apparent that the maximum torque output of both engines is significantly less in the mid RPM range than previously

THE CURSE OF KERS

With seven race wins (at press time), Red Bull's RB8 has rivalled McLaren's MP4-27 as the strongest car of the season. The Silver car missed out on certain wins due to accidents and gearbox failures, while some minor reliability glitches have hampered the blue machine. An alternator failure cost a certain victory in Valencia, and resurfaced at Monza.

Other minor issues have also hampered progress in some sessions, notably one that has carried over from the RB7, which suffered with frequent KERS failures.

'The layout and packaging and indeed many of the components of the KERS are identical to RB7,' reveals Newey. 'I think one of the problems we had with RB7 as far as the KERS was concerned was not so much how we packaged it or what we were doing with it – we are as a team not KERS specialists and we were teaching ourselves about something we knew nothing about. As in all such things when you're doing that it's a rapid learning curve and mistakes were made. I think that the main difference hasn't been design features or layout – rather it has been us getting to grips with the technology.'

Red Bull has twice been before the beak to explain parts of its car. It lost on the rear floor slot and was forced to change.

seen at other events. In my opinion this is therefore in breach of the technical regulations as the engines...Furthermore this new torque map will artificially alter the aerodynamic characteristics of both cars which is also in contravention of technical directives.' The mid-range torque map is critical in optimising the car's exhaust gas flow to get a blown diffuser effect, though it was not clear that this was what Red Bull was doing. Nonetheless, Bauer referred the matter to the event stewards.

Three hours after Bauer's report was released, the FIA stewards of the meeting announced that no further action would be taken. Their statement read: 'The stewards received a report from the FIA Technical Delegate, along with specific ECU data from Red Bull Racing Cars 1 and 2. The stewards met with the team representatives and the representative of the engine supplier Renault. While the stewards do not accept all the arguments of the team, they however conclude that as the regulation is written, the map presented does not breach the text of the Formula 1 technical regulations and therefore decided to take no action.'

Drivers of rival teams feel that the RB8 has more downforce at their disposal, but transmitting that downforce to the track is just as important.

TYRE MATTERS

Indeed, one of the biggest talking points of the 2012 season has been the tyres, the impact of which Newey feels has been somewhat overplayed. 'Everybody talks like the tyres have become so much more critical this year compared to last year,' he says. 'I think they are trickier to use generally, but equally the grid has closed up again and that's partly due to regulations being restrictive and this being the fourth season since those regulations were introduced. The cars are converging and the grid is getting tighter. Now if you are a tenth or two tenths a second slower, it might be a few grid places dropped whereas last year it might have made no difference at all. It puts tyres into a bigger focus and quite often when you get these big swings between grid results between the teams, tyres are singled out as being the reason. But that's a bit too simplified in truth. Some cars will be better in high speed corners and not so good in low speed corners; some cars may be better on bumpy circuits, but tyres are the visible feature that people just latch on to.'

Despite this, Newey admits that the 2012 Pirelli tyres are more challenging than expected. 'The tyres are very difficult to understand,' he says. 'Sometimes we think we've got a handle on them, then something happens that makes us realise that we've not properly understood them. Effectively we are trying to reverse engineer someone else's product so it is tricky, and for all of the teams. Inside our own team we have not highlighted anyone purely as a tyre specialist. But it's fair to say we have dedicated more time among our engineers than we would have done previously, or we would have done with a Bridgestone or a Michelin. If you compare them to - say - the height of the tyre war between Michelin and Bridgestone, then you got to the point where the race was really a series of qualifying laps and the drivers would therefore push very hard throughout without worrying too much about degradation, be it thermal or wear. That's different now. I think that brings a different set of skills to the floor, almost like Prost in the 80s, when he got the reputation for being The Professor, thinking about how he did the race. I think that's coming back, which gives some variety and change in the field both race-to-race, during the race and qualifying to race. I think that's all good for the sport, good for spectating.'

As Racecar closed for press Red Bull had an 82-point lead, and the RB8 was clear favourite for another title. And to compound things for the rest of the grid, the RB9 is to be another evolution of the family line. But for 2014 a major rule change will bring the RB5-RB9 family line to its end.

"Effectively we are trying to reverse engineer someone else's product, so it is tricky"

TECH SPEC

Red Bull RB8

Class: F1 2012

Chassis: Composite monocoque structure, designed and built in-house,carrying the Renault V8 engine as fully stressed member

Suspension: Wishbone and pushrod (front)/pullrod (rear) activated torsion springs and anti roll bar

Wheels: OZ Racing, front: 12.0in x 13in diam., rear: 13.7in x 13in diam.

Tyres: Pirelli

Brakes: Brembo calipers Carbon/Carbon

Electronics: McLaren Electronics Systems standard ECU and FIA homologated electronic and electrical system

Transmission: In house seven-speed gearbox, longitudinally mounted with hydraulic system for power shift and clutch operation.

Clutch: AP Racing carbon plate

Engine: Renault RS27, 2.4 litre N/A V8

Max rpm: 18,000 rpm (limited)

Bore angle: 90deg

Bore: 98mm

Valves: 32, pneumatic

Block: Cast Aluminium

Lubricants: Total

Engine weight: 95kg

Making up lost ground

Mercedes, as Brawn GP, got off to a blistering start with a Championship titles in 2009, but innovation at the design stage has been hampered by frustration on and off-track

BY SAM COLLINS

Mercedes has found itself needing to move forward in Formula 1 in the last few seasons. As Brawn GP, the team finished fourth in the world championship in 2010 and 2011, after winning both the drivers' and constructors' titles in 2009. It was, as team principal Ross Brawn commented, simply not good enough. Brawn told the press at the roll out of their 2012 car: 'My dream would be for Michael Schumacher to win again and for Nico Rosberg to win for the first time - that's our ambition.'

Rosberg did win at the Chinese Grand Prix in the Mercedes F1 W03, and came close to repeating that victory at Monaco, but the second half of the year was a struggle for the team and Mercedes found itself fighting to keep fifth position in the constructors championship ahead of Sauber.

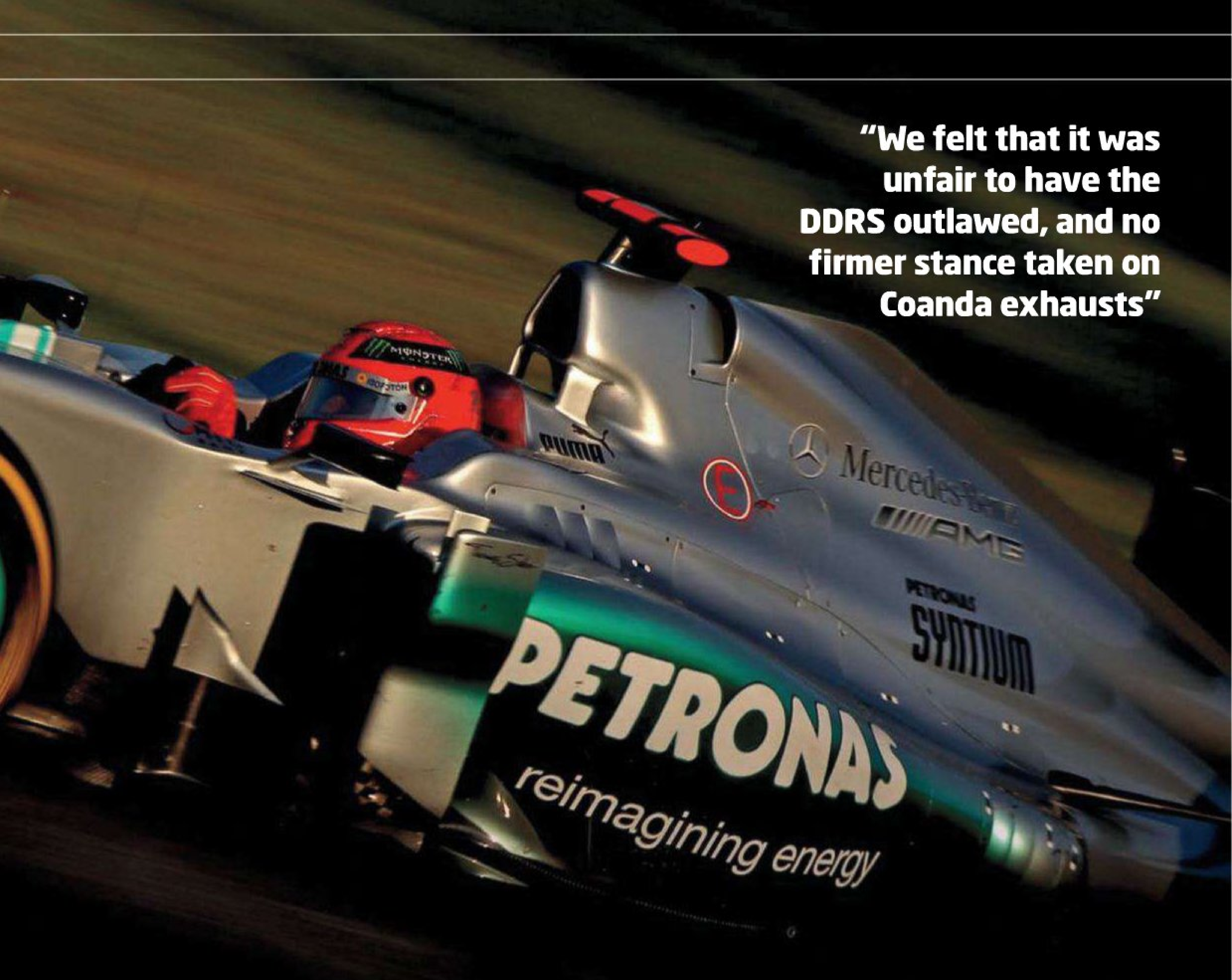
In terms of concept, the W03 is largely an evolution of the 2011 W02, a car that also disappointed. 'I don't think that there was anything revolutionary about the car in terms of concept,' explains Bob Bell, Mercedes AMG F1's technical director. 'The 2011 car was not the most successful, and one of the biggest problems was that it was hampered by a number of design issues which meant that it did not cool particularly well. This made it difficult to manage the cooling in some conditions, and that compromised aero performance.'

The aerodynamic shortcomings of the 2011 car were compounded by a number of other factors, including the major technological development of the season. 'We were late off the mark with the final version of the exhaust blown diffuser,' he says. 'There were several other issues like that across the car, that as much as being design issues, said something about the way we were organised and the way we were running the business.'

This gave the Mercedes engineers some clear objectives for the W03. Although the whole concept was not dropped, major changes were clearly required. 'The 2012 car was a lot about accepting that we needed to do things differently in terms of how we design the car,' Bell continues. 'We put a lot of work into the organisation and the structure, to make sure that we did not carry those issues from 2011 over into 2012 as a result of not doing a good enough job in the design office.

'It was also clear that we had to more than anything else find a big step forward in aero. You could do the sums and see that there was quite a deficit in aero performance, so we set very aggressive targets on that. With the car we got most of the way there, which was more than you would normally expect a team to make from one year to the next. The other features on the car - the suspension layout and concept - were refinements of what we had in 2011. We also did all of the usual things, we had a hard push on making things lighter and lowering the centre of gravity. Overall the car got a bit longer, we found aero benefit from that and it allowed us to have a longer and narrower fuel tank, which made packaging the radiators easier.'

One significant carry over from the 2011 concept was the car's suspension, which features hydraulically-interlinked Penske dampers. This is becoming the state-of-the-art for grand prix cars and all of the major teams are thought to run a similar system. 'Interlinked front and rear suspension systems are not



"We felt that it was unfair to have the DDRS outlawed, and no firmer stance taken on Coanda exhausts"

new – they've been on and off cars for many years,' says Bell. 'You can arrange them so that the car is very stiff in heave and very soft in pitch if that is what you want for the handling of the car, and depending on how you plumb the thing up. Dependant upon what you are trying to achieve with the suspension characteristics of the car, you can change it.

'But there is very little you can do with an interlinked suspension system because of the way the regulations are written. You are restricted to doing things that only function as a result of the vertical load on the wheels, which is basically what a traditional suspension system reacts to. You are not allowed to do anything beyond that, but even within that limited scope of control parameters you can hydraulically connect the front and rear suspension and you can therefore affect how the car handles in a different way to having a completely independent suspension front and rear. Connecting it hydraulically is the only thing to do because to connect the front and back of the car with a mechanical linkage would be impractical. And, if you do it electronically, you would fall foul of the regulations as it would be a powered device.'

DIGITAL ADVANCES

Bell says that the re-emergence of interlinked suspension in grand prix cars is due to the advances made in the digital tools available to the teams, and the resulting change in development methodology.

'Various teams in the past have tried it, and its never really, until now, become a standard feature on the cars,' he says. 'I think nowadays we are much more sophisticated in our analysis and prediction of what these systems can do. We can model their behaviour properly, whereas before you sort of plucked an idea out of the air, did a little bit of thinking, a little bit of scheming work, a little bit of analysis and if you then thought that it might offer something you would put it on the car to test. If it didn't work, you'd put it in the bin and start on something else. These days, when you see something that clearly offers you a performance benefit, you can absolutely exercise the concept in the theoretical domain and it's almost more of a formality to see if it works at the track.

'These systems are quite delicately balanced, and if you get them slightly wrong you don't get the performance advantage. In the old days it would have been lost in the noise. These days we are prepared to work much harder to dig right down into the detail and get the most out of it. As a result, the interlinked suspension is here to stay, unless the FIA decides otherwise.'

It is not only the suspension on the W03 that is linked front-to-rear. The car also features a controversial aerodynamic linkage between the rear wing and front wing, the so-called 'double-DRS' front wing stalling device. Its operation is essentially fairly simple: when the drag reduction system opens, a pair of ducts on the inside of the rear wing end plates is exposed. These ducts are linked by a pair of tubes that run the length of the car through the front wing pylons down to a pair of slits on the underside of the front wing.

'The aero concept was fairly straightforward to implement,' Bell explains. 'When you activate the DRS you can feed some high pressure air from the rear of the car to the front, and that is enough to interrupt the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The rear end of the Mercedes W03 has been heavily updated with a switch from an aluminium gearbox case to a lighter carbon fibre design

was somewhat inconsistent to have the DDRS outlawed and no firmer stance taken on the Coanda exhausts.'

Indeed, Bell was to find out first-hand how costly the Coanda-effect exhaust exits, which have appeared on most of the 2012 F1 cars, really are, and not just in financial terms. In an echo of Mercedes' slow adoption of the exhaust blown diffuser in 2011, the team was also slow on the uptake when it came to Coanda exhausts, first running such a system at a test in September, as it believed that the system would be banned. 'Where I think we dropped off, in terms of the concept of the car, was missing the opportunity to have it from the start of the year,' admits Bell. 'We mistakenly believed that the FIA would regulate them out, but clearly they were not able to do that. We felt that, because of experiences we'd had in 2011, where we had a lot of tyre-related problems due to exhaust blowing effects overheating the rubber, we were a bit reluctant to dive straight into a Coanda system.

'We were all looking at the Lotus E20, thinking that it seems to be the most consistent of the bunch. It had good performance and it did not have a blown exhaust, so if you wanted to pick a car to follow in terms of a trendsetter, it's probably that one. You have to bear in mind at that stage Red Bull, who you may see as the obvious target to follow now, were taking their exhaust on and off at different races, while Ferrari were chopping and changing configuration every five minutes. We should have bitten the bullet right at the start, said clearly that a Coanda system is the way to go, and then had a year to develop it rather than the couple of months that we ended up with.'

EXHAUSTING ALL AVENUES

Although tight restrictions on engine and transmission maps were introduced by the FIA at the start of the 2012 season in an attempt to outlaw blown diffusers, teams are still working hard to increase the exhaust flow to work with the Coanda layouts. 'You could get a huge amount more out of the exhaust if there were no restrictions on mapping, so there is a big incentive to find ways where you can legally exploit the maps to generate more exhaust thrust,' Bell explains. 'All teams are working hard to get what they can within the regulations, but sometimes teams overstep the mark. Not necessarily by deliberately breaching what is written, but by opening up a new avenue that the FIA had not considered. Several teams have done that this year and the FIA have told them to stop it as it is in their opinion aimed solely at increasing exhaust flow which they have said that they do not want to see. They sometimes stop it by issuing a technical directive limiting set up parameters for the mapping.

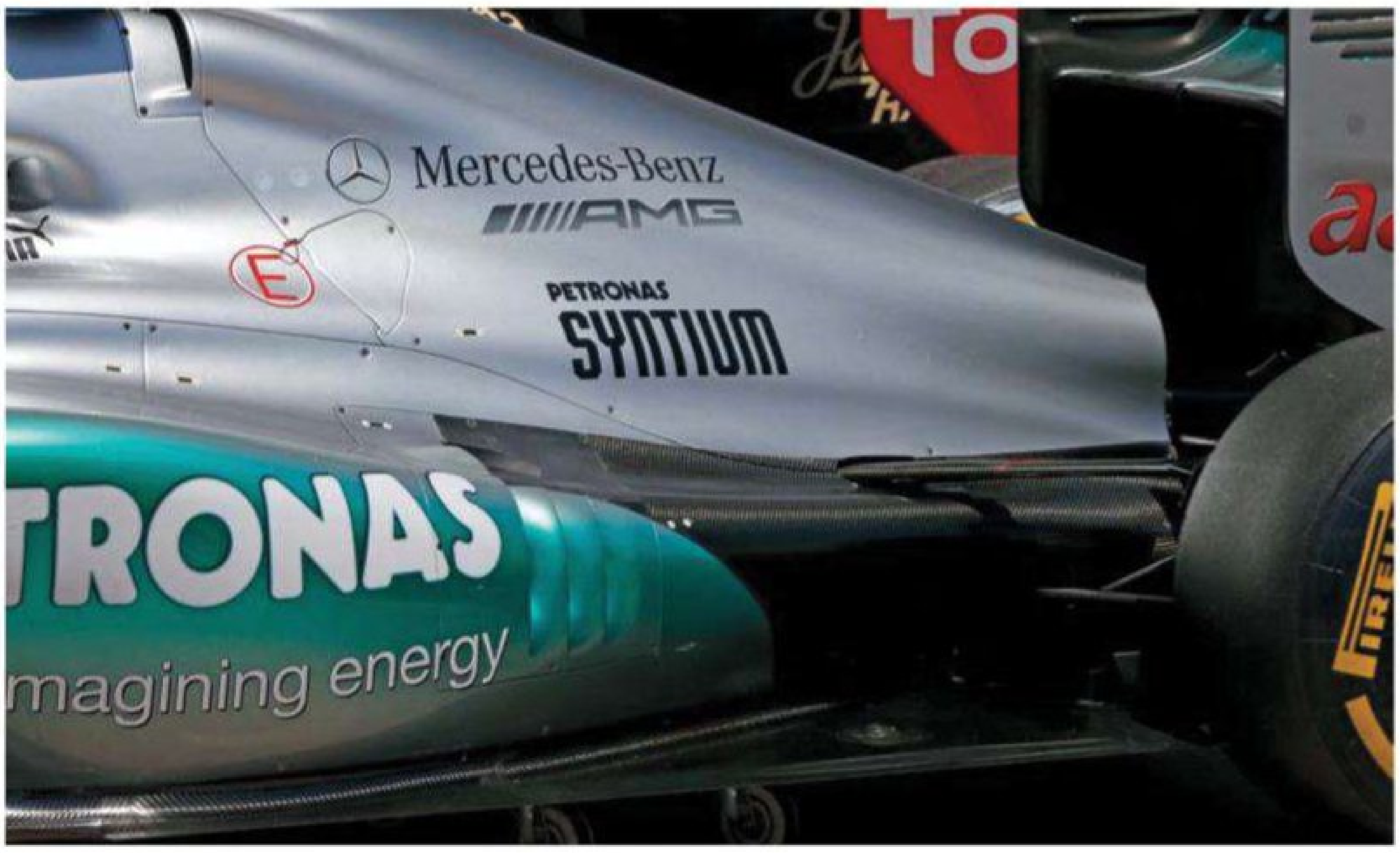
'So it's a bit of a cat and mouse game: they cut off development in one route, and we find another, which they then sometimes cut off too. The reason is that it can give you such an advantage if you find a way to do it, it is very powerful.'

While the Mercedes did not lack innovation for the second half of the season, it has certainly lacked in pace and has struggled to accumulate many points. Indeed, at time of writing, it has failed to score any at the Japanese, Korean, Indian and Abu Dhabi Grands Prix.

'I think there is no great surprise that we are weakest at circuits with lot of high-speed content,' Bell concedes. 'We are weak in high-speed corners. We lack high-speed grip. We also do not get as much out of the tyres as other teams – we have struggled to heat the fronts and cool the rears. The balance of the car on these tyres is not great either. The things that you have to do to protect the tyres give us a difficult balance. We tend to get a lot of understeer and that's been a common complaint from the drivers. I don't think any of us, going into the season, anticipated the problems with the tyres.'

"We are weak in high-speed corners because we lack high-speed grip. We don't get as much out of the tyres as other teams"

The installation of a Coanda exhaust (above) is something the team admits that it should have done earlier in the season, but it believed the concept would be outlawed. As a result for much of the seaon the W03 was fitted with a more conventional layout (below)



TECH SPEC

Mercedes AMG F1 W03

Class: F1 2012

Chassis: Moulded carbon fibre and honeycomb composite structure

Suspension: Wishbone and pushrod (front)/pullrod (rear) activated torsion springs and rockers

Dampers: Interlinked Penske

Wheels: BBS forged magnesium

Tyres: Pirelli

Brakes: Brembo calipers. Carbon/Carbon

Steering: Power-assisted rack and pinion. Carbon-fibre construction wheel

Electronics: McLaren Electronics Systems standard ECU and FIA homologated electronic and electrical system

Transmission: Seven-speed unit with cast aluminium maincase, later replaced with carbon case. Sequential, semi-automatic, hydraulic activation

Clutch: Carbon plate

Engine: Mercedes-Benz HPE FO108Z, 2.4 litre N/A V8

Max rpm: 18,000 rpm (limited)

Bore angle: 90deg

Bore: 98mm

Valves: 32, pneumatic

Engine weight: 95kg

Number of cars built: 9

Length: 4800mm

Height: 950mm

Width: 1800mm

But, despite the team delivering a competitive car early in the year, it has fallen off the pace with development of the W03. 'I think that we made a good step in terms of aero performance, but it simply wasn't big enough,' admits Bell. 'During the season we've had a number of things which hampered the aero development. The net result is that towards the end of the season we are not in great shape. Each thing is not too much on its own, but when you put them all together it leads to a pretty torrid end of the year. One of the things was making the transition from 50-60 per cent wind tunnel models. All the front running teams have done it previously and it's no small undertaking. I was very impressed with the team here and how they took it on and delivered it. It went remarkably smoothly, but it took a large degree of capital investment. Now all our development is at 60%, but it was pain we had to go through to keep up with the front of the grid in terms of facilities.'

"We made a good step in terms of aero performance but it simply wasn't big enough"

Bell and the staff at the team's factory in Brackley, England, are not disheartened by this. Indeed, there is a sense of hopefulness among the staff. 'We are through that development now, through the difficult things we had to do and that gives us great optimism for next year,' says Bell. 'It's not something you see physically on the car, but we have very much raised our game in terms of doing our homework; the analysis used to design the systems on the car, be they cooling or suspension systems or whatever, and properly understanding them before we get to the track. Although this year's car is lacking basic performance in terms of what it does and the way it does it, we understand it, and we know what it does.

'We have genuinely taken a step forward in understanding the car and its strengths and weaknesses, and that's what you need to know what to improve for next year.'

Civic duty

With loud calls for them to return to international racing, Honda were only too happy to oblige. Particularly as they had a very useful turbo engine on the test bench...

BY SAM COLLINS

The arrival of Honda late in the 2012 World Touring Car Championship came as a direct result of criticism the Japanese firm received at the 2011 Frankfurt Motorshow. 'Ever since we pulled away from F1 we have had criticism from the media and the customers asking why we are not doing any international racing,' explained a Honda spokesman at the launch of the WTCC Civic. 'On top of that, our president was at the Frankfurt motor show last year for the launch of the Civic and many journalists asked him "Is Honda no longer interested in motor racing?" That certainly stimulated him!'

Indeed, soon after the German show it was decided that the marque would have to embark upon a new racing programme as soon as possible. By coincidence at that time, Honda R&D in Tochigi, Japan – responsible for most of the firm's competition car engines over many years – already had a prototype turbocharged 1.6-litre four cylinder 'global race engine' on the test bench, although it had no intention of ever actually racing it.

'At Honda R&D we have to create new technology not only for racing, but for everything. For that reason we have to develop engines like this to learn,' explains Daisuke Horiuchi, the WTCC project's chief engineer. 'At first our target was purely to run a research project in an attempt to improve thermal efficiency in any engine. We developed an almost full-race engine, and it was a close match to the GRE rules. Downsizing, direct injection and turbocharging are a major trend in motor racing and we needed to have the knowledge gained from doing it.'

It is not the first Honda R&D-developed racing engine with direct injection. Indeed the V6 engine used in Indycar, also designed by Horiuchi, injects its E85 fuel directly into the combustion chamber.

As the original prototype engine wasn't designed for any particular application, the Honda engineers weren't working within any technical regulations initially, but when the FIA WTCC entry was announced, major changes were made, not least to the sand-cast aluminium block.

INCREASING WEIGHT

'The FIA regulations are based on a production engine, but our first engine was just a normal race engine,' says Horiuchi. 'That meant that is was far too lightweight. As a result we had to increase the weight of it substantially. For example, the cylinder block as we designed it weighed 15kg, but the regulations state that it must be at least 20kg and we had to add a lot of material to the block.'

As efficiency was the key to the original concept, a lot of work went into finding new avenues in certain areas such as coatings. Indeed the work is still ongoing, as Horiuchi explains: 'Friction reduction was very important in the project, but that was only a starting point – there are many other areas such as combustion speed that we need to look at too. Things like the piston shape are far from final at the moment. Turbo lag is a big problem. Unfortunately this is the first time we have used an anti-lag system at Honda – previous turbocharged racing engines we have developed have all been for categories where anti-lag was banned. It is very difficult.'

The WTCC regulations have their basis in the old Super 2000 rulebook and until the Honda arrived, every car on the grid was a converted S2000 design. All the cars must be fitted with FIA appendix or 'global race' engines, the chassis must be based on a saloon or hatchback with more than four seats, and at least 2,500 examples must have been produced in 12 months.

For Honda the obvious choice was the new Civic, already racing in the British Touring Car Championship in NGTC form. Dealers around the world had told the Honda president that they wanted to see an international competition version. So Honda R&D approached its long-time touring car development partner JAS Motorsport of Italy to create a chassis to fit the Honda R&D engine.

> **"We'd developed an almost full-race engine, and it was a close match to the GRE rules"**

'It was very difficult to install the engine into the compartment in a production car – it was the first time I had done it and it was much harder than I expected,' says Horiuchi. 'Heat management and cooling is also an issue on the car. We use an electric water pump, but the heat from the turbocharger is a concern and on a touring car there is very small engine compartment you have to work in.'

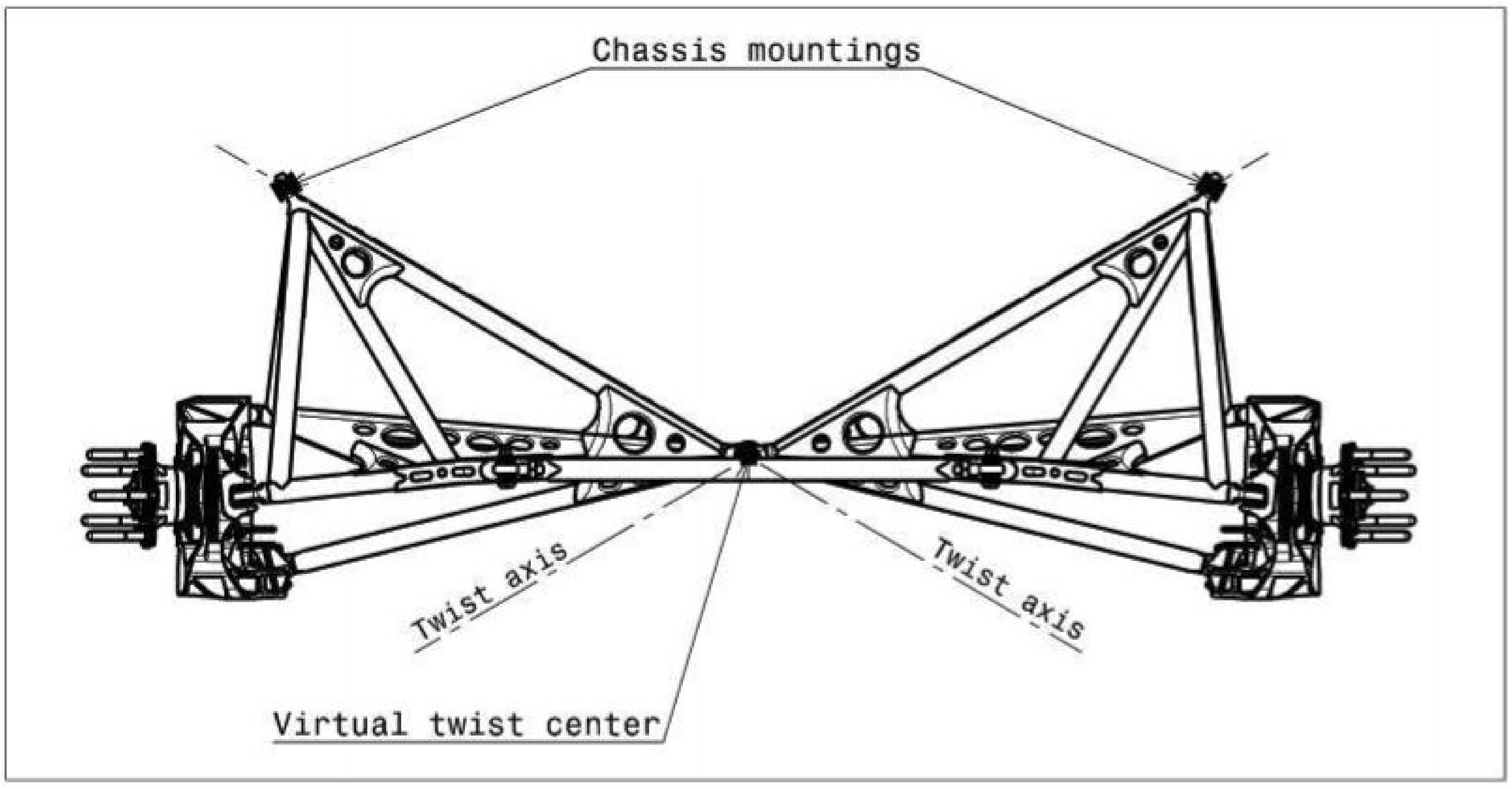
So Horiuchi worked closely with Stefano Fini at JAS. 'It was fundamental to the project. In fact both chassis and engine teams made changes to suit each other,' says the Italian. 'We had daily exchange of CAD data, so there were no big problems when the first engine arrived. Packaging the powertrain is just a big a challenge, not just fitting it into the compartment but also in terms of serviceability. The gearbox is an off-the-shelf sequential six speed unit from Xtrac – it took us a long time to find the right position for it, as it's very tight with some steering components.'

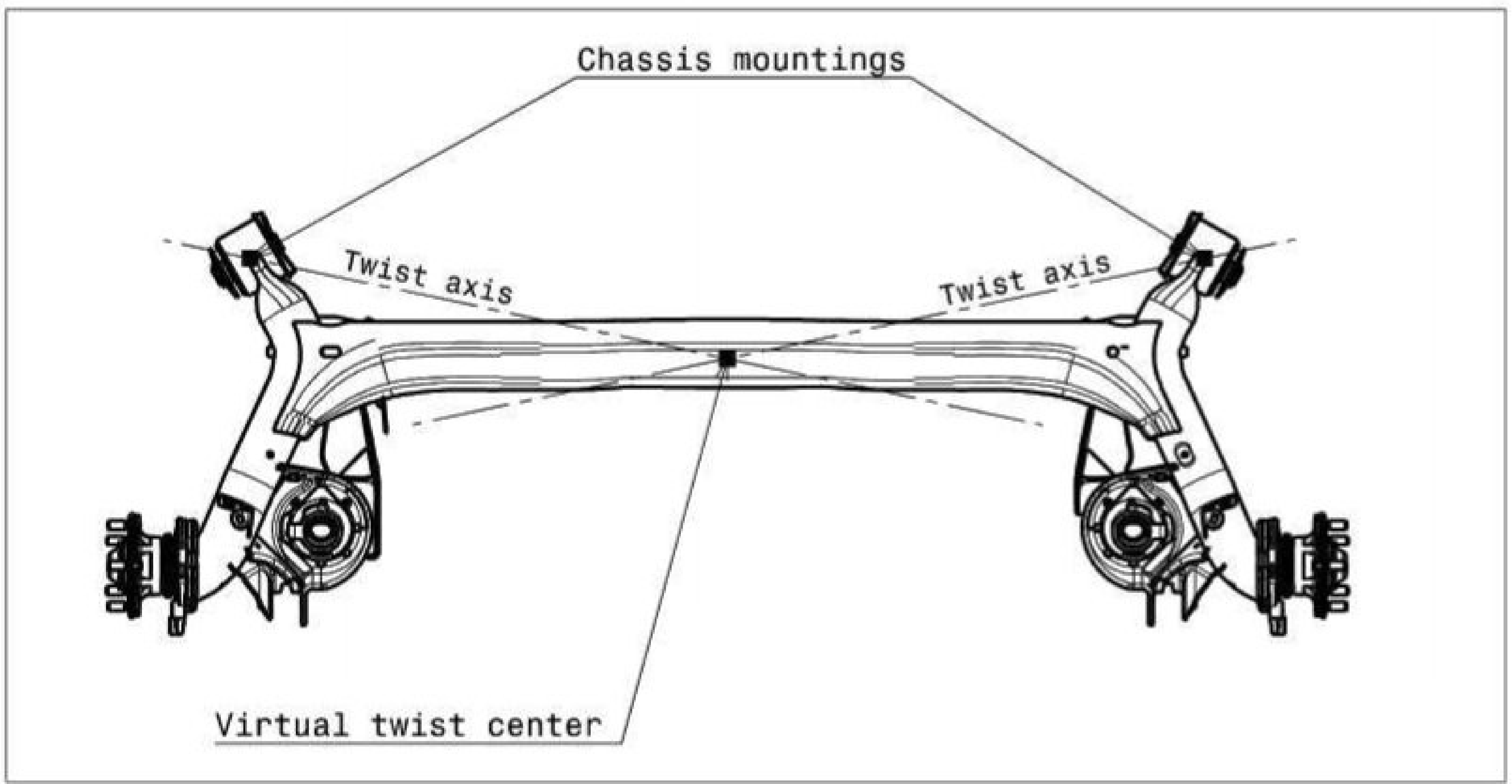
(Above) Tiago Monteiro in Honda's World Touring Car Championship entry; (left) the engine was swiftly and subtly repurposed to operate within the WTCC spec

The aerodynamic development of the car presented JAS with a number of problems, most of them due to the very restrictive rulebook. But the new Civic was a very good starting point as it employs a design that Honda call the 'blended wing body' which was inspired by aircraft design. It is part of the quest from the Japanese marque to improve fuel efficiency by reducing drag. As a result, the standard Civic has a Cd of 0.27 which is claimed to be the best of any C-segment five-door hatchback. But as is the case with the engine, the aerodynamic regulations are highly restrictive.

'You are allowed to enlarge the bodywork to make the car a slightly wider track, but you cannot have very sophisticated fenders,' Fini explains. 'They must be as close to the original road car shape as possible, and winglets and aero profiles are strictly forbidden. What you can do is design a new bumper which has a very small area where you are free on shape but all the rest is dictated by the regulations. The inner ducting is free though, especially from the forwardmost part of the bumper to the radiator, and this area was critical on the Civic.

'It was not perfect on day one, but we developed it in the wind tunnel and in track-testing to get the best solution. That work is not yet finished. The rear wing has to use an FIA-specified profile and endplates so you can only adjust the angle. There are also restrictions on where it can





The emphasis of the Civic's development has been on 'driveability' over aerodynamics - its suspension is inspired by a Vauxhall design from 2004

TECH SPEC

Honda HR412E
Class: Global Race Engine
Type: DOHC in-line four cylinders with direct injection
Displacement: 1600cc
Weight: 89.2kg
Maximum speed: 8500rpm
Power: in excess of 315bhp
Torque: in excess of 400Nm
Air Restrictor: 33mm
Electronics: Cosworth with DBW throttle
Lubrication: Dry sump
Injectors: Bosch
Turbocharger: Garrett GTR2560R

be mounted - all of this is meant to control costs and limit aero developments.'

JAS developed the car using the full-scale rolling road Pininfarina wind tunnel near its factory in Italy, but it has also utilised the substantial facilities at Honda R&D's Tochigi HQ.

Aerodynamics though were not Fini's first priority - he had to make a car that could be driven on a range of circuits around the world. 'This is a front wheel drive car, so driveability is one of the most important issues,' he says. 'We needed to ensure that we had good traction and also be able to transmit a lot of power to the road. As a result of that there was a lot of work on the suspension, weight distribution and managing the masses.'

Indeed when the car was revealed it didn't take long for it to leak out that the WTCC is fitted with a fascinating rear suspension layout inspired by the concept used by Vauxhall for the BTCC in 2004.

'The suspension is very interesting,' says Fini. 'The regulations demand that you keep the same kinematic principle of the base car and you must keep the original pickup points - you cannot add additional points.

'We have kept the same principle, but used different angles and camber changes. Unfortunately for us this became public when the homologation form came out and there was no longer a secret. The front suspension too is critical. It is a MacPherson, but the key thing is to find the right points that will give the right geometries. This is not that obvious. Within the high number of restrictions of the rules with this you still have freedom with the anti-dive, anti-squat and camber change.'

"Within the rules you still have freedom with the anti-dive, anti-squat and camber change"

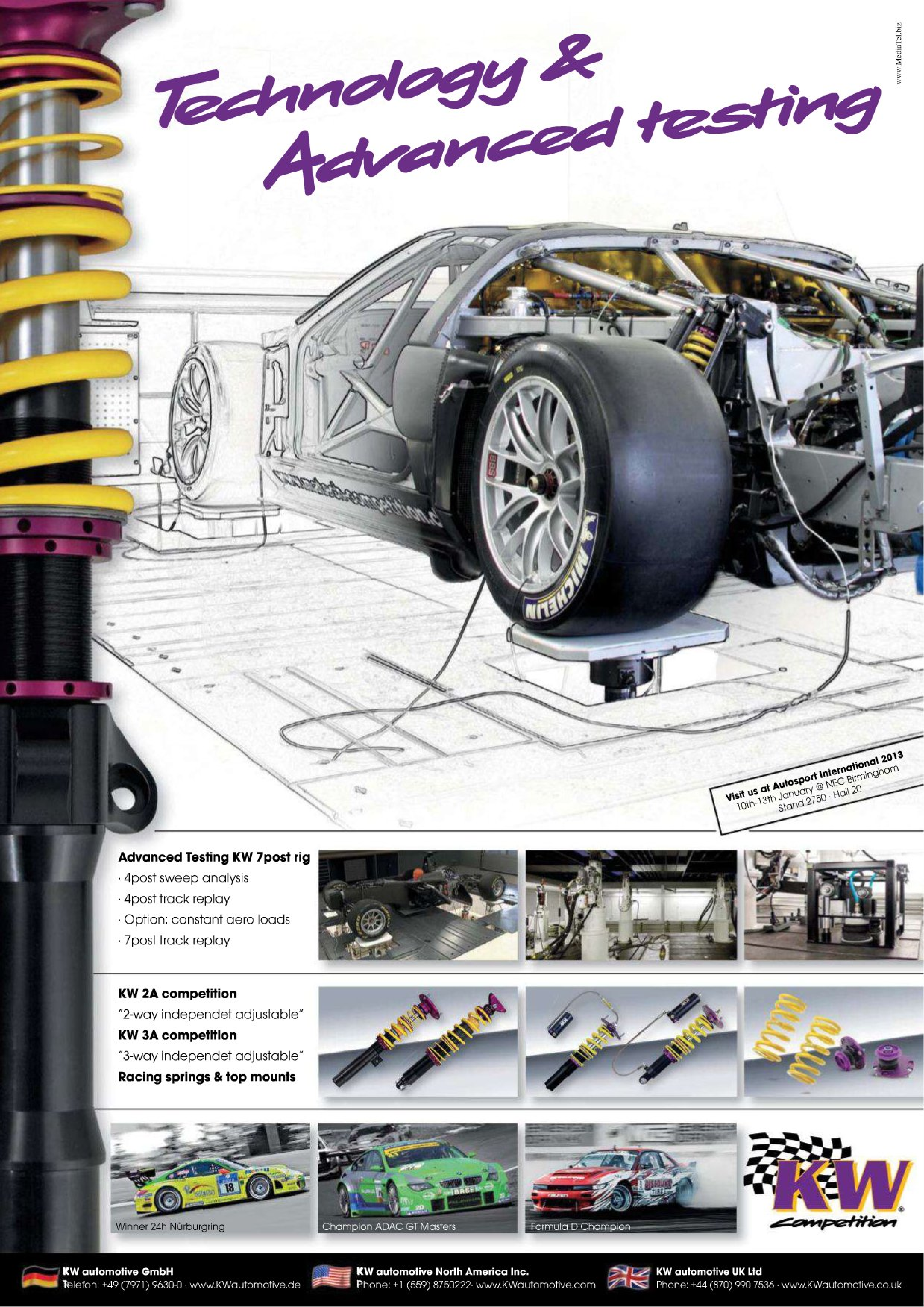
The chassis is largely a standard road car component but with the obvious addition of a steel rollcage. This, as usual, serves more than one purpose.

'The safety cage may extend up to the suspension pick-up points,' says Fini, 'but you cannot change the original chassis energy-absorbing characteristics, so we can only go to the front and rear turrets. Of course we designed it not only for safety but also for torsional stiffness.'

FUEL TANK TROUBLE

Being forced to utilise the standard production car chassis raises a substantial and unusual problem for the JAS engineers. 'The fuel tank is quite unique on the mass production Civic,' adds Fini. 'It is mounted below the driver and passenger seats, so it is in the middle of the car. This gives a number of advantages on the road car for weight distribution and rear space, but on the racecar it is of debatable benefit. One of the problems for racing is that the driver sits higher than in other cars. We have asked to be able to change this so we can be in the same position as our competitors. We only have national homologation at the moment, so it is still under discussion.'

While the Honda's debut race meeting at Suzuka was not spectacular, it did manage to achieve a championship point, which his not bad for what was a glorified test, and the car is far from a finished product. With Chevrolet quitting the WTCC for a while it looked as though Honda would be the only works team on the grid in 2013, but it seems that this won't be the case: Citroen is expected to announce a DS3-based programme during the winter, and Toyota is known to also have a suitable engine on the test bench. The WTCC looks like it is about to become increasingly competitive and Honda has a head start.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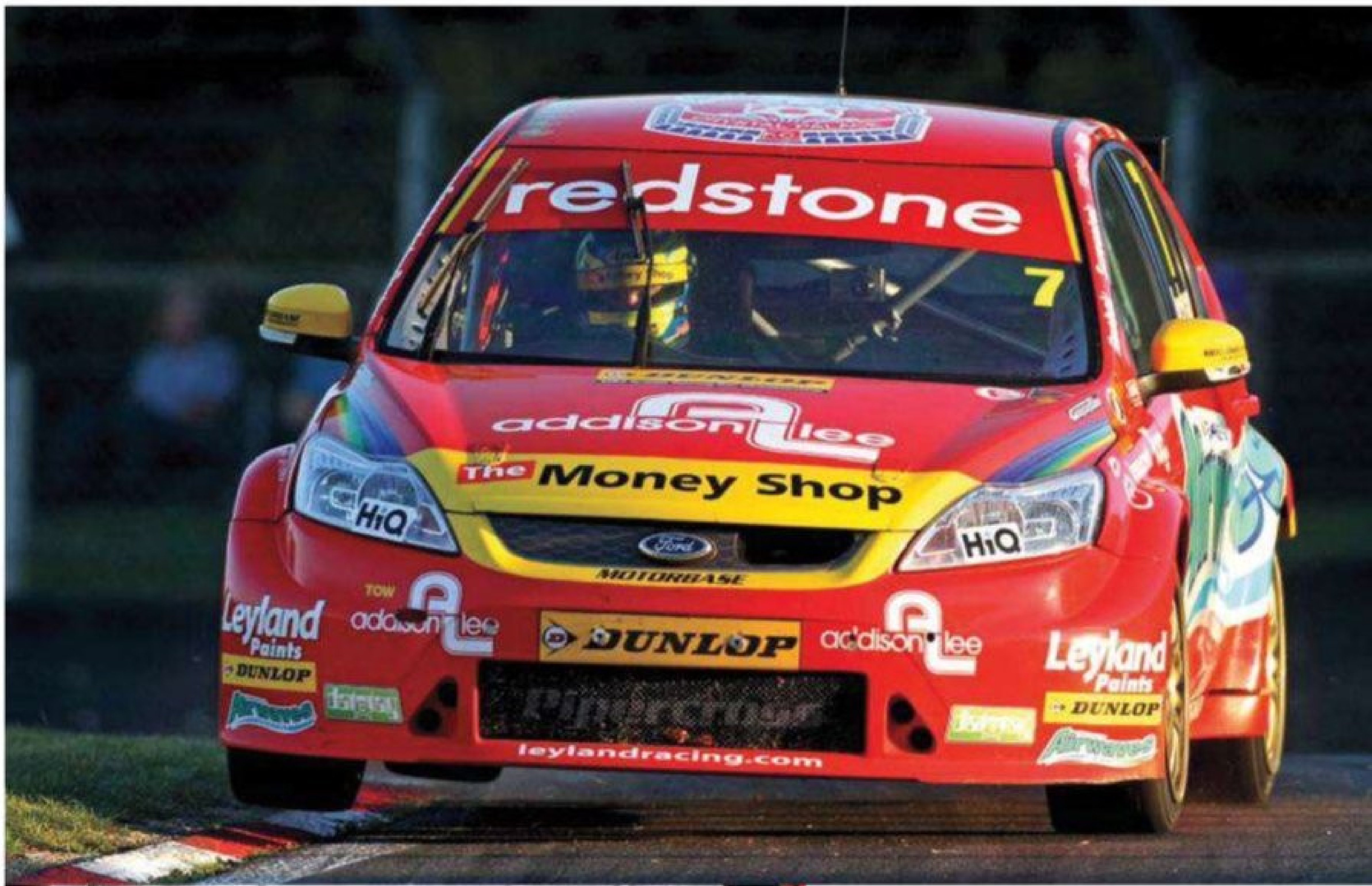
A true class act

The young team's ballsy ground-up approach is proving to be in tune with the spirit of the NGTC regs – while yielding eye-catching results

BY IAN WAGSTAFF



British Touring Car Championship technical director Peter Riches reckons the Motorbase Ford Focus to be closest to the spirit of the New Generation Touring Car regulations. The team, he says, had no previous experience of building a car and, therefore, no preconceived ideas. They have followed 'the design manual', unlike some of the other teams who have taken that book and tried to do better.

Motorbase team manager, Oly Collins, sees this as something of a simplification. The team itself may be new to construction, but the individuals concerned certainly are not. Three of them – Collins, project manager Richard Townsend and chief engineer David Potter – had all spent a number of years at championship-winning Team Dynamics, working on the design and build of the Integra and the S2000 Civic. Motorbase may never have made a car, but there was no lack of experience in its personnel. There did have to be changes in the operation's infrastructure, however. In particular, team principal David Bartrum invested in new tooling as the decision was taken to produce the shells in house.

The team had run Schnitzer BMWs in the BTCC for three years. With the turbocharged NGTC cars looming, these were going to be at a disadvantage. Arena was showing what could be done with a turbocharged S2000 Focus, and the feeling was that the same would be true with the NGTC engine. With a lack of suitable BMW engines for turbocharging and a feeling that the TOCA engine wouldn't be appropriate, Motorbase purchased three S2000 cars from Arena, and successfully moved on from its BMW era for 2011.

'The NGTC cars were out that year, and were clearly progressing well,' recalls Collins. 'It seemed obvious that by this year they would have an advantage over the S2000s.' So, towards the end of 2011, Motorbase commenced work on an NGTC Focus project, the idea being to have a car out by the last one or two races of the following season and then spend the winter developing it.

Motorbase made the decision early on to create its own shell

SHELLING OUT

'With Richard Townsend on board, it was a no-brainer to do the shells,' says Collins. 'I class him as the best fabricator/shell builder in the BTCC paddock.' There were options. GPRM, for example, could have provided a shell, but with the in-house expertise it was thought logical for Motorbase to produce its own. This meant investment in tooling, such as a flat-plate jig on which the shell is built. 'We got hold of a road car shell,' says Townsend, 'we stripped it out, removed the roof and sent it away for surface processing. This basically removed anything organic. On its return it was put on a spit, de-bracketed and everything from the rear seat squab back removed. The tunnel was cut in half so that the seat could be moved towards the centre. From there the car went on to the jig

The Mountune engine is a direct carry over from the S2000 regulations, and was a natural fit for the new car given the experience of the British company

and we started joining the dots. We've done a lot of work in the front bulkhead which I believe gives us an advantage over some other teams. The front end needs to be really torsionally stiff for a front wheel drive car.'

TOCA supplied the diameter for the cage, which – rearward from the A-post – is a basic spec. Townsend and Jason Harmsworth designed the cage for the Focus in conjunction with Custom Cages. It came plasma-notched and went straight in. It was all TIG welded, and was 'a joy,' Townsend recalls. He admits that there's nothing to be gained by this and it takes about a third as long as using MIG, but he likes his work to 'look right'. The shell has been labour-intensive, with roughly 900 hours going into the first one including building the jigs.

RML had been looking at taking part in NGTC this year, and already had a GPRM kit of the spec parts. When RML changed its plans, Motorbase purchased this from them. By the time of the summer break, the shell was also 75 per cent complete. Then Liam Griffin had an accident at Croft, effectively writing off one of the team's S2000 cars. Instead of funding a rebuild, Griffin helped the building of the NGTC car, bringing forward the project. With the initial development and tooling, Collins estimates the cost of getting a car to the grid will have been £300,000, of which the car will have accounted for £200,000. 'You set your budget out for the year and you don't expect an expenditure like this halfway though the season.'

Collins points out the help that was given during this period by Peter Riches's son, Sam. He was then employed by GPRM, which was the company originally chosen by TOCA to design the NGTC frame, as well as the steering and the suspension. For those teams that are unable to build their own cars, it will also supply a compete vehicle. Because Motorbase had bought an early kit from RML, there were some aspects that had since been uprated, and Riches's understanding of the car proved crucial to the team.

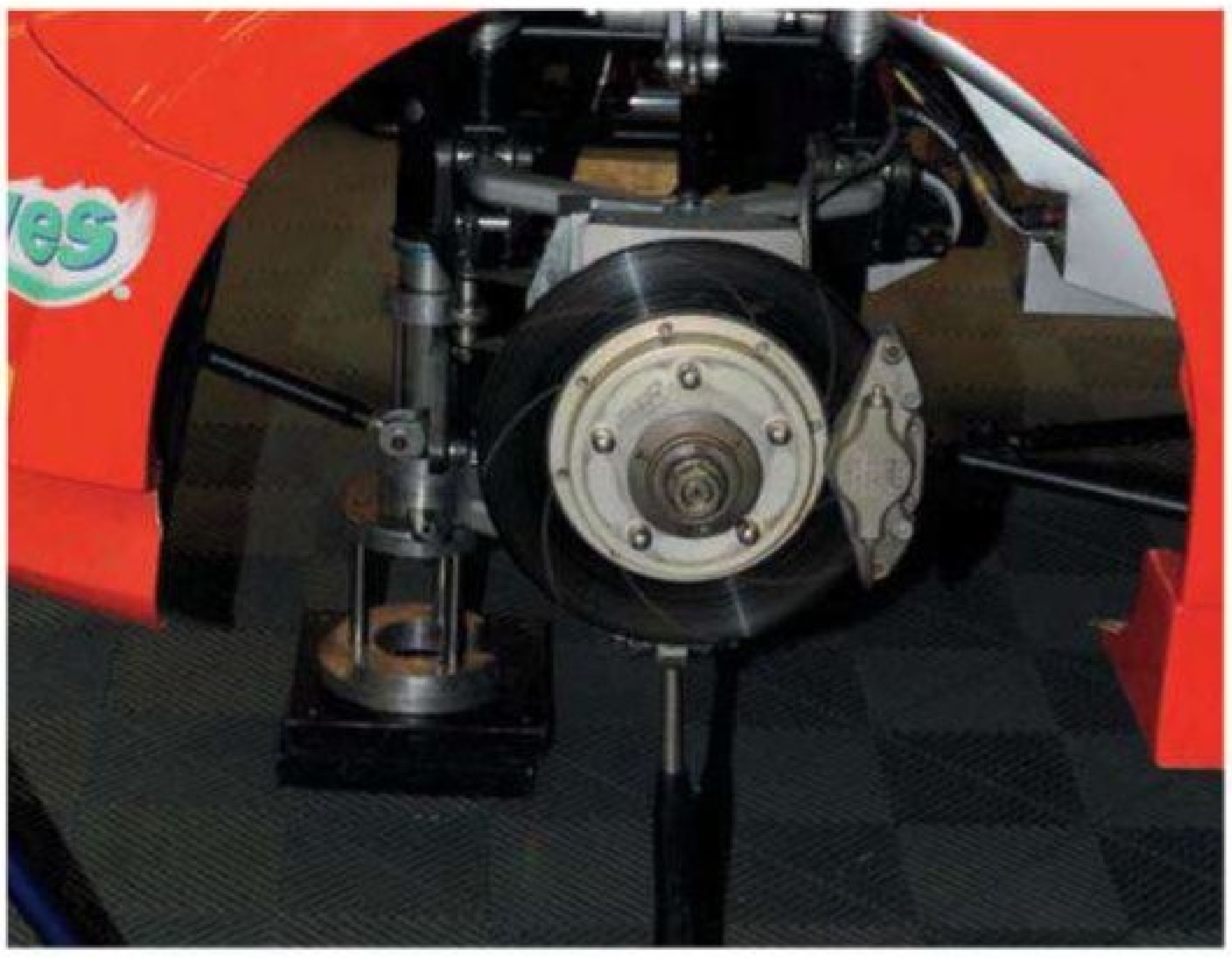
The car was only finished at 3am on the day of its Snetterton debut

Over a six-week break between races, the NGTC Focus was born. 'It wasn't the most straightforward car to build,' says Collins. 'There may be a lot of spec components, but you still need to house them. For example, the engine needs installation brackets, a bell housing, the induction system worked on and the bracketry for the bodywork calculated as well as the layout of the interior, including the steering column and dash display. The build manual does not cover everything,' he says.

FIRST PERFORMANCE

Collins readily admits that they 'cut it a bit fine', with the car only finished at 3am on the Saturday morning of its Snetterton debut. The car's arrival there made Motorbase unique as the only team to be running both NGTC and S2000 cars. Naturally, there were teething problems that day, with steering and boost issues. 'We were comfortable in the knowledge that we were learning from this,' he says. 'Our shakedown was free practice one. By qualifying the car was running reliably and we got three top eight finishes.'

Collins feels that the NGTC regulations were built for teams such as Motorbase. There would never have been the possibility of it taking on an S2000 design and build project – it could only ever have been a customer. An S2000 would have required far more design and development work, and the only really successful ones have had the backing of a manufacturer, but with an NGTC so much is already set out. The suspension layout with the common uprights, wishbones and anti-roll bar system mean that there are no extra costs in this area, although the way the regulations have been framed mean that there are still plenty of engineering challenges. While everybody uses a common Penske damper, there are plenty of options in the kit for you to build it in a variety of ways. 'There is a very good possibility of getting it very wrong or very right!' he says.



Double wishbone suspension makes the MacPherson strut outdated

Build cost was around £200,000, plus £100,000 to get the Focus to the grid

With its double wishbones, an NGTC car has become an outright racecar. TOCA had a clean sheet of paper with this and, as Peter Riches remarks, one would not design a racecar today with MacPherson struts. That means the engineers are having to take a different view. 'The experience they had making the MacPherson work the best has gone out of the window,' he says.

Riches reckons that because of this, a sportscar engineer would now be the man to have in BTCC but vehicle dynamics expert David Potter contends that most of the leading teams in the paddock do have staff with this kind of experience.

'The car is still a touring car with its high centre of gravity,' says Potter. 'It's not a sportscar and we haven't got a high aerodynamic package. You still can't set it up like a Le Mans car.'

The engineers also have the freedom to design their own springs. In the case of the Focus, Potter designed a progressive spring, which was then manufactured by King in Australia.

The engine is an ideal fit for Motorbase, as Bartrum's relationship with tuner Mountune goes back many years. 'They know this engine inside out in so many different forms,' he says. 'I reckon it is the best engine package available - we knew that we could carry this element straight over from the S2000.'

In addition, Geoff Kingston has had a strong involvement in the development of the aero and the cooling design. A composite company, known as Fibre Glass Phil, was used for the aero work starting with a simple road car set at the correct ride height. Under the guidance of Kingston, the front and rear wheel arch extensions, front bumper, splitter and side sills were manufactured with the bodywork bucks all done by hand, 'It was a bit of an old-school way of doing things - we didn't go down the CAD design route.' says Collins. 'It was one of the most challenging aspects of building the car, but one we're very happy with. The radiator duct, for example, is more efficient than on the S2000 car.'

In keeping the engines as production-related as possible, the BTCC has been faced with the problem that the performance of the road engine will always be reflected in the race version. There is little that can be done to make a poorly performing road engine into a competitive one for an NGTC. To achieve what Riches calls 'package equalisation', the BTCC has therefore used a lap-time formula and equated this to boost adjustment.

When the NGTC Focus made its debut with a base boost, it was 2.5 seconds off the pace in qualifying, but just 0.5 seconds off by the end of the third race. This was still slow enough for it to be given the maximum 0.125 bar boost for the next round, which equates to about 25bhp. However, the team's understanding of the chassis was rapid. By the time of the penultimate round of the BTCC at Silverstone, Motorbase was on a 0.075 bar increase.

The spec gearbox is the Xtrac six-speed sequential FWD 1046, with a fixed choice of 16 ratios. A regular topic in team meetings is that this could be reduced. Arguably first, second and third are fixed, so 16 seems a little excessive. The spec, externally (pre-load) adjustable differential can be built in a number of different ways. Potter has tried to achieve on a mechanical differential much of what he has learnt working on hydraulic active diffs.

"NGTC will evolve quicker if teams are open about problems"

TEETHING TROUBLES

The team had issues with the spec Titan steering rack early on, but this was upgraded by the Silverstone round where the car performed well - Matt Jackson won one of the races and led another before a throttle problem caused retirement. The BTCC had already brought in a DC Electronics motor to deal with some steering issues that it had experienced. However, drivers have still felt that the power steering was locking out. Motorbase certainly found this on the first few runs with the NGTC Focus - on opposite lock, it would overload. The data was sent back to DC Electronics and the feedback said that it wasn't locking up. 'It was all part of the evolution of this product,' observes Collins. 'As long as the teams are open about a problem, NGTC will evolve quicker. This isn't so when a team has a problem and tries to solve it on its own. How can a spec supplier help when they don't know there is a problem in the first place?'

Collins believes that the tyres are probably the major reason why the NGTC Focus is quicker than the S2000 version. The brakes are bigger, the boost slightly more but the car is 100 kilos heavier,' he says. 'The tyres make a massive difference, mainly on durability because of the extra inch.'

'It's a totally different design - much more competent,' Potter adds. 'Although there is not a massive difference in the radial stiffness between the 18-inch and 17-inch, the lateral and torsional stiffness are very different.'

Potter is impressed by the data supplied by Dunlop considering that this is a single supplier formula. Using the Pacejka, Delft University Magic Formula as a model, he was able to simulate the car with the tyre data included before it had been anywhere near a track.

Now, Motorbase's plan over the winter is to use the Multimatic shaker rig at Thetford to help further understand the suspension. It also wants to put the car on a K&C rig. However, and while it may have been born prematurely, the team has already proved its Focus to be a success.

A weekend with the Scrutineers

British Touring Car Championship officials use the latest technology to ensure safety and parity throughout the field

Until the early-90s touring car racing - AKA saloon car racing - was largely a supporting act to single-seater racing. The collapse of Group C sportscar racing and the exodus of manufacturer support from that category to the nascent FIA Super Touring class greatly elevated the status of touring car racing so that by the mid-90s the British Touring Car Championship was arguably the UK's premier motorsport series. In the new millennium the BTCC was obliged to re-invent itself after dwindling manufacturer support brought an end to Super Touring. Series organiser TOCA drafted its own regulations, which morphed into the FIA S2000 regulations. These saw the BTCC flourish again until the global financial crisis towards the end of the last decade prompted a further recalibration. As a result, in 2012 the British Touring Car Championship finds itself undergoing another period of transition from S2000 to TOCA's own Next Generation Touring Car (NGTC) regs. These new changes have placed even greater usual emphasis on the work done by the BTCC scrutineering team.

The team is led by chief scrutineer Peter Riches. Working alongside Riches is BTCC technical commissioner Trevor Johnson, and eligibility scrutineer Sam Riches, who is Peter's son.

UNDER THE BONNET

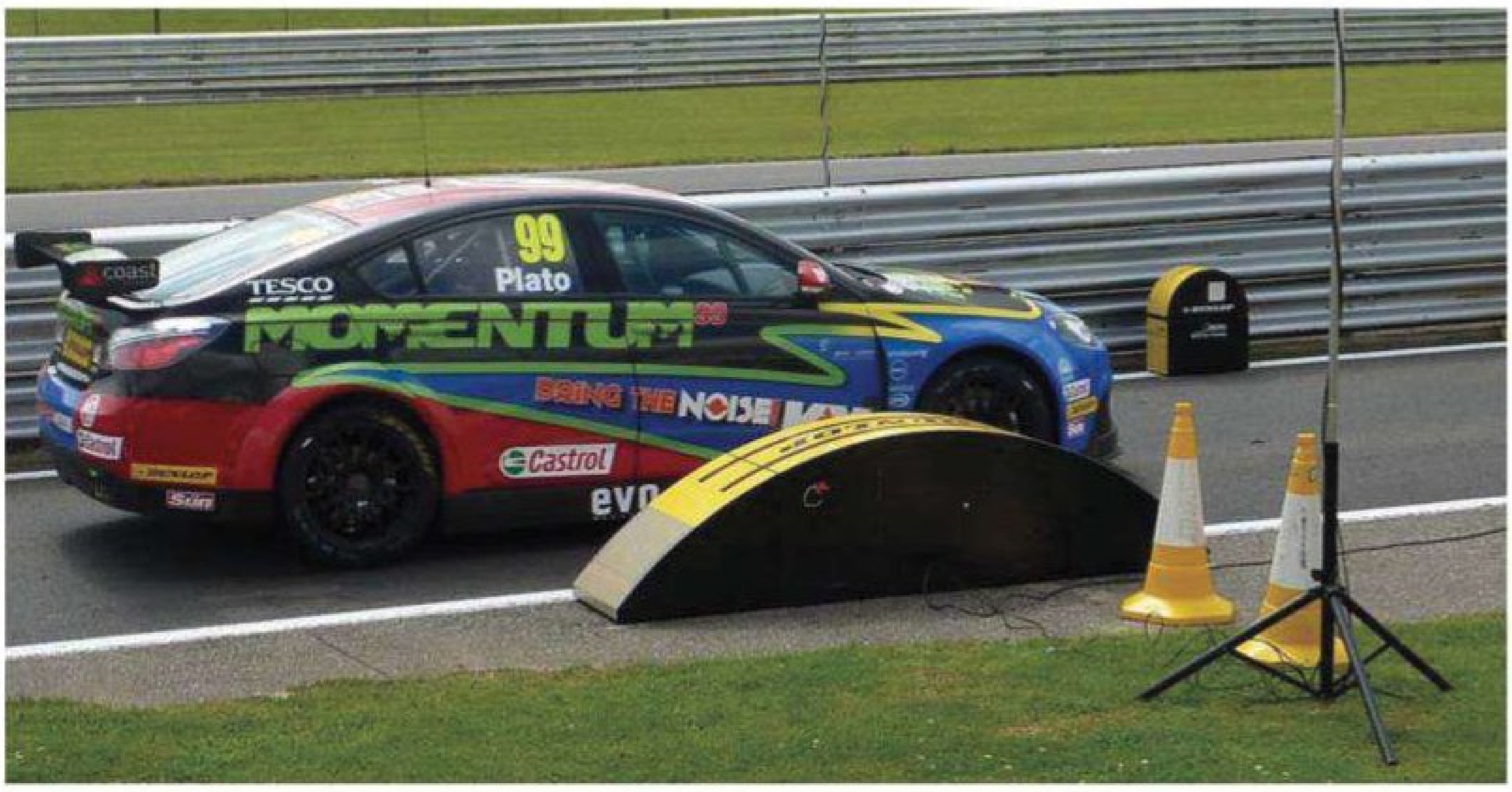
In 2012, all the competitors in the BTCC, including those still running S2000 chassis, are using NGTC-specification engines. During the BTCC season each car is allowed a single engine change or rebuild without incurring a championship points penalty. To

BY ALAN LIS

ensure that the same engine in unchanged condition is used at consecutive race meetings, four plastic seals are fitted when the engine is first inspected - two on the cam covers and two on the sump. A seal is also attached to the turbocharger to prevent work being carried out on this unit. Due to the heat generated in this location the turbocharger seal is all-metal. Each engine and turbocharger seal has an individual serial number, which is recorded by the scrutineer and checked at each race meeting.

Self-destruct sticker-type seals are used to mark the driver's seat after initial inspection at the first race meeting of the year. 'We check the FIA label on the seat to make

Self destruct stickers are used to identify driver seats after inspection at the first race meeting of the year



Electronic tagging on Dunlop's tyres means that the checks can be made electronically for each car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Inspections post qualifying and post race use specially made jigs that slot straight into a correctly manufactured suspension or chassis.

sure that it complies with the homologation standard and when we've done that we put on one of our own TOCA stickers,' explains Johnson. 'That saves me having to do the full inspection each time. If the TOCA sticker is in place I know that it's the same seat.'

A self-destruct sticker is also applied to the chassis so that it can be identified as the car that was scrutineered at the first meeting of the year. The SD stickers are also used during the build process to ensure that that body shell is not taken apart. During the Super Touring-era, a car build would typically start with a bare floor pan to which the roll cage/chassis frame was added and the body was assembled around that structure. An NGTC car must be built using an assembled bodyshell into which the rollcage must be fitted. To ensure this, SD stickers are applied to the joints between the floorpan, the A, B and C posts and the rear bulkhead, if there is one. Self-destruct stickers are also occasionally used in parc ferme and can be placed across appropriate panel joints if the scrutineers wish to carry out checks on a car

The weighing scales and ride height facilities are available to all teams

"If one team complains about another, we check both in case the complaint is a smokescreen"

without the team having access to the car's interior or engine bay.

If the scrutineers remove a component from a car for later inspection, it is sealed in a labelled evidence bag. In some instances, wire seals may also be applied to the component. After the race meeting the component is taken back to the company that supplied it and in the presence of a TOCA scrutineer and a team representative it will be stripped down and inspected to ensure that it conforms with the regulations.

Components are taken at random as well as in cases where there is 'probable cause'. 'In 2011 we had reason to believe that contents of one team's dampers included non-SPA/Penske parts,' explains Riches Sr. 'When the dampers were stripped down at SPA, our suspicions were proved correct – there were Ohlins parts inside.

'In some instances where one team complains about another we will check both of them in case the complaining team is using the complaint as a smokescreen. If a team has a complaint or suspicion about another team they can come and talk to us and we will listen. If it requires a non-obtrusive check we may do it there and then. If the complaint is about something internal in the engine or transmission we will probably advise them to make a formal protest, but if you do that you must be prepared to pay the rebuild costs if you are wrong. We haven't had a formal protest for a long time in the BTCC...'

FUEL ANALYSIS

The cars competing in the BTCC and its package of support races run on fixed specification control fuel supplied by the UK based company Carless. The company sends a chemist to each BTCC race meeting to carry out checks on samples to ensure that only the specified fuel is being used.

Testing of fuel samples is by infra-red analysis. The first stage of this process is the checking of a reference sample of the fuel supplied to the race meeting after which the instrumentation is corrected to take into account the environment in which the tests are being conducted, allowing for factors such as ambient temperature, atmospheric pressure and so forth.

With the reference sample established, the tester then has a baseline against which to compare the samples taken from the fuel tanks of the racecars. The test equipment uses a laser, which causes the molecules in the fuel to vibrate and effectively allows the tester to take a snapshot of the molecular bonds in the fuel in the infra-red region of the spectrum. From the results generated, it can be seen if there is water, carbon dioxide or another form of contamination in the sample. Even if a contaminant can't be specifically identified, oxygenate components and potential additives will show up in the infra-red region. By comparing the results from the car sample with the reference sample, the tester can decide whether or not to take further action. If necessary the sample can be taken back to the Carless laboratory for more rigorous analysis using gas chromatography, which can identify the peaks in the sample more accurately and determine the precise nature of the contaminant.

BEHIND THE SCENES AT A MEETING

For the scrutineers, a typical BTCC meeting begins on Friday morning when boarding for the garage is installed, a set of scales with attendant cabling and monitor screens are set-up on the flat concrete pad at the entrance to the pitlane. Also installed at this time is an illuminated LED pit speed limit sign, a red and green traffic light, and the system that monitors the tyres used by each car.

On Friday afternoon initial safety checks are carried out by Johnson, who will also seal any engines and turbochargers that have been worked on since the last race meeting. The 2012 season had reached its mid-point and many teams elected to either change to a new engine or rebuild their existing power unit.

Johnson will also ensure that the car is visually compliant – including all the required series sponsor's decals, the correct race numbers and the driver's name in the correct locations. This also means checking that the towing eyes, external fire extinguisher switch and electrical cut-off switch are all correctly marked. Each team is required to demonstrate that the headlights, rear lights, brake lights and direction indicators are operational on each car entered. Inside the car, a check is made to ensure that the driver's seat carries a current TOCA approval sticker. Johnson also inspects each strap of the six-point seat harness and ensures that the relevant stitched labels are in place and not out-of-date. Typically a driver's race suit, HANS and helmet are inspected on Saturday morning.

At the first BTCC meeting of a new season, scrutineering is a much longer affair as each car is subject to a full inspection. Johnson explains: 'As well as looking at the safety items that we check at every meeting, in the first inspection we also look at more fundamental things like the rollcage to make sure that it complies with the homologation form. Because the cage is an integral part of the car – it's welded into the shell – once we've seen that it complies we don't really need check it again.'

Each car has its own log book where Johnson records all checks made during the season. As the front and rear subframes of the Next Generation Touring Cars are TOCA-spec parts, it's felt that they don't need to be closely inspected.

"Keeping people hanging around doesn't make you very popular"

From around 5pm until the paddock closes on the Friday of each BTCC meeting, the scales on the flat pad are available to any team that wants to use them and they can also check ride height. On returning to the circuit early on Saturday morning the scales are re-installed and up until the first free practice session the teams again have free access to them. In this period, Johnson will also go back and check any items that he asked the teams to attend to on Friday before issuing their scrutineering stickers.

Because Snetterton was the halfway point of the 2012 BTCC season, a driver weigh-in was conducted on the Saturday morning. 'We usually only weigh the drivers twice in a season at the beginning and the mid-point,' says Riches. 'Those are the weights we use if we have occasion to weigh the car without the driver and he is unavailable. If he is around during the course of the weekend, we will weigh the car and driver together.'

Race day starts with the teams having access to the scales and ride height check. Usually some cockpit evacuation tests are carried out before the first race to make sure that the drivers can get out of their cars within the seven-second limit. After each race, the first three or four finishers are stopped at the pit entrance, weighed, a fuel sample is taken and a few basic checks are made. 'On race day there are three races, so we only have a 15 minute parc ferme period between them – it's difficult to do very much,' says Riches Sr. 'However, we will check all the data. Typically there will be more checks and they will be more rigorous on a Saturday after qualifying than on a Sunday. Keeping people hanging around at the end of the weekend doesn't make you very popular.

'If we find things wrong during the free practice sessions, we usually take no action other than advising the team of the infringement. If we find something during qualifying, the driver loses his times and has to requalify with a legal car. If we find something wrong after qualifying, the car is sent to the back of the grid. If a team has a problem with a car that we haven't picked up on they can come and talk to us.'

The testing of a sample takes only 2-3 minutes, so any potential problem can be quickly identified. If one occurs, the procedure is to rerun the reference sample, redo the background correction and retest the competitor sample. However, problems with fuel samples are pretty rare. At the time this was written no fuel sample taken from BTCC car had failed testing for more than two years.

CHECKING THE DATA

Each NGTC car has a controlled specification electronics system comprising a standardised ECU, logger, wiring loom and sensors. The system contains a segregated area where the output from every data channel on the car is logged and to which only the scrutineers have access. 'The teams are very limited in what they can do with electronics,' says Sam Riches. 'We also check the ECU base programme of a random selection of cars at each race meeting.'

In an effort to achieve competitive parity there are differing turbocharger boost limits for each chassis and engine combination, and at times this proves to be a contentious issue. Initially these levels are set following airflow tests done during the winter between race seasons as a way of equalising engine and car performance. Interim adjustments can be made during the race season if necessary.

'We keep a close eye on boost level,' says Riches Jr. 'We do that by having our own independent boost pressure and temperature sensor fitted to each car and most teams fit their sensor as a back-up. The TOCA sensor is an off-the-shelf part that we issue on the Friday of each race meeting. The sensors are individually numbered and a representative of each team draws one randomly from the box. It's largely seen as a fair way of regulating boost.'

POST-RACE CHECKS

Data is collected from each car after every practice and qualifying session and after every race. On the older S2000 cars, data is downloaded into a laptop while on the NGTC cars it's done by swapping memory cards. 'I use Cosworth's Toolbox analytical software to check the data,' says Riches Jr. 'Although the first parameters checked are turbo boost and RPM, I can also look at wheel speed, throttle position, brake pressure, manifold pressure and various other things. After each qualifying session and race I have to go through the data from more than 20 cars so the checks tend to be comparative rather than a close analysis of a car's performance. The system is configured in such a way that I can set alarm levels and the software will highlight any problem areas. Turbo boost and revs are the headline considerations. If a driver is not over-revving and the engine is not over-boosting, there is not much that can be done to improve performance.'

'We have to allow some leeway on boost levels because they can be affected by mechanical issues on the cars and bumps on the track,'

Samples are checked, but to date, no one has failed a fuel sample test

observes Riches Sr. 'It's better to have a tolerance than a strictly enforced limit where you end up investigating minor infringements by almost every car. Knockhill is a classic example, as the cars cross over the startline there is a hump that causes them to "go light" and everyone over-boosts and over-revs there. You have to make allowances for circumstances like that. In general we will allow a car to overboost for 2 per cent of the lap time.' At Snetterton the BTCC cars were lapping the 2.99-mile circuit in around 88 seconds and were thus allowed an approximate 1.7-second period of overboost per lap.

The other logged data is occasionally used in the investigation of incidents on the track. For instance it can be used to determine if a driver has braked earlier than usual, ie: brake-tested another driver. 'That again is a comparative exercise and can be done quite quickly if the stewards of the meeting request that information,' says Riches Jr.

PARC FERME

After qualifying the scrutineers make a selection of cars to be taken to parc ferme for inspection. Typically this will be the fastest two or three cars in qualifying and a further selection depending on the make-up of the field. 'If, for instance there are three Hondas in the top six, we would probably only take one to parc ferme,' says Riches Sr. 'You tend to assume that they are all the same, although of course if you find a problem with one of them you check all the others. Like any formula, you could probably run at the back of the field with an illegal car and nobody would know. It tends to be a case of the more successful you are the more checks you get.'

"It's better to have a tolerence, as otherwise you end up investigating almost every car"

For some of the inspections at post-qualifying or post-race scrutineering, specially-made jigs are used to check things like the location of suspension pick-up points.

'A lot of the standardised components are laser-etched by the manufacturer, which makes it easier for us to see that the correct parts are being used rather than the team's own replica parts,' explains Johnson. 'If the pick-up points are in the correct position the jig plugs straight in.'

If sub-assemblies or components provided by contacted suppliers are being inspected, the services of representatives of those companies will be used. At Snetterton, the crews of the chosen cars were asked to remove the top of the fuel cells to allow the assembly to be inspected by the ATL representative.

Each car that races in the BTCC is fitted with a TOCA-issued cockpit mounted onboard camera. The footage recorded by these is mainly used for judicial purposes such as the investigation of racing incidents. The cameras have wide-angle lenses, so that their field of vision covers both the interior of the car and the view through the front windscreen. 'We can see the hand and foot movements made by the driver including the operation of switches and the making of other adjustments,' says Riches Sr.

The cameras are operational at any time that the cars are running on the track. If a car is involved in an incident footage can be and often is reviewed by the race stewards and can also be reviewed by the scrutineers for unusual behaviour. 'Switches can be configured for all kinds of things, for instance changing the engine mapping,' says Riches Sr. 'Having a wide angle, high-definition view of the cockpit means there's nowhere to hide.'

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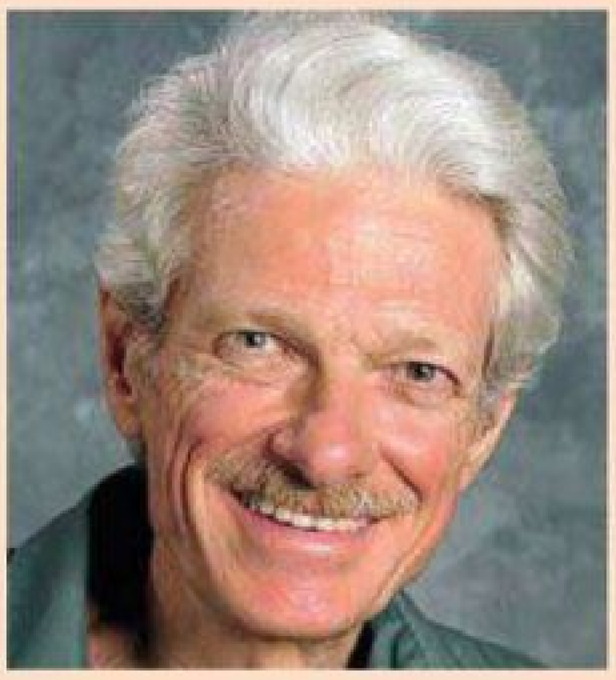

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Unconventional thinking

Trying other ways to make a two-wheel vehicle stable

Q A friend came up with an idea for a 'bike' with racecar slicks – a pair of very wide, low-profile tyres. They would not camber like regular motorcycle tyres do. Instead, they'd stay perpendicular to the road, always upright. His idea is that the main body wouldn't lean but would laterally translate relative to the wheels. His suspension system relies on power hydraulics and electronics to operate.

My feeling is there may be a better, more 'natural' way to achieve the desired result. Instead of shifting the body laterally in response to the front wheel's steering, it would be better if the body could be moved laterally just before the front wheels steer.

This idea is similar in a sense to what Phillip James's FTC three wheeler is doing (see tiltingvehicle.net). I am thinking that something similar could be achieved by sliding the body sideways and having the front wheel steer occurring as the result of that action. If this is possible it would negate the need for much of the electronic sophistication my friend wants to rely on. Any comments or ideas on this?

I have not studied this rather complex question of how the rider of a two-wheeler initiates a turn to the degree that others have, and I certainly haven't taken videos of motorcyclists, and slowed them down and analysed the motions, but I will attempt some reasonably intelligent commentary nonetheless.

The case of a narrow three-wheeler or four-wheeler that is leaned simply to avoid rollover is different from the case of a two-wheeler. Also, it matters a lot whether the wheels lean, especially with a two-wheeler. In all of these cases, the needed lean angle, or lateral cg shift of the vehicle, is not a simple function of front wheel steer angle.

In the case of a two-wheeler, the vehicle is unstable in roll. That is, it won't stand up on its own when not in motion. Colin Chapman reputedly said: 'Silly things, motorcycles. If you let go of them, they fall right over.' In the case of a narrow three-wheeler or four-wheeler, even with suspension that's very soft in roll, the vehicle doesn't fall over unless the line of action of the vector sum of all x, y, and z forces acting on the cg intersects the ground plane outside the polygon described by the contact patches. When the vehicle is not single-track, the suspension can roll the vehicle within certain limits, because it has a base of support of some width to push against. When the vehicle is single-track, everything depends on a complex inertial balance. We can't just shift the cg laterally, without something else happening.

Let's first consider what keeps a bike upright when it's moving. The bike is always trying to tip one way or the other, because its center of mass is above the line of support described by the two contact patches. But as soon as the bike develops a roll velocity, gyroscopic precession induces a yaw acceleration that tends to bring the contact patches back under the cg. This doesn't make the vehicle hold itself upright for any distance without rider intervention, but it does make it rideable by most humans. If we push a trike and just let it roll, it will go sort of straight for a while, probably turn to one side eventually, and stop without falling over. If we push a bike and just let it roll, it will go a short distance, then tip to one side, turn to that side but not enough to catch itself, and fall over. The bike will have an increasing roll velocity, and an increasing yaw velocity, but the yaw won't keep up with the roll to the point where the vehicle will right itself.

The fact that the bike is unstable in roll makes it easy to initiate roll acceleration. This can be done in more than one way. If the roll acceleration needed is fairly small, just letting the bike tilt the desired way is sufficient. The rider's job is not so much to make the bike lean or turn as to arrest the lean and turn as needed to keep the vehicle upright and on course.

In all cases, however, the dynamics of the vehicle are highly dependent on precession. When the wheels are leaned, they try to yaw in the direction they are leaned. When the wheels are yawed without being leaned, they try to lean opposite to the direction of yaw. This means that if we lean the wheels into the turn, the bike will yaw in the desired direction. But if we try to steer the front wheel and keep the wheels upright, precession will roll the bike out of the turn.

A bike can steer like a two-track vehicle at very low speed. The front wheel is steered a lot, the bike leans very little, and the rider balances the bike as best he can. The manoeuvre is only slightly less difficult than a track stand (balancing the bike essentially motionless). If we try to steer a bike like that at speed, gyroscopic precession will make the bike lean out of the turn and steer the opposite way than we intended. Indeed, the main element of learning to ride a two-wheeler is to learn not to try to steer it that way.

It may be that some genius can devise a way to make a two-wheeler turn at speed without leaning the wheels into the turn, but I would not bid on a contract to develop the algorithm, and I certainly would not try to do it with any mechanism that mechanically shifts ballast or sprung mass simply in relation to front wheel steer angle.

"It may be that some genius can devise a way to make a two-wheeler turn at speed without leaning the wheels into the turn."


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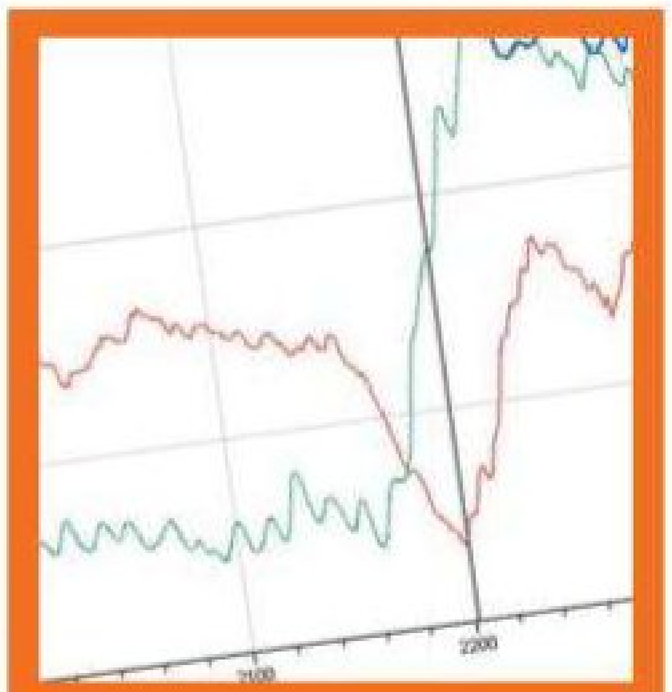

Databytes gives insights to help you improve your data analysis skills each month as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems. Plus we test your skills with a teaser each month

To allow you to view the images at a larger size they can now be found at www.racecar-engineering.com/databytes

Clock watching

Beacons and GPS are the key when you strive for accuracy

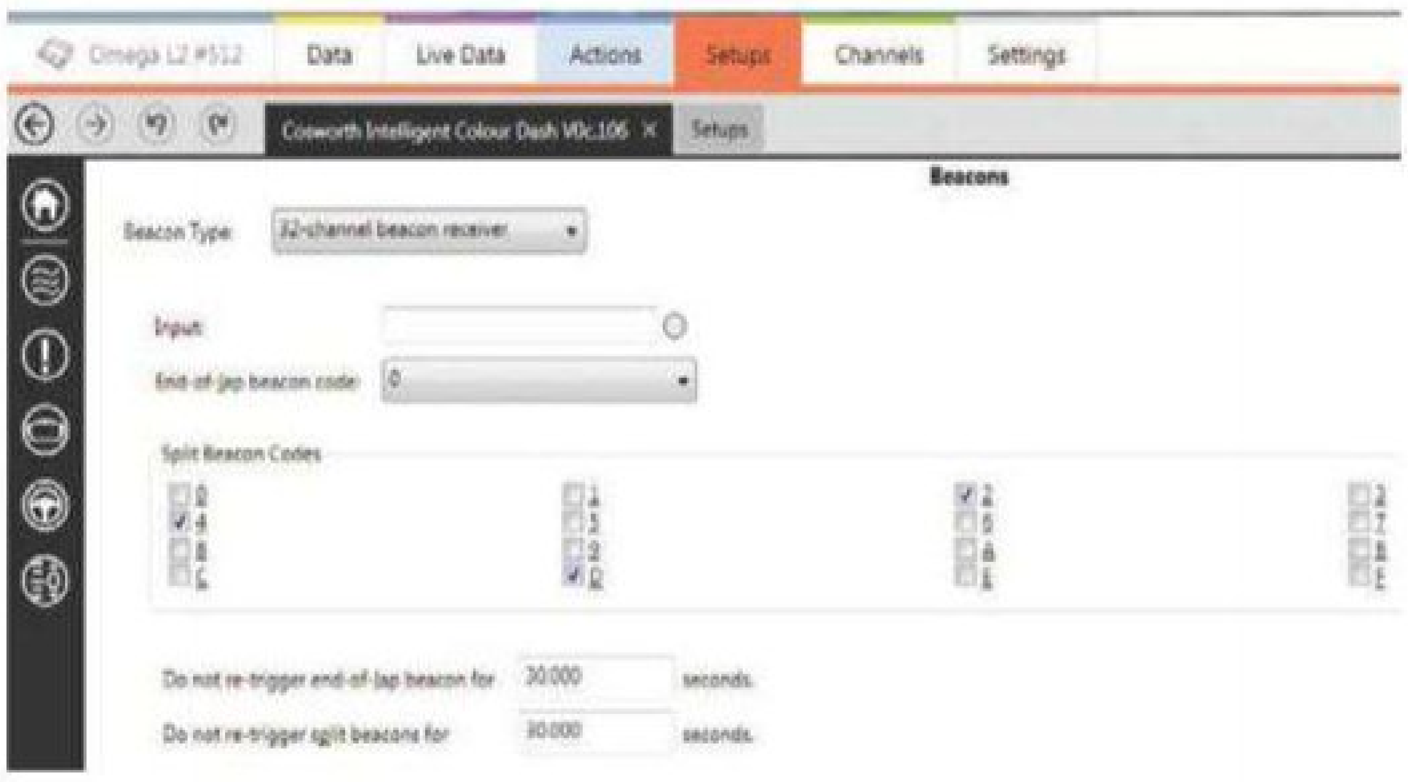

Figure 1: Cosworth ICD system configured to use a 32-channel coded beacon with splits. The split beacon transmitters are set to transmit on frequencies 2, 4 and D and 0 for end-of-lap

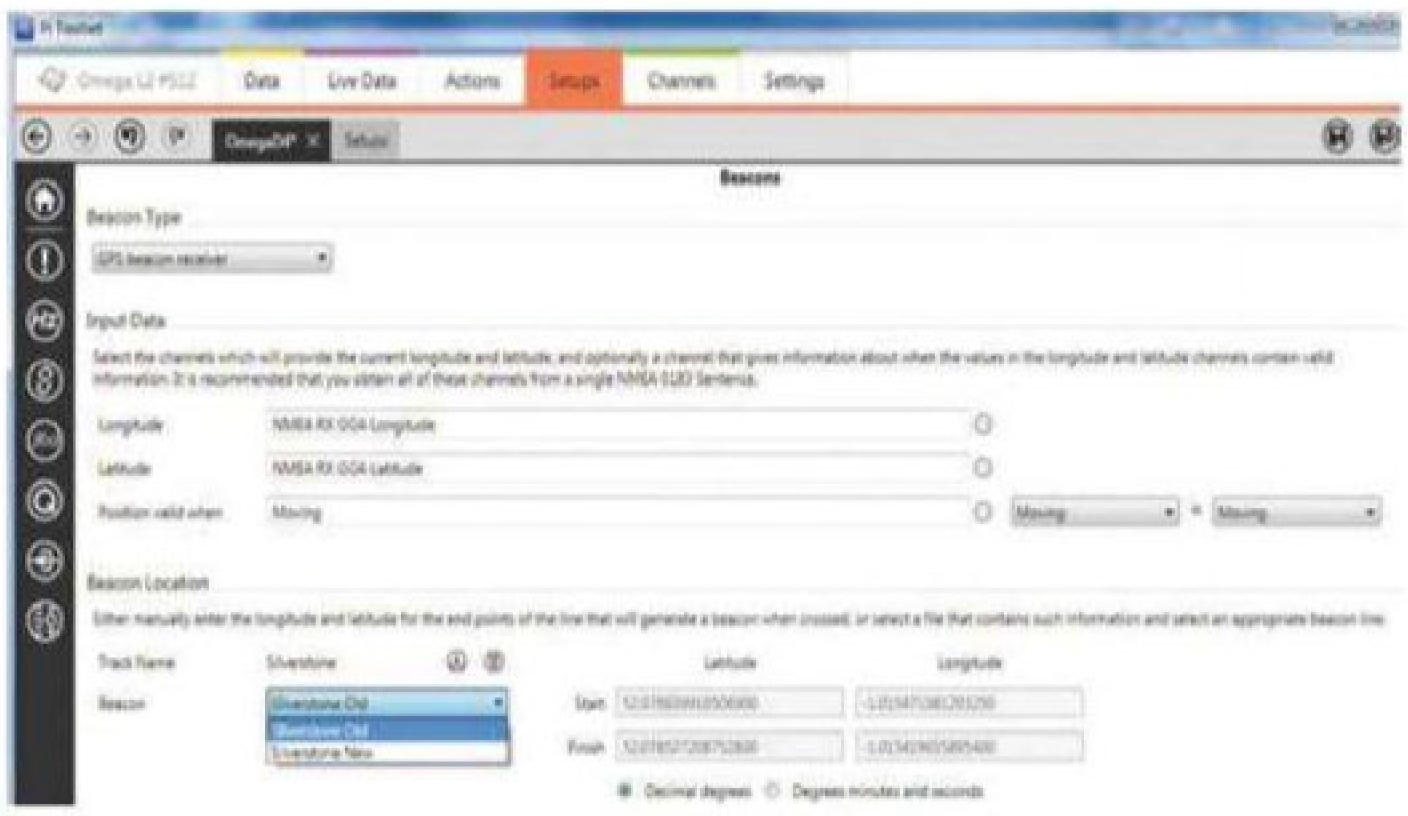

Figure 2: an example of how a single kml GPS data file can be programmed to feature multiple start/finish lines

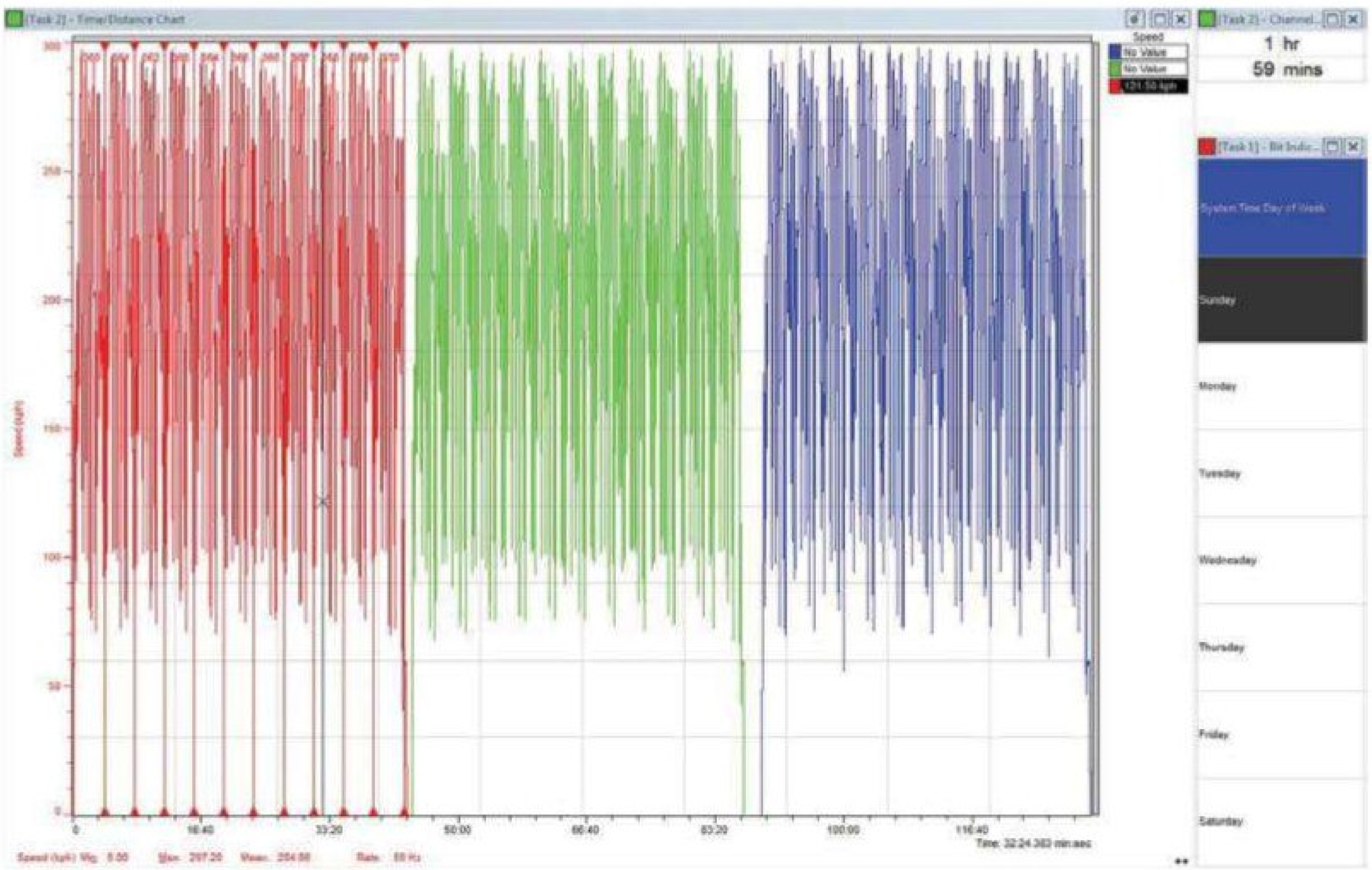

Figure 3: time displayed to the right using the above functions, the time at the cursor crosshair is 01:59 on Sunday

Accurate timing is one of the fundamental things needed when tuning a racecar for optimum performance. Being able to set a benchmark time, and then measuring how each change effects the lap time or stage time, is the basis for any data analysis. If a racecar is fitted with a data system it will always have a method of logging time, and generally there will be a method for splitting the logged data up into laps. The prevailing method of doing this is to use beacons. This means a beacon transmitter is placed near the start/finish line and transmits an infrared cone across the track. The car side will have a receiver connected to a digital input, which is configured to be the beacon input. The data system will then interpret the digital signal and put a marker in the dataset to indicate a lap. If the data system has a display, the lap timing can also be viewed live by the driver.

DOING THE SPLITS

The infrared beacon system also has another ace up its sleeve and this is the coded infrared beacon. Not all data systems have the ability to use coded beacons, but this allows a team to place beacon transmitters not only on the start/finish line but also around the circuit to indicate splits. The split transmitters are then configured to transmit a slightly different frequency so the data system can be configured to recognise the different beacons

There are a few things to consider when installing both pit side and car side beacon equipment. Looking at the car side first it is important that the beacon receiver has a direct line of sight to the pit wall, and preferably unobstructed by any glass, on occasion it is necessary to create a small hole in the vehicles glass in order to get a reliable beacon signal. Another important thing that is often overlooked is to make sure that the beacon can be fitted on both sides of the car as not all tracks have the same orientation or pit wall placement. For the track side beacon it is preferable to fit them near the start/finish line. It is almost never possible to get the beacon directly on top of the start/finish line as the official time keeping equipment is normally fixed there, and it is possible for infrared beacon transmitters to interfere with that equipment. It goes without saying that this would prove unpopular with majority of competitors.

GOOGLING IT

In recent years GPS has become a more popular addition to data systems as it offers a great deal of information, both with respect to time and obviously position. Using a GPS system it is also possible to determine the start/finish line and even split beacons, simply based on GPS coordinates. One good way to get GPS coordinates is using KML files generated by programs such as Google Earth. These types of GPS data files can potentially hold information for a whole season's-worth of GPS coordinates. Some data logger configuration tools allow the user to import these files directly and select what the appropriate location and track configuration.

SUMMING UP

Being able to manipulate the time axis in data analysis software can reveal some interesting and valuable information. In majority of cases, the lap time is the prevalent channel used for looking at data. The ability to show data on a global time scale can be very useful to display trends, but it is often not easy to visualise the time of day or even what day it was. In most cases data loggers present time as Unix time in two separate numbers, System Time High and System Time Low. The maths channels, shown above, show how to get important day, hour and minute information from these channels.

The data from these functions can then be used as part of the analysis of one or more data sets. **Figure 3** is a sample of how this could look using global time as the X-axis and the day and time displayed to the right giving a much clearer picture of when the data was collected.

MATHS CHANNELS

```
Day:
    /*
    Function returns day of the year as a single number by subtracting 1325376000
    (System time at 01/01/2012) from the System Time High channel which represents
    time in seconds.
    The floor function is used to take out any fractions present.
     */

    floor ( (
    [System Time High] - 1325376000 ) / 60 / 60 / 24 )
Day of the week bitfield function:
    /*
    Day of the displayed as a decimal number from 0-6 and converted into a value
    for bitfield generation
    */

    register @a1;
    register @a2;

    @a1 = ( [System Time Days] -
    ( floor ( ( [System Time Days] / 7 ) ) * 7 ) );

    @a2 =
    choose ( @a1 == 0 , 1 ,
    choose ( @a1 == 1 , 2 ,
    choose ( @a1 == 2 , 4 ,
    choose ( @a1 == 3 , 8 ,
    choose ( @a1 == 4 , 16 ,
    choose ( @a1 == 5 , 32 ,
    choose ( @a1 == 6 , 64 , 0 ) ) ) ) ) ) );

    @a2

Hour:
    /*
    Similar to System Time Days, but this time the value for the day is subtracted from
    the equation
    */

    floor (
    ( ( [System Time High] - 1325376000 ) / 60 / 60 ) -
    ( [System Time Days] * 24 ) )

Minutes:
    /*
    Again similar to the System Time Hour function, but subtracting both the day value and
    also the hour value
    */

    floor (
    ( ( [System Time High] - 1325376000 ) / 60 ) -
    (  [System Time Days] * 24 * 60 ) -
    (  [System Time Hour] * 60 ) )
```

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

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Tunnel visions

Continuing our in-depth look at the 2007 Honda F1 car

As the most up-to-date Formula 1 car we have tested for Aerobytes, the Honda RA107, has given us an idea of the aerodynamic performance of cars from the period. Our thanks once again go to Bjorn Arnils and Nadine Geary, the owners of this fabulous F1 machine as we work our way through some more of the configuration changes made in a fascinating half-day session.

We have seen in the past couple of issues that the overall downforce and drag numbers generated by the Honda RA107 were remarkably similar to those we measured on the 1999 Benetton B199, that we studied in V19N7 to V19N10. This similarity in aerodynamic performance seems to have resulted from a classic manifestation of Newton's Third Law, wherein continuous development and periodic regulation changes appear to have been equal and opposite!

FRONT WING CHANGES

Among the regulation changes the FIA made to reduce downforce, was the 150mm increase in the minimum height of the outer portions of the front wing, introduced in 2005. The minimum height of the central section remained as before, and this gave rise to the dramatic spoon-like front wing shapes that prevailed until the current regulations were introduced in 2009. Not only would this have reduced the downforce from a given wing design by moving the outer portions further above the ground, it would also have made the cars less sensitive to dynamic changes in front ground clearance, in that wing-generated downforce would fluctuate less with typical ground clearance fluctuations. We had available a pair of thin (4mm) spacers with which to reduce the height of the front wing assembly, which we tried in order to see the effect on the aerodynamic coefficients. **Table 1** shows the results, with the changes (Δ) in counts, where one count is equivalent to a coefficient change of 0.001, also given. As ever, we must remind ourselves that although 'trip strips' were attached to the wheels to simulate the effect of wheel rotation, the MIRA wind tunnel has a fixed floor so our downforce data will have been underestimated, and this would have applied especially to devices operating in ground proximity.

Table 1: the effect of lowering the front wing by 4mm

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Datum	1.054	2.207	0.818	1.389	37.06%	2.094
4mm lower	1.052	2.218	0.824	1.393	37.15%	2.108
Δ, counts	-2	+11	+6	+4	+0.09	+14

So the changes in the coefficients were very small, as expected, given that 4mm reduction in wing height was proportionately very small relative to the height of most of the front wing. But there was a small increase in downforce, mostly at the front, although interestingly a small increase was also felt at the rear. And drag reduced by a very small amount, giving an increase in efficiency (-L/D) of 0.7 per cent. Such a modification as lowering the static front wing height would not be permitted of course, but this trial served to illustrate that dynamic reductions in the height of one of these high front wings yielded very small changes to the aerodynamics, and quite benignly as well given that the front to rear balance altered very little.

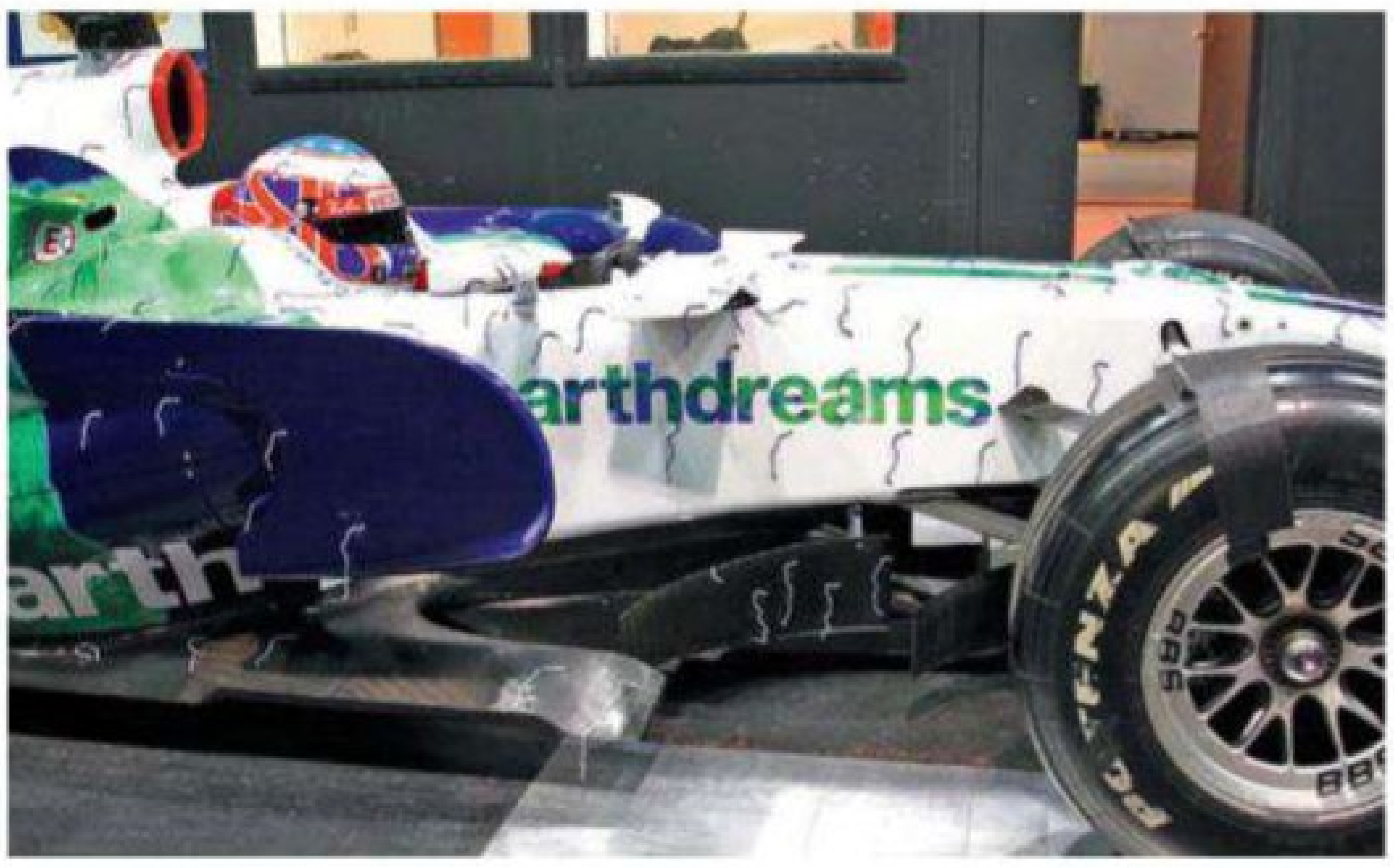
RIDE HEIGHT ALTERATION

Small changes in a high-mounted front wing's height may have had commensurately small

The Honda's 'spoon-shaped' front wing was typical of its time

4mm thick spacers dropped the front wing height aerodynamic effects, but changing the front ride height also alters the height of the entry to the underbody, which of course runs much closer to the ground. Time being all too short in this session, just one change of ride height was attempted, the front being raised by 10mm to give an idea of the overall level of the effects. **Table 2** provides the data.

The magnitude of the effects on the coefficients this time was considerably larger than with the 4mm change of front wing height. Overall downforce dropped by over 7 per cent, while front downforce dropped by almost 16 per cent, and there was a significant balance shift off the front end. And taking into account the results of the previous change to the front wing height only, we can be pretty confident that most of the loss of front-end downforce arose from increasing the height of the underbody at the front rather than the wing. This is one of the consequences of the mandatory flat bottom on an F1 car, which must start in line with the rear of the front tyres – it means that the underbody's low pressure area begins well forwards, so there is a significant front downforce contribution from the underbody.



The central underbody is compelled to start well forwards on the car

Interestingly, rear downforce decreased slightly with the increase in front ride height too. This was most likely down to the change in rake angle of the whole underbody, analogous to a reduction in the angle of a wing. That drag should have increased very slightly with increased front ride height is interesting too, especially as downforce decreased. This may simply reflect that the flows over all the various downstream components have been altered with this fairly significant ride height change, with the net effect that the aerodynamics are not operating in their optimised window and are simply less efficient in this configuration.

STALKING AROUND

Finally this month we'll take a brief look at the effect of removing the 'aero stalks' that were located just aft of the radiator exit chimneys, atop the sidepods. These were essentially a complex-shaped single element wing section mounted on a short pole. Their effects are shown in **Table 3**.

So these produced an increase in downforce of 24 counts for 11 counts of drag, a small but useful incremental benefit of around 1.1 per cent extra downforce with slightly better efficiency than the overall car's efficiency. But what was unexpected was that a device that was mounted on top of the sidepod and which must have been aft of the centre of gravity, appeared to have created an increase in front downforce and a small decrease in rear downforce, with a commensurate forward shift in balance. If the time and opportunity ever arise, this would certainly be something well worth revisiting...

Join us next month for the final and instalment of our analysis.

Many thanks once again to Bjorn Arnils and Nadine Geary

'Aero stalks' comprised a small single element wing section on a short pole

View of the car with aero stalks removed

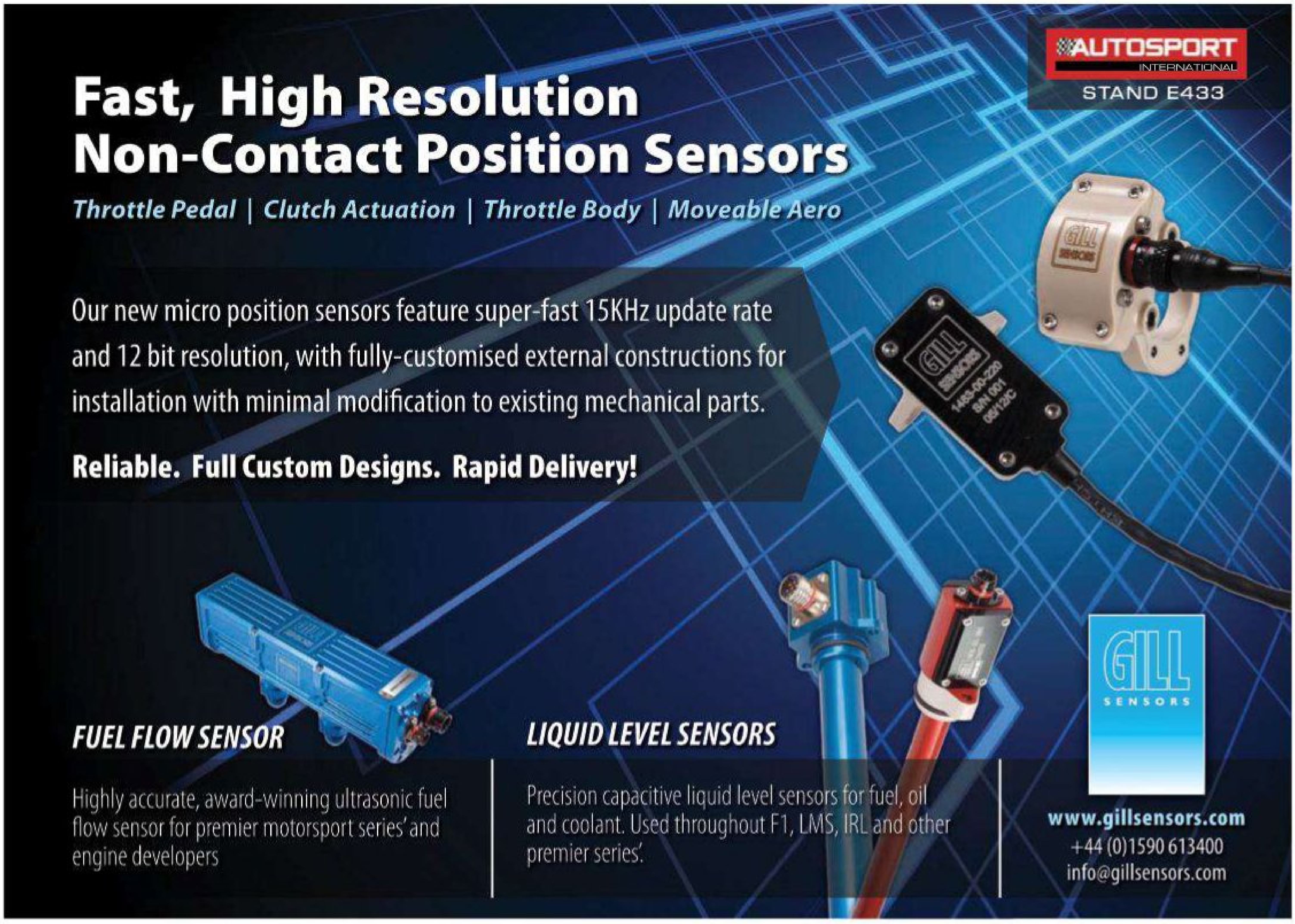
A close-up look at one of the aero stalks

Table 2: the effects of raising the front ride height

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Datum	1.052	2.218	0.824	1.393	37.15%	2.108
FRH +10mm	1.065	2.058	0.693	1.365	33.67%	1.932
Δ, counts	+13	-160	-131	-28	-3.48%	-176

Table 3: the effects of aero stalks

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With	1.052	2.218	0.824	1.393	37.15%	2.108
Without	1.041	2.194	0.795	1.399	36.24%	2.108
Δ 'with', counts	+11	+24	+29	-6	+0.91%	Same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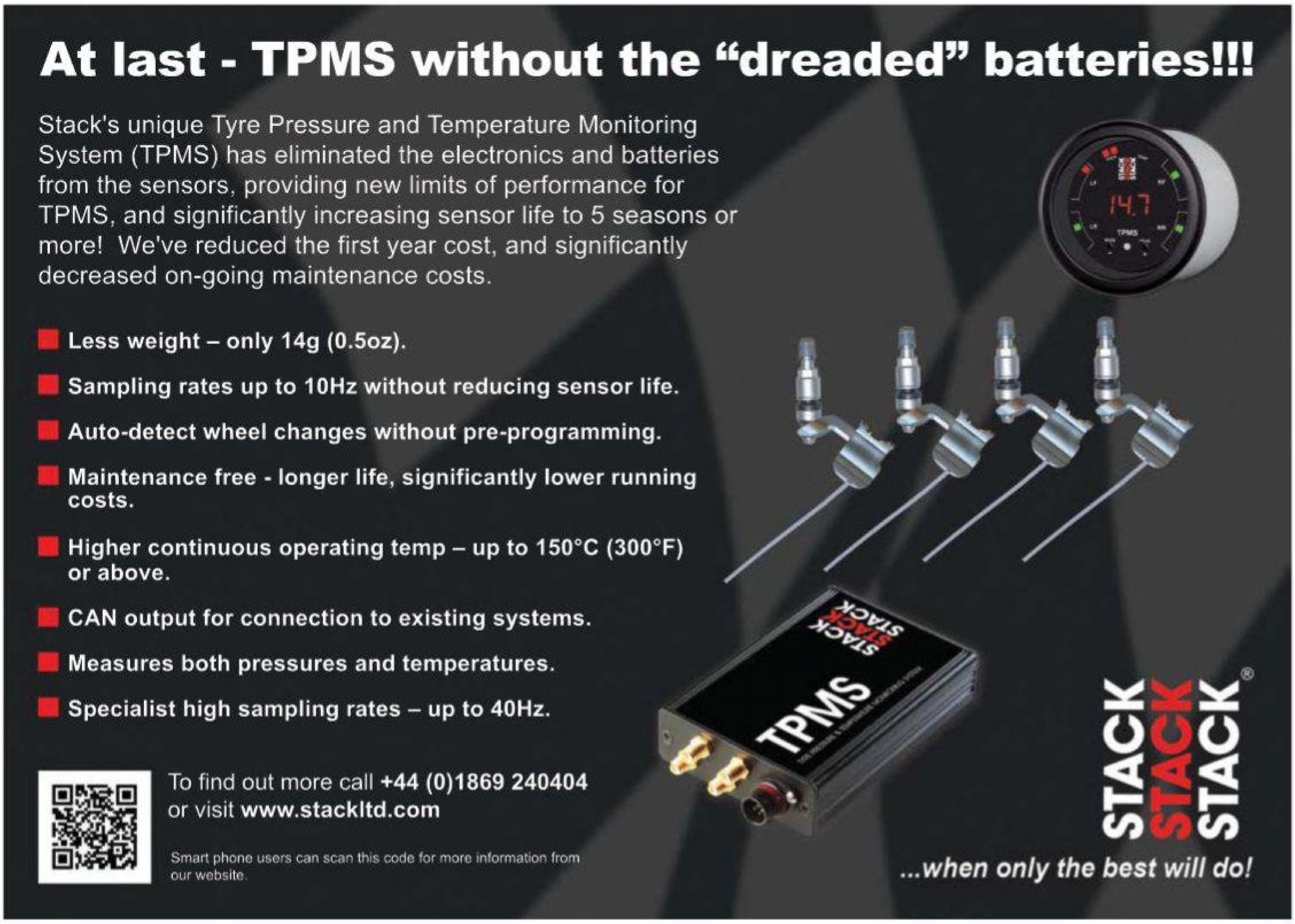
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The new breed of info-gathering systems are portable, economical – and critical

BY CHARLES CLARKE

We've come a long way since the days of the clipboard and the stopwatch, and like every other field of technical endeavour, data acquisition and analysis has benefitted from advances in computer power, wireless technology, satellite communications and affordable memory.

Not long ago we used to marvel at the capability of leading teams, even in the lower formulae, when they could download data from a hot lap, transfer it to their trackside servers and have analytical traces available to show their driver when he came in from the slowing down lap.

Now much of this can be done in real-time, and much of the processing can be done on-board (it isn't, because even the most talented multi-tasker can't review traces and drive at the same time). In any event it's beneficial for several pairs of eyes to review and suggest tactical changes.

The idea behind all these acquisition and analysis systems is to capture and provide data in such a way that it helps the driver go faster and the engineer to tweak the car to achieve optimum performance lap after lap. The driver behind the wheel is busy and has very little surplus peripheral attention, so the data displayed to him in real-time must be as comprehensive as possible and delivered in such a way that it requires no separate thought processes to assimilate.

There was a time when data acquisition was the preserve of the elite teams and racecars in motorsport, with the data acquisition system being designed in at the outset. With the general availability of small, portable electronic devices, there is a proliferation of kit for the racecar

The 'straight line' racers are just as demanding of data acquisition and analysis as the circuit racing community

Rob Barff checks his Video VBOX OLED display in qualifying

at every level, from F1 to dirt track and any car can be retro-fitted with a fairly sophisticated system in minutes for a modest outlay.

The buzz phrases today are 'plug and play' and 'customer setup.' Systems are being delivered today that can be installed by the owner-driver or the weekend warrior and don't necessarily need the skills of a specialist technician. These systems also tend to be 'minimally invasive' in that most connect to the CAN bus in the ECU to gather vehicle and engine data. And most sensors are 'stick-on' and don't require the car's primary systems to be opened or tapped into.

THE SMART DASHBOARD

The crucial component these days is the smart dashboard. A typical state-of-the-art system is the recently announced DDU 7 dash logger from Bosch Motorsport. The DDU 7 is based on the same platform as their already introduced DDU 8 performance line dash logger and integrates a freely programmable colour dashboard with a data logging system.

It features a 5.7in, full-colour, trans-reflective TFT display with 10 multicolour LEDs as well as fully configurable display pages and LEDs. It allows for synchronised acquisition and visualisation of engine data from the ECU and chassis data from six analogue and four digital wheel speed input channels. Additional input devices can be connected via ethernet and two CAN buses. Recorded data from the internal 2gb flash memory can be downloaded via high-speed ethernet. It also offers recording on a removable USB flash drive as an optional upgrade.

The DDU 7 comes in a lightweight synthetic housing, about the same size as a modern road car satnav/GPS device. It is small enough to replace the dashboard in most performance motorcycles and yet big enough to be read easily at speed. For customers who just want a data logger, Bosch Motorsport offers the C50, offering all the advantages of the DDU 7 but without a visual display.

In the case of Bosch, the entire vehicle electronics and every sensor is configured using their RaceCon software. This is easy to operate: simply connect your PC to the control unit for access to all components. The Bosch software solutions for data analysis then provide you with flexibility for analysing your data, with a multitude of calculations and standard display formats available.

LIVE VIA SATELLITE

GPS is probably the most recent innovation to change the game as far as data acquisition or analysis is concerned. As well as allowing you to dispense with trackside beacons and wheel speed sensors there are lots of less obvious benefits to the GPS enabled racecar.

GPS units provide speed and position information, as well as altitude, heading, date, time and GPS statistics. The lap and speed features are independent. You can choose to only use the 'end of lap' feature and measure speed with a traditional wheel sensor or use both a wheel sensor and GPS speed to help analyse wheel spin and lock.

You can also adjust the sensitivity for dropout-free speed data under bridges and trees. With most systems the racecar position is recalculated 250 times per second to yield a laptime accuracy of about 0.02 seconds. In most cases the accuracy, noise and jitter of the speed signal will be significantly better than any wheel speed sensor and is unaffected by brake lock and wheel spin.

Depending on the precision of the GPS receiver, it could be possible to generate traces of the track. MoTeC for example with their 10 or 20Hz receivers can calculate the position of the GPS antenna to within a few centimetres, enabling you to generate racing line traces.

GPS position information can be used in MoTeC's i2 data analysis software to show and compare the driven lines and to create track maps. The driven lines can also be plotted over a Google Earth image, allowing circuit racers and rally drivers to see the path travelled in a real-life context.

In circuit racing, a GPS unit can be a cost effective alternative to the traditional lap timing system. With the Competition Data Systems Inc (CDS) GPS system, for example, the driver sets a virtual start/finish line by pressing a button on the GPS controller. This position can then be used by the logger or display as a beacon to calculate the lap time and by the data analysis software to indicate the start of each lap.

AIM's Solo GPS lap timer, meanwhile, comes pre-loaded with information about the start/finish lines for a variety of tracks, minimising the setup procedure. Its sister model, the Solo DL, adds connectivity to several engine management systems, as well as AIM's own SmartyCam GPS overlay camera, and offers the ability to record a wide range of information including throttle position, RPM, temperatures and pressures.

The data logger on the 200mph Scheid Diesel Dragster

TAKING THE STRAIN

Another CDS offering is their Load Cell kit, which consists of strain gauges attached to the push rods (or pull rods) of the racecar to enable you to log dynamic corner weights. The company's Track Master software turns this corner weight raw data into many useful charts.

The front load, rear load and total load are calculated, and from those signals CDS calculates the load bias and aero bias. The load bias is the percent of total load that is acting on the front of the car, which includes weight transfer due to acceleration, deceleration, and change in pitch of the road (hills). If you take those effects out you are left with just the aero loads.

Aero bias is the percentage of total downforce that is acting on the front of the car. The aero bias formula has built-in conditions to ignore the times when the car is under hard acceleration, braking or turning so that front/rear load transfer does not factor into the calculation.

If your system has a vertical G sensor then you can also factor out road pitch. Since there is always some acceleration, deceleration and road pitch in actual track data, the aero bias calculation is not perfect, but it's close and very good for comparing aero changes on the same car at the same track. It can also be used in coastdown testing where the results are very close to wind tunnel results.

The front and rear lateral load transfer is calculated and plotted separately. The roll couple, which is the percentage of lateral load transfer that occurs at the front of the car, is also shown separately. The roll couple illustrates how the load transfer distribution changes as the car goes through the various phases of cornering. Since the higher values of roll couple correspond to more weight transfer occurring at the front, these points could indicate high damper forces or bump rubbers engaged at these points.

Other calculated signals that can be generated from the load data include Percent Inside Wheel Load at each end of the car. This is the percentage of total load at each end of the car that is carried by the inside wheel.

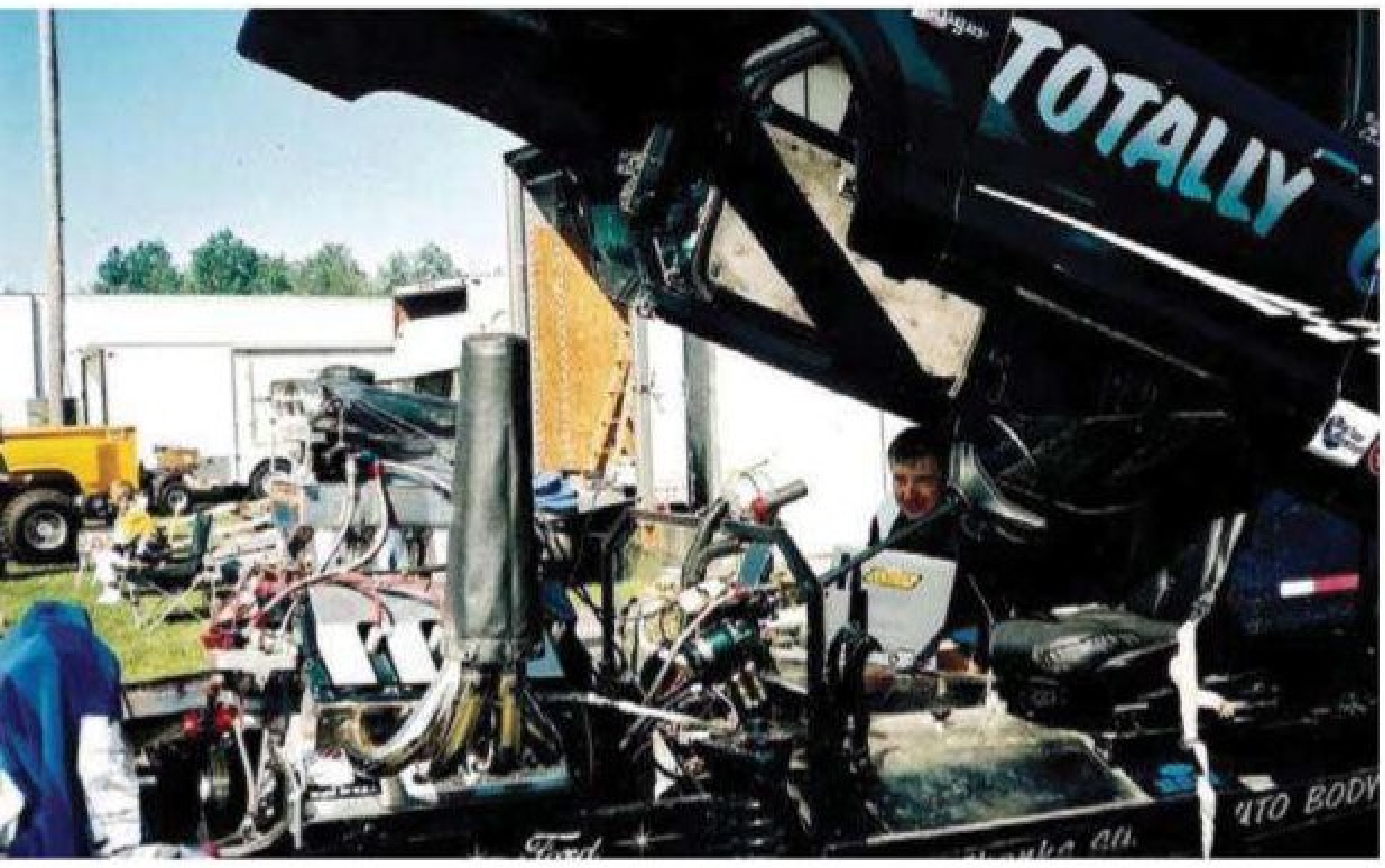
The rear inner percent minus the front inner percent is called the dynamic wedge. Usually, the greater the dynamic wedge, the more the car will tend to understeer, since the rear of the car is working better than the front.

CAN-DO APTITUDE

The CAN bus is an automotive bus developed by Robert Bosch, which has quickly gained acceptance in the automotive and aerospace industries. It's a serial bus protocol to connect individual systems and sensors as an alternative to conventional multi-wire looms, allowing automotive components to communicate on a single or dual-wire networked data bus up to 1Mbps.

The BMW 850 coupe was the first CAN bus vehicle to enter the market in 1986. By reducing the vehicle's wiring by 2km, the vehicle's overall weight was significantly reduced by at least 50kg and using only half the connectors. For the first time, each of the vehicle's systems and sensors were able to communicate at very high speeds (25kbps-1Mbps) on a single or dual-wire communication line as opposed to the previous multi-wire looms.

Some engine control units (ECU) will have a CAN output. CAN is used in some racing fuel injection computers and in most new vehicle applications.



This engien relies on data analysis to be 'on-song' for its short run

Racelogic's Video VBOX is small enough to be handlebar mounted

The DDU 7 'smart' dash logger from Bosch Motorsport

The CDS Co Pilot 2 has a programmable display

'Sidebar Brain Power is the new horsepower' is Racelogic's slogan for their Video VBOX data logger and driver training aid. The idea being that the video element, coupled with GPS data analysis, helps coax an extra couple of seconds off lap times, and also demonstrates why sometimes the intuitive approach isn't always the fastest. They've also produced a free ebook written by pro drivers and driving coaches that has some surprises in it.

The notion is that some trainee drivers have trouble putting into practice what the trainer is telling them, or sometimes they don't seem to believe that the particular technique they are being taught will actually make them faster. Or perhaps it is increasingly difficult to identify areas for improvement, or the instructor would like to show the student exactly how much quicker the advised line or technique will make them.

Using a video and GPS data-logger will identify areas for improvement. It provides objective back-up to what the instructor is saying with data and video, which helps when dealing with situations where there is a difference of opinion. It also adds considerable value to the training experience and aids continuous improvement if the student installs the same system in their own racecar.

INSTANT FEEDBACK

The Video VBOX combines broadcast quality video from up to four bullet cameras, accurate GPS data-logging, crisp graphics, and highly-rated driver training software. For immediate driver feedback, you can connect Video VBOX to Racelogic's high-brightness OLED display with LineSnap predictive lap-timing.

'Since using Video VBOX as a training aid I have noticed a big improvement in how quickly my customers learn,' says Ben Elliott, an ARDS Grade A racing instructor. 'I can therefore offer greater value-for-money as a racing instructor.'

Radical Sportscar British Champion Anthony Dunn, an ARDS & ATDO licensed instructor, says: 'It helps distill the finer details of driving technique, which can't always be appreciated in the heat of the battle.'

Nigel Greensall is a pro driver and coach. In over 20 years of professional racing he has 140 outright race wins and 92 lap records under his belt, including the outright record at Castle Combe (averaging 130mph) in a Tyrell F1 car. Having coached individuals from track days to the Le Mans 24 Hours, he understands the importance of objective data and video to support his instruction.

Interesting observation: more time is spent in slow corners than in fast corners, so you can often gain the most laptime by concentrating on these areas. Greensall uses video screen-shots, circuit maps and videos to demonstrate this approach.

Of the VBOX, he says: 'It provides high-quality video with clear graphics and easy-to-use data for driver comparisons. When on a track day, test or race meeting, it's invaluable to have a system that is reliable, easy to use and provides the exact information that we, as drivers and instructors, need.'

As GPS technology becomes more and more reliable, predictive lap-timing becomes more accurate and useful. Predictive lap-timing is nothing new, it has been around for some time on many high-end data-logging systems. GPS positioning may only be accurate to a few metres, but a typical average race speed would be well in excess of 30m/s, minimising any errors to around 1/10th of a second. The ability to see if your current lap is quicker or slower than your fastest, in real-time, is invaluable for driver training.

These systems enable amateurs to see where they're losing time and try out different lines and braking points, while

STUDYING STRAIGHT-LINE ENGINES

The short duration straight-line motorsport categories have very different data acquisition requirements to those of circuit racers. It is fundamentally important in these categories that the engine is on-song for the whole duration of a run, which could be as little as six seconds.

Drag racers and tractor pullers, for example, find that knowing what the Exhaust Gas Temperatures (EGT) for each cylinder and supercharger boost were during the whole run help them to tune the engine for performance and to prevent expensive meltdowns. Many racers also monitor fuel pressure and nitrous pressure for the same reason. Several Corsa Instruments customers have reported that the system saved them an engine by detecting a problem before the engine was destroyed.

Wideband air-fuel-ratio (AFR) sensors are extremely useful for tuning carburettors or fuel injection systems. The Corsa AFR sensor gives you a graph showing the exact air-fuel-ratio (for example, 13:1) under all conditions. You can see how the fuel mixture changes with RPM, and how it changes with load or throttle position or other variables. This is exactly the information you need to tune and troubleshoot your fuel system. It's much more convenient and accurate than reading spark plugs and it can show you the conditions all through the race – not just what the spark plug saw the instant before the engine was shut down. The Corsa AFR sensor is a true wideband unit that will give accurate readings from about 10.5:1 to17:1. Inexpensive O2 sensors only tell you if your fuel ratio is lean or rich. They can't tell you if you're only a little bit lean or about to destroy your engine. The Corsa sensor can help you quickly determine how much tuning you need to do. It will work with leaded or unleaded gasoline, alcohol, and other fuels – sensor life is reduced when using leaded fuel.

The standard Corsa Diesel Puller Package gives you all the information you need to get the maximum torque out of your engine. Pulling customers often choose to add additional pressure sensors for fuel pressure, water injection pressure and exhaust pressure. Some add wheel-speed sensors and additional temperature sensors for the engine air intake. Corsa offers a relay kit specifically developed to turn on a water injection system or an alarm light at programmable sensor values.

You can also get after-market digital water controllers that turn on an extra water stage to help cool your engine. This controller is typically used with the Corsa Data Acquisition system or the IntelliDash. Corsa and the IntelliDash are fully programmable and can turn on this water stage based on readings from other sensors (typically exhaust gas temperature). When the EGT's reach your programmed setpoint Corsa or the IntelliDash will open this water solenoid and cool your engine, helping to prevent a meltdown.

'Our new product will be released in Q1, 2013,' says Erik Kauppi, president of Corsa Instruments. 'It's a simple and inexpensive way to monitor and do "closed-loop" control of almost anything on a vehicle, without needing a computer. I know diesel [tractor] pullers will use it for controlling water injection based on exhaust gas temperature (EGT). Like our other products it is designed to be flexible – I'm sure customers will use it for things I can't even imagine. It can be used for anything from nitrous oxide control based on boost pressure or throttle position, to turning on a fan based on temperature.'

---

pros can verify that the lines they are using are indeed the fastest. Real-time comparison also saves time and money in vehicle setup.

PREDICTIVE LAP-TIMING

Racelogic has developed a new feature they call 'LineSnap'. Rather than distance, it uses GPS position to accurately align two different laps, 10 times a second. This offers unrivalled accuracy, even if the driver takes a completely different line each lap. The system will maintain 0.1s precision the entire way around any circuit, including very long circuits such as the Nurburgring or Spa.

The technology has been built into their high brightness OLED dashboard display, which can be connected to the Video VBOX product range. It provides drivers with accurate, real-time lap comparison, and it works at any track. You do not need any external beacons, and there is no setting up required.

It adds another element to data-logging, as drivers have a real-time comparison of their current lap against their previously recorded best lap – so they will always be trying to beat it. It means they can judge the effectiveness of different lines and get immediate feedback on the graphical display of how much time they're losing or gaining. It's becoming popular with race teams and individuals drivers too.

Predictive lap timing is also good for working on techniques such as slip-streaming, because slight adjustments show up in the display. It is also invaluable where there are a variety of different lines that you can take.

Racelogic's predictive lap-timing is useful in races where testing is limited, as it means you don't need to keep going back to the pits to analyse the data. This enables you to be even more adventurous with the lines you use.

Drivers and teams at any level can quickly see where time is lost – so you can make big gains in consistency. It gives drivers the confidence to try different techniques and lines, and then see the instant feedback.

The OLED predictive lap-timing display is designed to connect to a Video VBOX GPS and video data logger. A key advantage of Video VBOX over rival systems is that it is a one-box solution, combining a multi-camera video recorder, GPS data logger, and real-time graphic overlay into a single unit. Racers need to be sure that a video system is easy to use, quick to install, and above all that it can function reliably in the demanding conditions inside a racecar.

Video VBOX is small, flexible, and reliable, with automatic power back up to ensure data is never lost. It also has automatic logging that can be set to start over a certain speed, meaning that drivers don't have to think about switching it on in the heat of the moment.

CONCLUSIONS

In the past, some drivers have been called 'naturals'. Ayrton Senna's European GP at Donington Park in 1993 has often been touted as the race that showcased his racecraft and highlighted the importance of telemetry for the first time in tactical decision-making.

Like Senna, some drivers excelled in their racing career and some never made it out of the local level. It was also believed that a struggling driver just needed more seat time to improve. However, practice doesn't always make perfect – only perfect practice. Otherwise, just practising without good analysis may reinforce bad habits and good race driving skills may never be developed.

Now, with the introduction of affordable data acquisition, even local racers can develop the skills necessary to win or move up the racing ladder. With data acquisition and analysis you can 'see' where things are not quite right, rather than relying on seat-of-the-pants intuition. The bonus to approaching racing performance in this fashion is that you may discover there is nothing wrong with your racecar's setup, or that many of your imagined setup problems disappear with the development of good driving skills based on good data acquisition and analysis.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Ford's other V8

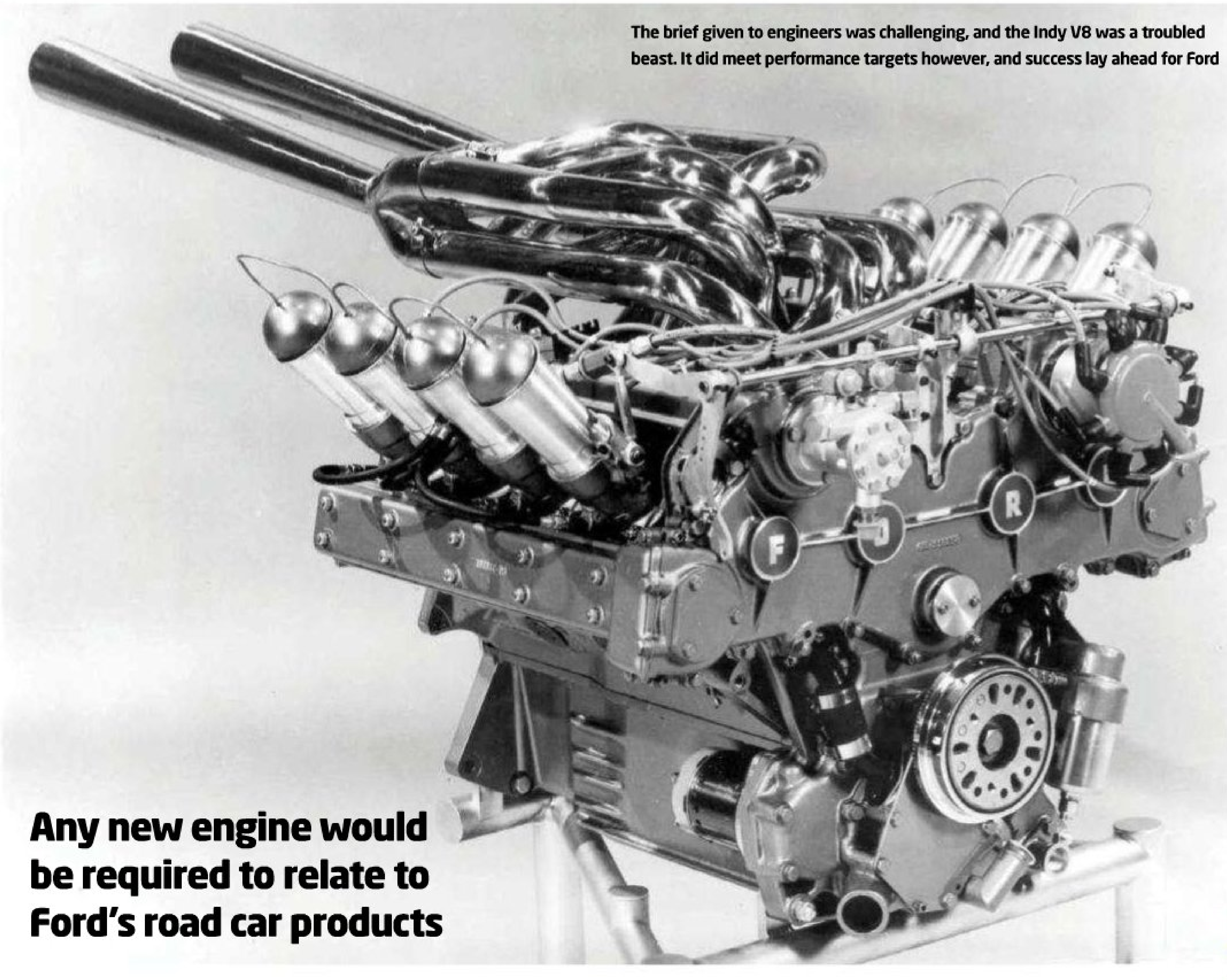
Ahead of the 1964 Indy 500, engineers had a gap to make up, which would call for a radical rethink under the hood…

BY LAWRENCE BUTCHER

Ask most people to name a twin cam Ford V8 built in the 1960s and they will say the DFV. But it's little remembered that the company's factory Indy engine came a few years earlier.

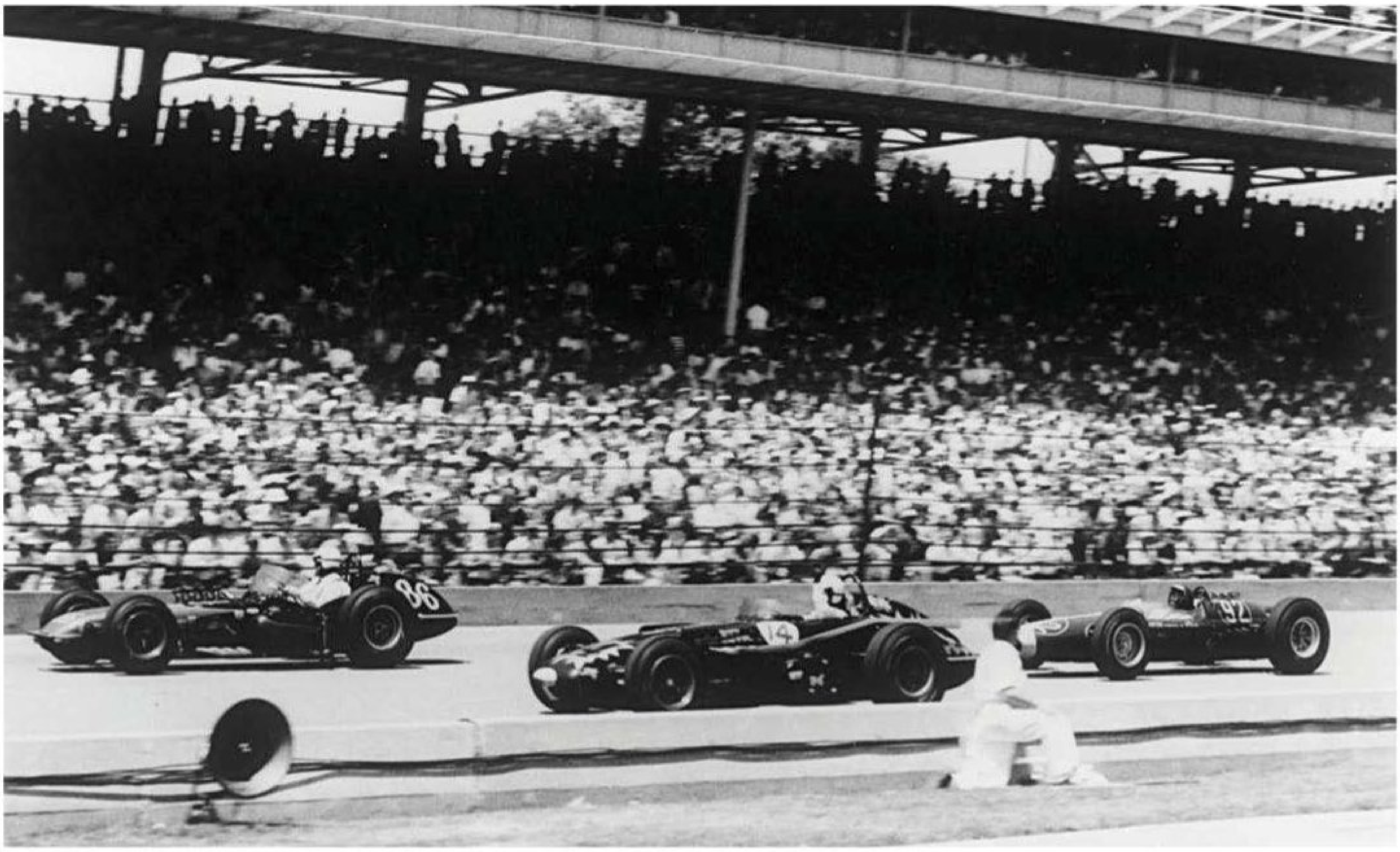
When one thinks of 1960s racing, the image that comes to mind is the garagiste operations such as Lotus and Cooper, with even Ferrari being far removed from what would today be considered a modern racing operation. However, when the Ford Motor Company decided to put its mind to building a new Indy engine, with it came the might of its R&D department. In 1963 a Ford-powered Lotus 29, driven by Jim Clark, came tantalisingly close to winning the Indianapolis 500, and was prevented from doing so only by the leading roadster of Parnelli Jones dropping oil on the track. The Lotus was running a development of Ford's Fairlane pushrod V8; drawing pump fuel through carburretors, it produced far less power than the competition's highly tuned Offys running on the more usual Indy brew of methanol. It was clear that the 375hp produced by the 255cu in V8 was not going to be competitive in 1964, regardless of the quality of chassis, so work began to create a new, twin cam unit based on the Fairlane block. This was not an acceptable situation for the Blue Oval, and the company embarked on a development program to take the venerable Fairlane engine to the next level. However; any new engine still had to relate to Ford's road car products – the fans had to be able to associate it with the motor under their hood. These performance and marketing requirements led to the team drawing up four key design criteria. Achieving these goals would be no small task and the engineers at Ford were presented with a challenging brief…

- Make the 1964 engine as competitive as possible in terms of horsepower at the minimum RPM.
- Keep total engine weight under 400lbs.
- Run on gasoline, not methanol, to maintain a stock car image.
- Retain carburretors or adopt an existing fuel injection system.



The brief given to engineers was challenging, and the Indy V8 was a troubled beast. It did meet performance targets however, and success lay ahead for Ford

Any new engine would be required to relate to Ford's road car products



The 1963 Indy 500 saw Ford power a Lotus 29. The engine produced 375bhp, woefully short of what was required for 1964 which saw huge development

The unit would be competing with engines from the legendary Offenhauser, and it was projected a power figure of 420-25hp would be required to keep up, an increase of 50hp over the 1963 engine's 375hp. Meanwhile, the weight could only increase by 40lbs over the 63's 360lbs.

To achieve this with a maximum engine capacity of 255 cui – the maximum permitted by the regulations – the engineers calculated that the engine must be capable of revving to 8000rpm. Though by modern standards, this doesn't seem particularly high, the manufacturing and material technology of the day made it a tall order to a pushrod V8. It was therefore decided very early on in the project that a double overhead camshaft arrangement would be called for, which was to become the primary design consideration. It is tricky to imagine in these days of incremental developments, stifled by regulation, that it would be possible to undertake such a monumental shift in design from one year to the next.

In1964, the days of 3D modelling were yet to be discovered, as were other useful computer aided design tools (though the Ford motor company did have significant computing resources even then). This meant that testing all had to be physical, so the Ford engineers embarked upon a programme to build a prototype engine. From this initial prototype the team could then determine which components were suitable for retention from the 1963 engine and, more importantly, validate the overhead camshaft system and ensure that the initial horsepower projections were actually met. Both dynamometer and vehicle testing of the first prototype confirmed that the aluminium cylinder block and the rotating components from the pushrod engine were up to handling the increased power output. It also showed that a pentroof cylinder head design would permit a peak of over 400hp at 8,000rpm, bang on target to compete against the Offys. The initial prototype also ran carburettors, 58mm Weber downdraught units, the same units as used on the pushrod engine the previous season. However, these were ultimately not deemed to be sufficient for the race version of the engine and were replaced with a Hilborn injection setup. This was a purely mechanical setup, but until 1964 it had only been used with methanol fuel, meaning that it needed to be modified to suit Ford's purposes. Beyond the basic mechanical modifications to accommodate the required flow rates, the injection system also saw extensive testing in the wind tunnel. These tests were undertaken with a running vehicle, to ensure that the system would not suffer from problems such as fuel vapour lock due to excessive temperatures. This is where the benefits of Ford's might really came to the fore, with the company's in-house testing facilities proving invaluable. Though originating as Hilborn equipment, the final system used on the Lotus 34 was extensively modified by Ford, not only to suit the fuel type, but also to improve the fuelling curves to provide smoother power delivery.

It was a monumental shift in design from one year to the next

Ford's engineering clout also appeared in the manufacturing practices used to construct the Indy motor. The combustion chamber shape devised by the engineers was impractical to machine using the equipment available, so a then cutting-edge technology was put to use: EDM, or Electrical Discharge Machining. At the time this technology was being investigated at Ford's Manufacturing Development Group and it proved ideal for the task at hand. The basic principle of the EDM method is simple: metal removal is achieved by an intermittent or pulsed high energy spark from a direct current source. The spark discharges from an electrode to the work piece in the presence of a dielectric solution which covers the piece. The metal is removed by the spark through melting and vaporisation of a minute volume of material at the point where the spark meets the dielectric/workpiece interface. Using this method, the engineers were able to produce the complex combustion chamber geometries far more

The 1965 Indianapolis 500 saw the Ford engine upgraded to run on methanol fuel for the first time, which produced more power and cooler engine temperatures, helping Jim Clark to win the event for Lotus having led 190 of the 200 laps

accurately than would be possible using traditional machining. Additionally, the process was quicker than milling, saving time on what was a very compressed development schedule.

One area of the engine's design that presented problems was the lubrication system. Initially, the design team carried over the existing dry sump system from the pushrod engine, consisting of single scavenge and pressure stage pumps, with the oil stored in a tank towards the front of the car. The first problem the designers ran into was providing sufficient oil to the cam lobes, which necessitated an increase in size for the pressure side of the pump. This, in turn, placed a greater demand on the scavenge stage, not only in terms of the volume of oil needed, but also as a consequence of the increased tendency for the oil to foam as it drained back from the camshafts.

To counter this, the scavenge stage was doubled in size while the pick-up pipe diameter was increased by 50 per cent. The result was a sufficient supply of oil to the bearings, in addition to adequate scavenging of the crank case.

MORE TROUBLES

Another problem the engine suffered from was excess oil being ejected from the breather system. The cause was identified as a combination of two issues: windage from the action of the crankshaft, combined with the large amount of throw-off from the reciprocating components caused by the large bearing clearances. It must be remembered that bearing and machining technology was not as advanced as it is today, and to ensure sufficient cooling and lubrication, race engines tended to run very generous clearances. To put this in perspective, modern race engines will run on multi-grade oils as thin as 0-40w, the Ford Indy twin cam ran on 50w mono-grade, after testing showed 30w accelerated wear to unacceptable levels. The oil system breather also needed to cope with the volume of air and gases being drawn from the sump by the scavenge pump. The problem of breathing was solved by simply increasing the diameter of the tank breather system to reduce the internal tank pressure. To increase the effectiveness of the system further, a second scavenge pump was subsequently added to the system, which also insured against failure of either pump. Overall, the changes made to the system sound very familiar to those one would undertake today in converting a road engine for race use.

Unfortunately for Ford, the 1964 Indianapolis 500 was not the success it was supposed to be. Lotus entered three Type 34s in the race, with Jim Clark taking pole and beating the existing lap speed record by 7mph, but come race time the cars ate their tyres and failed to finish. The engine, however, proved its worth and met its performance targets. For 1965, Lotus returned with the 38, a dedicated Indy car (the 34 was a modified F1 chassis), which it was hoped would prove much more durable. The chassis featured a revised monocoque of much stiffer and more substantial construction, and the engine was also more powerful. The biggest difference between the 64 and 65 engines was the decision by the team to switch to methanol fuel, which not only provided more power, but also allowed cooler running. While methanol engines need to run far richer than gasoline units to overcome the fuel's poor octane rating; however, its high heat of vaporisation results in considerable internal cooling of the engine. The result was a near 100hp increase in power with the evolution produce over 520hp at 8600rpm. With the new car, revised engine and the slickest pitstops on the grid courtesy of the legendary Wood Brothers pit crew – drafted in by Ford from NASCAR – history was made at the 1965 500. Clark led 190 of the 200 laps comfortably winning the race; from that point on no front engine car would ever win at the Brickyard again.

TECH SPEC

1964 Ford Indy V8 Specification
Type: 90-degree V8 DOHC
Bore: 3.76 in
Stroke: 2.87 in
Displacement: 255.3 cu in
Power output: 425bhp @ 8000rpm
Compression ratio: 12.5:1

Perfecting the spaceframe chassis

It's been written that the spaceframe chassis has been optimised. It hasn't, says one former Coventry University student

The hybrid spaceframe has a torsional rigidity of 4,450Nm, which is over four times greater than the steel spaceframe that it was designed to replace. There were negligible weight savings due to constraints on material dimensions, although the specific strength of a hybrid spaceframe is significantly higher

The tubular steel chassis is not fashionable any more. These days almost every young engineer wants to use advanced composite materials like carbon fibre to design their new car. They even turn their noses up at the use of a tubular chassis. They argue that steel chassis are heavy, lack rigidity and are not as safe as composite monocoques. Those in favour of the tubular steel chassis argue that the 'spaceframe' is cheap, easy to manufacture, easy to repair and highly versatile.

But one student at Coventry University in England wondered if it would be possible to get the best of both worlds. Replicating the thoughts of many low-cost formula car designers over the years, such as those behind the British-built Rossalini FV391 Formula Vee, could he replace at least some of the steel with readily available composite tubing?

Giorgio Demetriou took his university's 2012 Formula Student car design (a steel tube frame) and investigated converting the design into what he calls a hybrid spaceframe. The results are relevant to anyone designing or building cars in an open rules environment, such as Formula Ford, Vee or a number of SCCA classes.

'I aimed to develop a chassis which is competitive with composite monocoques used in Formula Student, but which could be manufactured for substantially less cost in a shorter timeframe,' explains Demetriou. 'I realised quickly that there were two key points to address: the use of tubular carbon fibre in spaceframe construction and the application of direct metal laser sintering as a manufacturing process to create connection nodes.'

One of the key points of the project was that Demetriou and the other Coventry students did not want to modify the existing design in any way, leaving the hard points and geometries as they were.

'Spaceframes have been used for many decades, and as a result much research and testing has gone into the optimised design. An ideal framework would consist of only struts and ties, pin jointed and loaded at the joints,' adds Demetriou. 'It could be argued that tubular chassis design has been completely optimised, and literature has been written to this effect. The design of a spaceframe chassis is unique to each vehicle and each will pose a new set of packaging constraints. A good spaceframe will receive loads directly into nodes and distribute these throughout the chassis, causing minimal distortion to any of the members.'

Table 1: carbon tube selection

Tube	Material	OD	Wall Thickness
Baseline 1	Steel	25.4mm	1.6mm
Baseline 2	Steel	25.4mm	1.25mm
Replacement 1	CFRP	28mm	1.84mm
Replacement 2	CFRP	26mm	1.56mm

EQUATIONS

$$Internal\ Surface\ Area\ (mm^2) = 32\pi\ x\ Length(mm)$$

$$External\ Surface\ Area\ (mm^2) = 36.8\pi\ x\ Length\ (mm)$$

$$\therefore Total\ Area\ (mm^2) = Internal\ Surface\ Area + External\ Surface\ Area$$

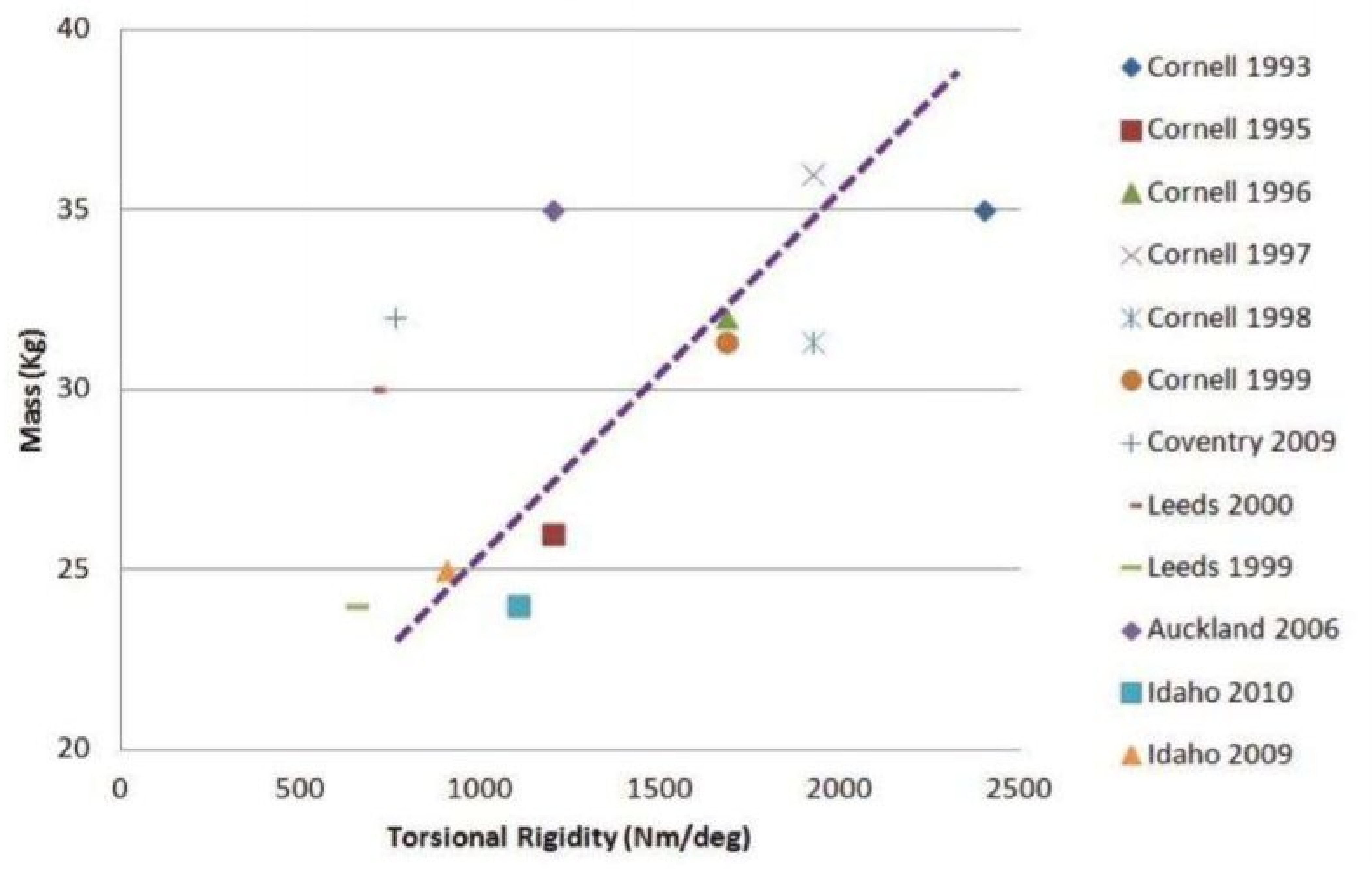
$$Adhesive\ Joint\ Shear\ Force = Total\ Area\ x\ Adhesive\ Shear\ Strength\ \left(\frac{N}{mm^2}\right)$$

The required Joint Shear Force was to be equal to the force required to take a baseline steel tube beyond its elastic limit. This force was calculated, using the below formula, as 18.8KN.

$$Cross\ Sectional\ Area\ (mm^2) = \pi r_o{}^2 - \pi r_i{}^2 = 62mm^2$$

$$Yield\ Force\ (N) = Yield\ Strength\ \left(\frac{N}{mm^2}\right)\ x\ Cross\ Sectional\ Area\ (mm^2)$$
$$= 18.8KN$$

Figure 1: FSAE chassic comparison



The ethos of the Coventry University 2012 FS Vehicle was 'lightweightness', which restricted the quantity of tubing that could be used to construct the chassis. There was a balance to be found between torsional rigidity and mass. Collected data for various Formula Student vehicles can be seen in **Figure 1** above, which shows mass vs rigidity.

Demetriou wondered if the same stiffness could be achieved for less mass by using off the shelf carbon fibre tubes, which are relatively low cost and readily available. He realised that he would have to overcome the metal-to-composite bonding challenge, and went on to investigate how the concept would impact the 2012 Coventry car.

The Carbon Fibre tubes were sponsored by Exel Composites UK and were to be from their Exelite range of high strength tubes. A spreadsheet was created which utilised macros to derive wall thickness. This allowed the outside diameter of a tube to be specified, due to compact packaging constraints, while the wall thickness was varied. The spreadsheet also had the ability to display the mass of each tube and thus derive the percentage weight saving between the two tubes. Savings for equivalent tubes were 68 and 75 per cent respectively. These savings, however, don't include the mass of a metallic node.

'Due to the sponsor only offering us a specific type of tube with 36.8mm OD and 32mm ID, we were a bit limited in the real world,' says Demetriou. 'This tube only provided a 46 and 45 per cent weight saving and was over-specified by a factor of 3-4 in terms of strength. The other major impact of the increased tube diameter was that the floor thickness would consequently change. That would have a big impact on the damper mounts on the Coventry car which are incorporated into the floor. With an increased diameter of the floor rails, it would not have been possible to use the same mounts or floor.'

STEEL OR COMPOSITE?

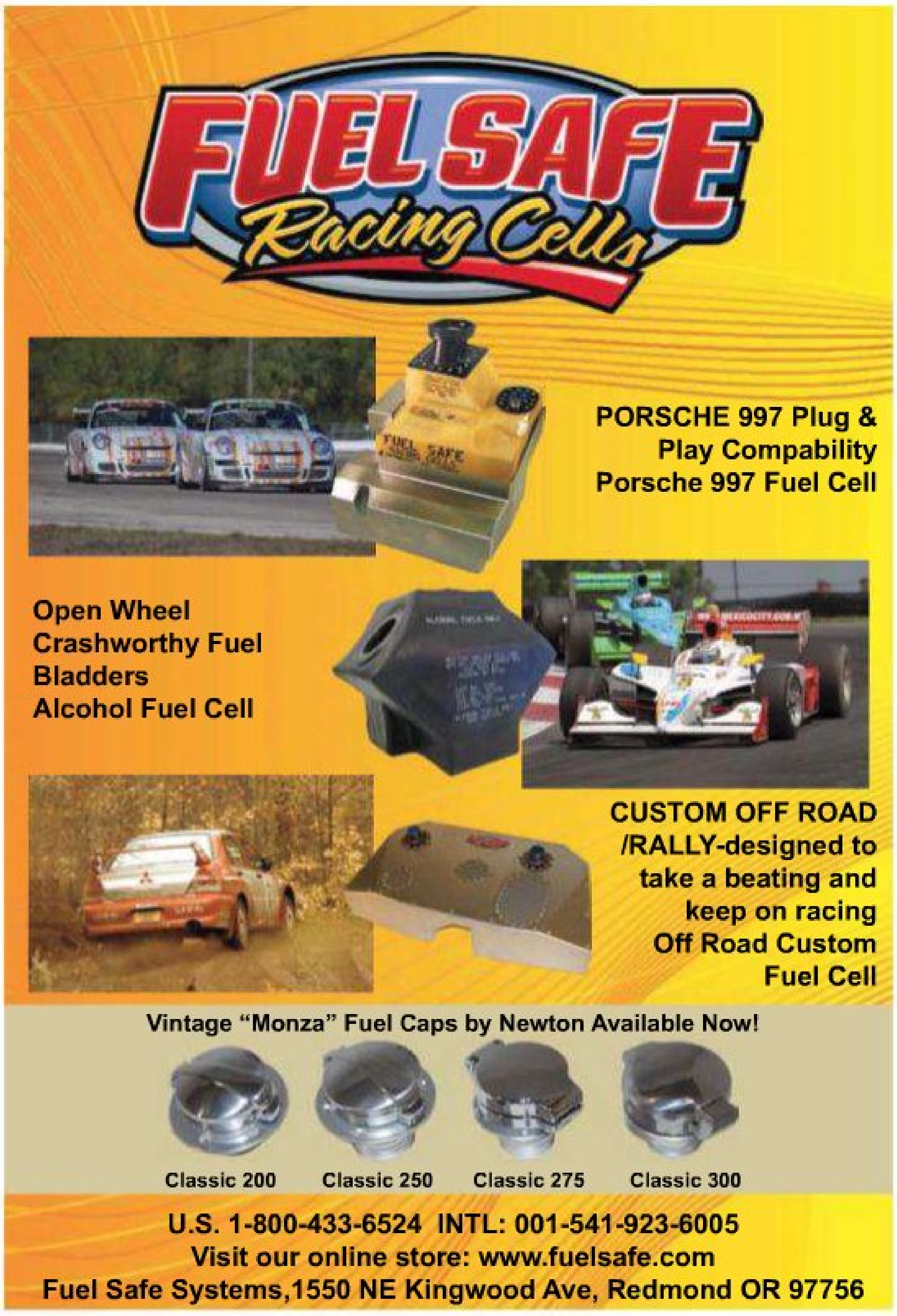
Despite this, Demetriou managed to complete the modified hybrid design, which can be seen (see **Table 1**, p61) showing that while some steel members could be replaced by composite tubes, not all of them could be. However, in many cases, this was due to the lack of choice in carbon tube availability to Coventry, and in reality would not be a major concern.

The bulkhead needed to remain in steel to accommodate the mandatory FSAE crashbox. The design of the Coventry crashbox was such that it required the anti-intrusion plate to be welded, around its perimeter, to the frame. With a carbon frame an alternative method of attaching the plate would be required.

As previously explained, any increase in the diameter of the tubing would not accommodate the existing hardware for the damper mounts. There would also have been an issue regarding ground clearance – the bottom of the spaceframe would be 11mm lower, plus the depth of a node causing the vehicle to ground out when experiencing heave or single-wheel bump.

The pull rod used for the front suspension operated along an arc, which avoided a clash with the diagonal member (at point four) by 2mm as full bump/

'A good spaceframe will receive loads directly into nodes and distribute them throughout the chassis with minimal distortion'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rebound. Increasing the diameter of the tube to 36.8mm would create a bending moment at the point of clash, causing the pull rod to catastrophically fail. In a similar fashion, both the lower and upper rear wishbones would foul on the rear bracing supports if the diameter of the tube was increased to beyond 26mm. The wider tubes also meant that the FSAE mandated cockpit template would not fit, so the cockpit surround remained in steel.

The next challenge was what to make the nodes out of and how to attach them to both the composites and the remaining steel chassis elements. Titanium has the greatest strength per unit of mass, although mechanical properties alone cannot be viewed in isolation when deciding node material. FSAE regulations state that: 'alternative tubing geometry and/or materials may be used except that the Main Roll Hoop and Main Roll Hoop Bracing must be made from steel, ie the use of aluminium or titanium tubing or composites for these components is prohibited.' This presented three possible methods of attaching a node to the Roll Hoops:

Adhesives
Mechanical Joint
Welding

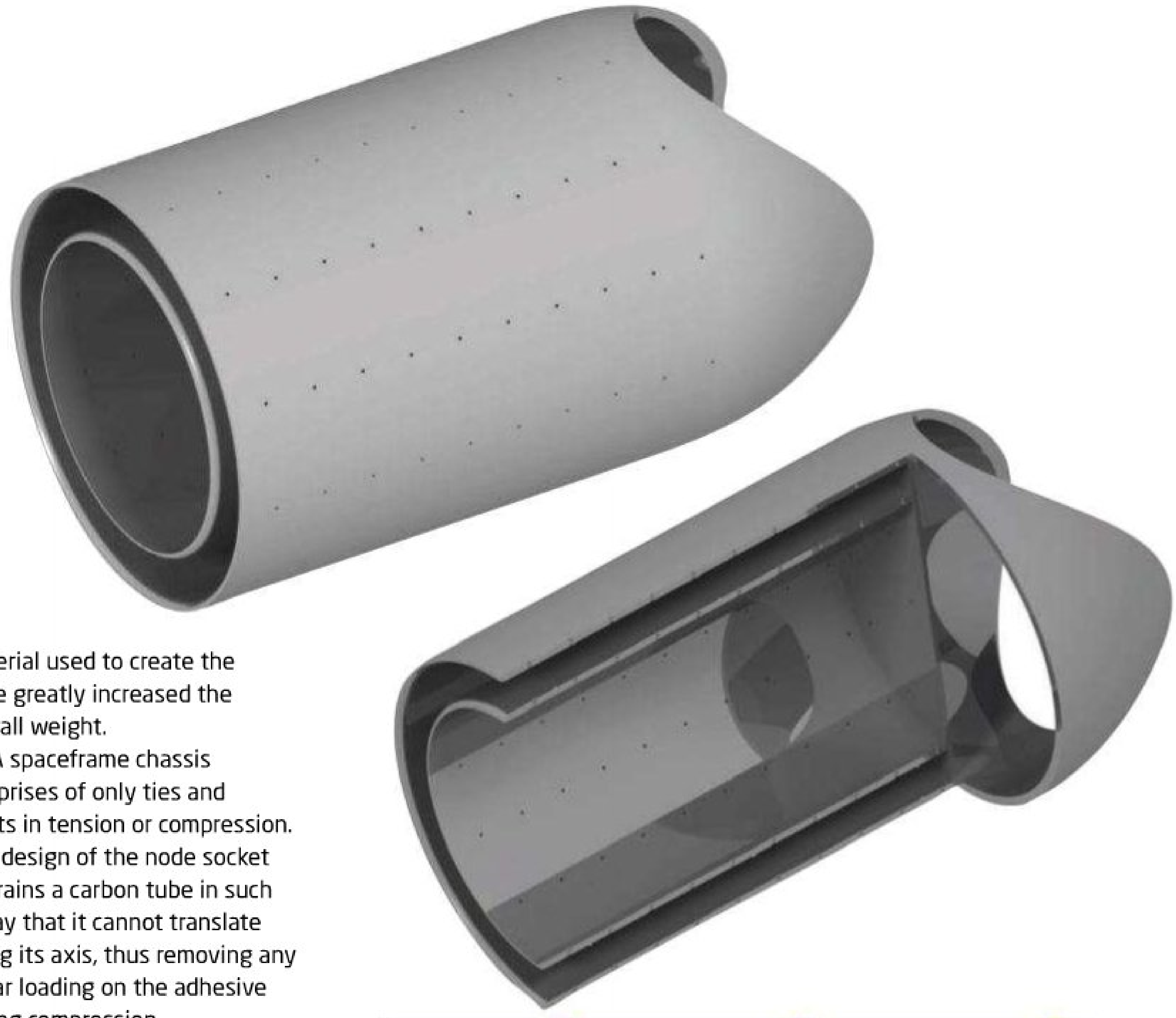
An adhesive connection was designed, although it was deemed to be too high risk. It was thought that welding steel and stainless steel would be the most reliable method of joining the nodes to the roll hoops. However there is up to a 35 per cent reduction in yield strength when welding steel. The temperatures required to rework (Post Welding Re-annealing) under 300degC would damage the carbon and adhesive, so this process could not be used. So eventually Demetriou decided that a mechanical joint would be the simplest method of attachment, although adhesives would replace any bolts. The addition of a bolt and the extra material used to create the node greatly increased the overall weight.

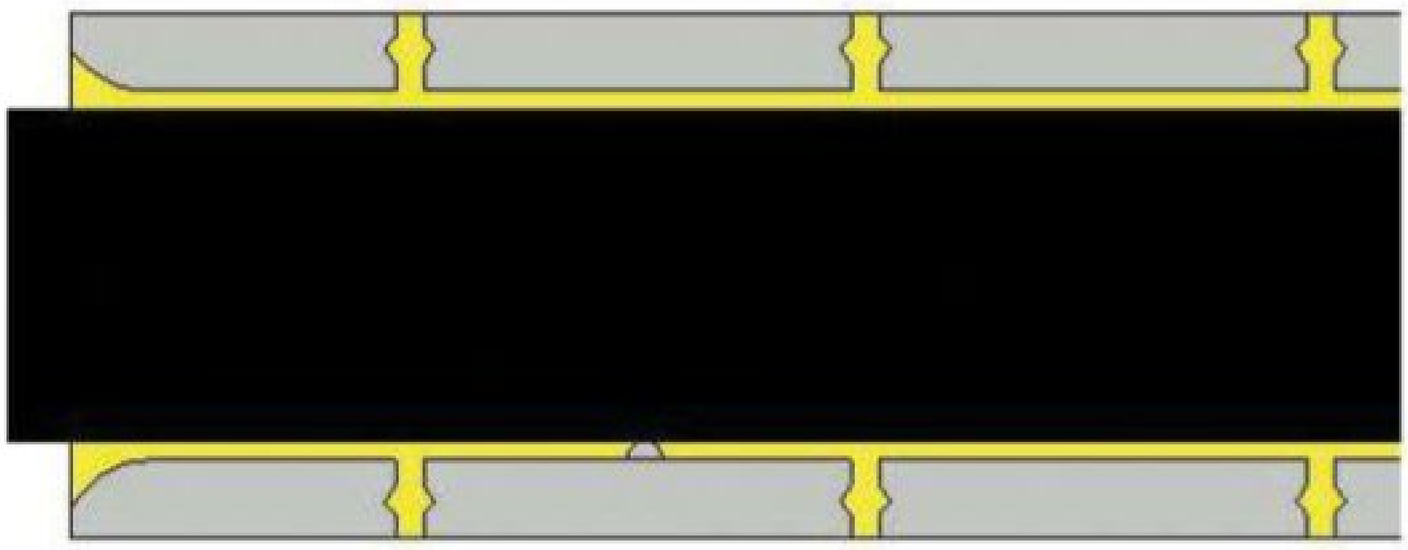
A spaceframe chassis comprises of only ties and struts in tension or compression. The design of the node socket restrains a carbon tube in such a way that it cannot translate along its axis, thus removing any shear loading on the adhesive during compression.

The tensile forces acting on a member are resisted by the adhesive; creating a shear stress. By using ALM (Additive Layer Manufacturing), it is possible to grow small arrow-shaped pins on to the surface of the metal part, which embedded into a carbon fibre part can provide a tough and durable joint.

The principle of incorporating mechanical 'pins' to reinforce a chemical joint in shear has been applied to the node ends. An alternative method of manufacturing a mechanical joint was creating cavities by allowing adhesive to flow through the substrate to form an adhesive pin, illustrated by the yellow region seen in the image above.

The ideal dimensions of the node end would be 0.5mm larger/smaller than the carbon tube, with the 'pip' keeping the tube concentric and controlling the bond gap. The dimensions of the socket were dictated by the internal and external diameters of the carbon tubes, and to compensate for any manufacturing errors in the tube, the size was made to accommodate a tube furthest from specification as per the manufacturers tolerances.





One of the key elements of the chassis concept was the adhesive joint, which utilised small holes in the nodes to form an adhesive pin (seen above in yellow). These were the actual reason for the project not seeing fruition. Formula Student judges did not feel that an adhesive joint could be visually inspected. Giorgio Demitriou argued that you could indeed visually inspect such a joint, and offered empirical test data, but the decision went against him

The length of the sockets would dictate the surface area of the node socket, thus defining the bonding surface area and the resultant joint strength. A spreadsheet was created which computed the minimum socket length required to produce the necessary bond area. The spreadsheet caters for different adhesives and baseline material dimensions and mechanical properties. This allowed retrospective changes to be made to calculations, should full-scale adhesive testing results vary from scale testing.

But as anyone who has put up a modern dome tent knows, arranging a set of composite tubes and nodes is not always straightforward. Indeed, with

'The temperatures required to rework steel would damage the carbon and adhesive, so this method of joining the nodes was rejected'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the Coventry design it was impossible. Demetriou found that it would not be possible to slide multiple tubes into position as each tube/socket aligned along a different axis. The solution that the team created was to fabricate the chassis in segments, which could then be welded together. Meanwhile, the steel segment of the spaceframe would only be tack-welded during assembly to allow for the some flex in the members, permitting the internal shapes of the nodes to locate on to the internal faces of the tubes.

Even once the manufacture and design of the hybrid spaceframe had been worked out, the question remained: could the composite tubes take the load? A failure in any of the tubes when the chassis was at speed would likely be catastrophic in more ways than one. Extensive simulation work conducted by the Coventry students suggested all would be fine, but it relied on a number of assumptions. 'With minimal data it was crucial to complete physical testing to characterise the material to refine the limited FEA and verify theoretical values,' admits Demetriou. 'The only provided value for the tubes was to have a stiffness of 100MPa, although an orientation was not specified.'

Unfortunately, a proposed partnership to manufacture the nodes between the Coventry team and a German firm fell through. This meant that the hybrid chassis was never completed, and the physical testing did not take place.

But the design results showed great promise. A key criteria used to measure the success of the project was total chassis mass. The most basic of hybrid members had a total mass of 0.502kg, almost half of the equivalent steel tube (0.920kg). But the overall chassis weight saving was insignificant. The total mass of the original steel spaceframe was 26.2kg, not including the floor or bulkhead. The hybrid spaceframe had a calculated mass of 25.1kg, not including the adhesives. This is a total weight saving of 1.1kg, or 4 per cent.

BULKY PACKAGING

'The relatively insignificant weight savings are due to the over-sized carbon tubes,' explains Demetriou. 'Although the tubes still had 50 per cent less mass than the steel tubes, the packing of a 36.8mm tube created much larger and bulkier nodes, compared to one which was designed to accommodate a thinner tube. The most pertinent conclusion to make from my work is that tubular carbon fibre can be used to manufacture a spaceframe chassis, and that nodes are a simple and effective method of joining composite members. The scope for a carbon spaceframe, outside of FSAE, is vast and the ability to start from a blank sheet with design, as opposed to producing a replacement for an existing spaceframe, further extends the scope. The strength and weight advantages of carbon tubing, compared to steel, are considerable and without the mandated use of steel for roll hoops, further weight savings can be made.

'Carbon tubes are available in an almost infinite array of sizes,' concludes Demetriou. 'There is no reason why the lessons learnt from this project cannot be extended to larger vehicles.'

Giorgio's thanks go to James Jarvis, Mark Ali Akbar, Stuart Jackson of EOS, and Mark Stewart of Dassault Systemes Ltd

LOAD TRANSFER AND ROLL STIFFNESS

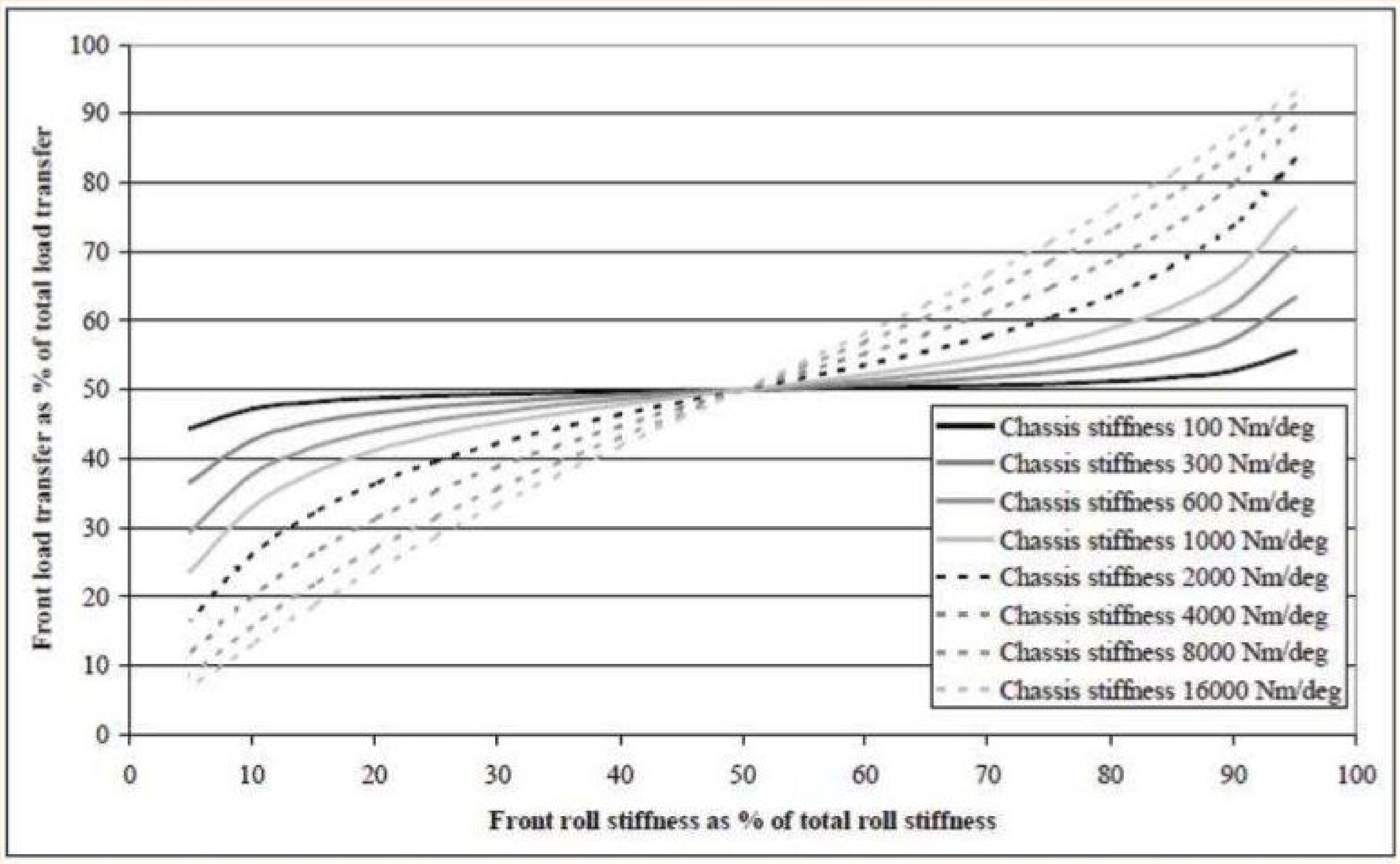
An investigation by The University of Leeds' School of Mechanical Engineering was able to determine the chassis stiffness that ensures the vehicle's handling is sufficiently sensitive to changes in the roll stiffness distribution. 'If a vehicle has a 50:50 weight distribution, with a 50 per cent roll stiffness distribution, it is the case that no load transfer is required,' they said. This is an idealised and unfeasible scenario, but serves as a useful example for the inverse. If an unbalanced vehicle has a large roll stiffness distribution, then the chassis is required to be capable of transferring large loads, achieved through high torsional rigidity.

The total roll stiffness – defined as 'the sum of front and rear roll stiffnesses' – can be viewed as a multiplier when selecting a chassis torsional rigidity. A vehicle is more sensitive to roll stiffness distribution and torsional rigidity as the total roll stiffness increases. The diagram below shows the results from a simulation by Deakin for a 50:50 weight distribution vehicle, with total roll stiffness of 15,000Nm using varying chassis stiffnesses.

It can be seen that if a 40:60 roll stiffness distribution was required, then a disproportionally large percentage change of roll stiffness is required to achieve the target when using the softer chassis. For example, to achieve a 40:60 distribution with a 300Nm/degree chassis, an 8:92 roll stiffness distribution is needed. The weakest chassis (100Nm/deg) was not able to transfer the required load.

The above figure shows that with significantly lower roll stiffness, the chassis which have a lower stiffness are still responsive to changes in roll stiffness distribution. All but the weakest of chassis (100Nm/Deg) was able to provide the required load transfer with all above 600Nm/Deg having an almost linear relationship.

The most crucial value used to decide the stiffness of a chassis is total roll stiffness as the non-linear relationship between roll stiffness distribution and load transfer worsens with higher roll stiffnesses. The nature of Formula Student creates lightweight vehicles which tend to have roll stiffnesses below 700Nm/Deg. Given that FSAE regulations insist on many safety tubes of given dimension, it is not physically possible to create a chassis which will be unresponsive to changes in roll stiffness distribution, for example below 300Nm/Deg.



Manual mathematics

The lack of bread-and-butter skills in graduates is a worry. Here's why...

Over the last couple of months I've been recruiting staff for ChassisSim. I've been recruiting from final year undergraduates to early postgrads. I've also been keeping a close eye on various forums such as those on the FSAE website. While the enthusiasm of these engineering students is beyond question, I have become increasingly concerned about the lack of basic skills on display. In particular I'm alarmed at the inability of many of these senior undergrads and recent postgrads to perform basic hand calculations.

BY DANNY NOWLAN

If you're in any way serious about engineering, the ability to do these straightforward calculations by hand is an absolute must. This means working something out without a computer, and it can be your ultimate fact filter as well as an invaluable sanity check when you're concerned about something a computer has told you. This skill has saved my neck on more occasions than I care to remember. The great Kelly Johnson, arguably one of the greatest aeronautical engineers who ever lived, had a freakish ability to look at an aero surface and tell you what the pressure distribution, CL and CD was to within about 10 per cent. It's little wonder he was able to lead teams that could pull off projects such as the U2 and the SR-71 Blackbird. So if you want to get ahead in the business, listen up.

FIRST THING'S FIRST

To begin with we'll consider how to calculate an RPM limit given a gear ratio and a required pitlane speed limit. I actually had to teach this to a bunch of undergrad students at a V8 Supercar support series race. Let's walk through the parameters they had and what they had to work out...

The first bit in this process is to figure out the rotational speed of the tyre. Once we know this, figuring out the RPM of the tyre is easy. To go from there to get the engine speed, we multiply it by the gear ratio to get the engine RPM. See **Equation 1** over the page to see these numbers crunched.

So, we need to set the RPM limit to 3010rpm in the pitlane limiter section of the engine management software. My apologies to the advanced reader if this is a bit long-winded –

EQUATIONS

Equation 1

$$V_T = r_t \cdot \omega$$

$$\omega = \frac{V_T}{r_t} = \frac{40/3.6}{0.325} = 34.18 rad/s$$

$$\omega = 2 \cdot \pi \cdot f_{WHEEL}$$

$$f_{WHEEL} = \frac{\omega}{2 \cdot \pi} = \frac{34.18}{2 \cdot \pi} = 5.44 Hz$$

$$RPM_{WHEEL} = 60 \cdot f_{WHEEL} = 5.44 \cdot 60 = 326.47$$

$$RPM_{ENG} = GR \cdot RPM_{WHEEL} = 3010 RPM$$

Equation 2

$$FtDownforce = MR_f \cdot k_f \cdot (FL\_Damp + FR\_Damp) = 0.9 * 140.1 * (10 + 10) = 2521.8N$$

$$RrDownforce = MR_r \cdot k_r \cdot (RL\_Damp + RR\_Damp) = 0.8 * 140.1 * (15 + 15) = 3362.4N$$

$$C_L A = \frac{FtDownforce + RrDownforce}{0.5 * 1.225 * (220/3.6)^2} = 2.57$$

$$AeroBal = 100 \cdot \left(\frac{FtDownforce + \frac{mt \cdot g \cdot a_x \cdot h}{wb}}{FtDownforce + RrDownforce} \right) = 100 \cdot \left(\frac{2521.8 + \frac{500 \cdot 9.8 \cdot 0 \cdot 0.3}{2.6}}{2521.8 + 3362.4} \right) = 42.9\%$$

$$C_D A = \frac{gr * T / r_t - m_t \cdot g \cdot a_x}{0.5 * 1.225 * (220/3.6)^2} = \frac{3 * 200/0.28 - 550 \cdot 9.8 \cdot 0}{0.5 * 1.225 * (220/3.6)^2}$$

Equation 3

$$L_{MF} = \frac{wdf}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2} \rho V^2 C_L A\right) + \frac{RLD_f \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

$$L_{MR} = \frac{(1 - wdf)}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2} \rho V^2 C_L A\right) + \frac{(1 - RLD_f) \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

Equation 4

$$F_{\max} = k_a \cdot (1 - k_b \cdot L) L$$

$$k_b = \frac{1}{2 \cdot L_{MAX}}$$

Equation 5

$$wdf \cdot m_t \cdot a_y \cdot g = k_a \left((1 - k_b \cdot L_{out}) L_{out} + (1 - k_b \cdot L_{in}) L_{in} \right)$$

$$L_{OUT} = \frac{wdf}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2} \rho V^2 C_L A\right) + \frac{RLD_f \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

$$L_{IN} = \frac{wdf}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2} \rho V^2 C_L A\right) - \frac{RLD_f \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

Equation 6

$$(1 - wdf) \cdot m_t \cdot a_y \cdot g = k_a \left((1 - k_b \cdot L_{out}) L_{out} + (1 - k_b \cdot L_{in}) L_{in} \right)$$

$$L_{OUT} = \frac{(1 - wdf)}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2} \rho V^2 C_L A\right) + \frac{(1 - RLD_f) \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

$$L_{IN} = \frac{(1 - wdf)}{2} \cdot \left(m_t \cdot g + \tfrac{1}{2} \rho V^2 C_L A\right) - \frac{(1 - RLD_f) \cdot m_t \cdot a_y \cdot g \cdot h}{tm}$$

Table 1: parameters for pitlane speed limit

Parameter	Value
Gear ratio (Eng speed/wheel speed)	9.2206
Rolling tyre radius	0.325m
Desired pit lane speed limit	40 km/h
RPM	?

Table 2: sample values for an aero hand calculation

Item	Quantity
Front Motion Ratio	0.9
Rear Motion Ratio	0.8
FL Damper/FR Damper	10mm/10mm
RL Damper/RR Damper	15mm/15mm
Front spring	140.1 N/mm (800 lbf/in)
Front spring	140.1 N/mm (800 lbf/in)
Torque at RPM	200 Nm
Rolling tyre radius	0.28m
ax	0g
Vx	220km/h
Gear ratio value	3
mt	500kg
h	0.3m
wb	2.6m

as they'll know only too well, what we've done here is incredibly straightforward.

The next thing I want to talk about is calculating downforce, drag and aero balance. I know, I know – I've repeated this example on a number of occasions, but it remains really quite shocking the number of people who refuse to do it or simply don't know how. As a result, I'll doggedly continue to repeat this example until I see a marked improvement on people in the greater race engineering community doing this.

To kick things off let's talk about zeroing conventions. The best procedure to do this is to look at the data and zero the dampers on the ground, or apply an offset as they are

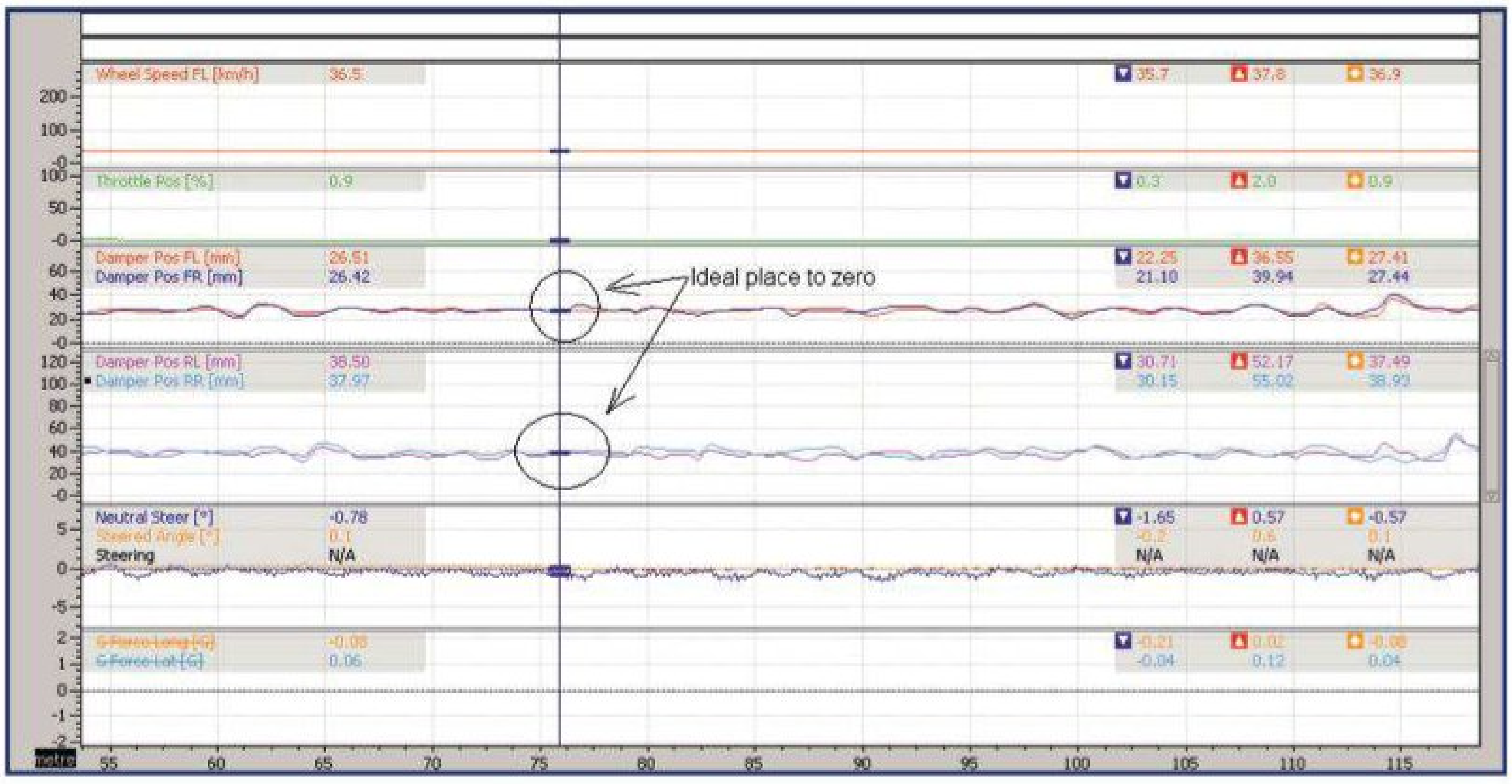


Figure 1: ideal place to zero

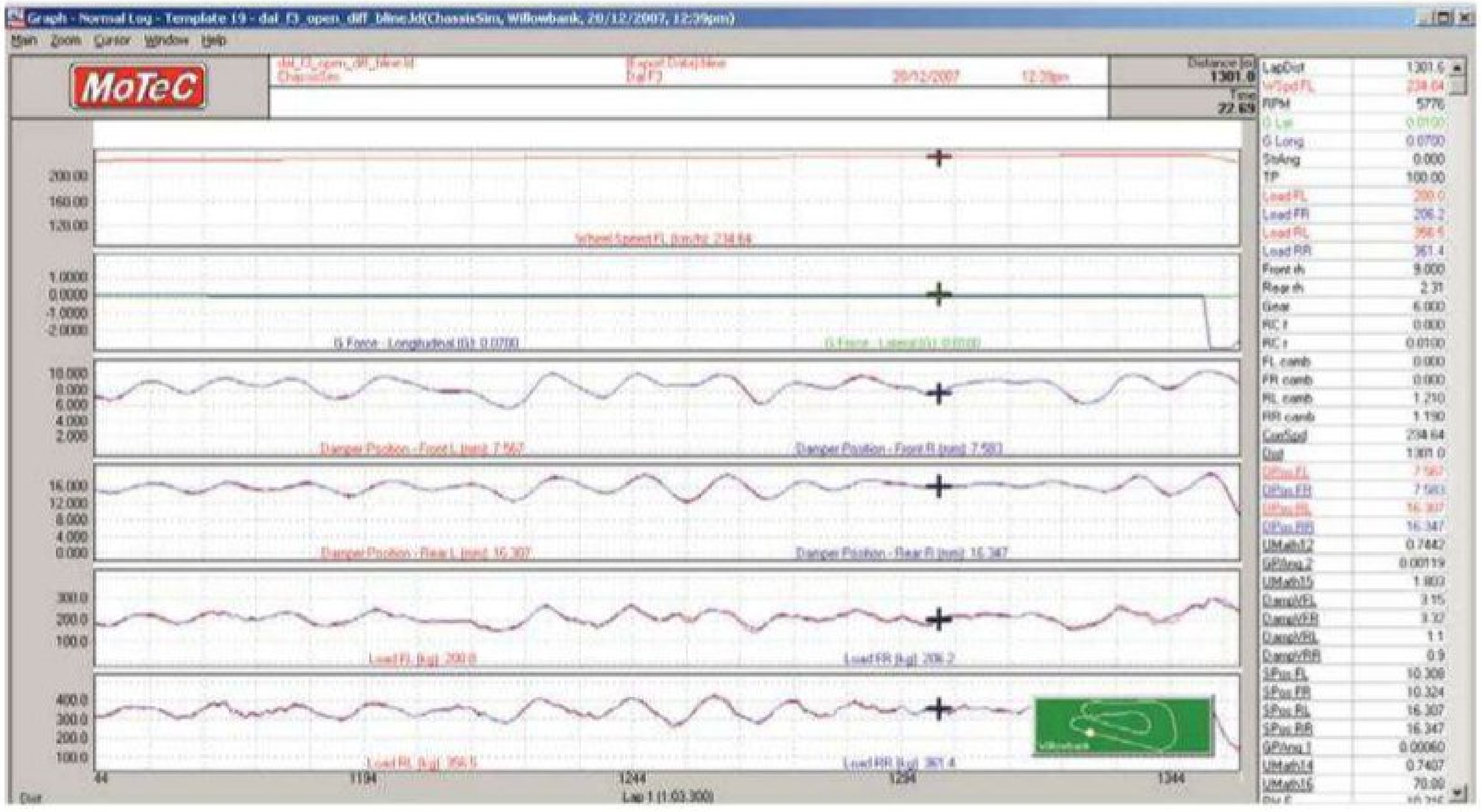


Figure 2: where to take hand calculation for aero from

Table 3: typical GT car parameters

Item	Value
Total Mass (mt)	1330 kg
CLA	2.4
Front weight distribution (wdf)	0.43 (43% on front axle)
Max ay	2.4g
Max speed at Max ay	220 km/h
Roll Distribution at front	0.5
Mean track (tm)	1.65m
Centre of gravity height	0.335m
Air Density (p)	1.225 kg/m3

coming out of the pits. A very good procedure to do this is illustrated in **Figure 1.**

As can be seen in the above example, the dampers are level and this will give us a very good measure of the zero condition.

The next step in the process is to identify where to perform the aero calculation. The best place to take the numbers for this calculation is either the fastest point in the circuit or the longest straight. The thing that takes priority is the car going in a straight line with minimum lateral acceleration. The point to take it from is shown in **Figure 2.**

Also, it is wise to filter the data as well. I like to take a low pass frequency filter of, say, 1Hz. That being said I still like looking at the raw data because it gives me an idea of what the car is doing. Once these points have been established, the next point is to calculate the downforce. The best way to illustrate this is by example consider a Formula 3 car – see **Table 2.**

Here all motion ratios are damper on wheel, the gear ratio is engine/wheel velocity, and for simplicity I've omitted bump rubbers. Crunching the numbers we see **Equation 2.**

As I hope you're starting to see, what we are essentially talking about here is some pretty straightforward high-school level maths that will tell you so much about what the car is doing. What we have discussed here is what I

Table 4: Max Tyre Loads

Tyre Load	Value
Front	8590 N
Rear	10052 N

would expect from a junior data/assistant race engineer. If you can't learn how to do this, other professions beckon.

The last example I'd like to discuss is techniques to estimate initial traction circle radius. Some people will tell you that this is far too complicated and should be handled by professionals. Well that's a complete myth – see for yourself how straightforward it can be.

Let's consider cars for a typical GT class sportscar. The particulars for this particular car are shown in **Table 3...**

KEEPING IT SIMPLE

For clarity's seek let me refer to the roll distribution at the front as RLDf. To simplify this slightly I'm going to assume two things: firstly the aero distribution will be the same as the weight distribution. This is rarely the case, but I'm keep to keep the discussion simple. I'm also going to assume a symmetric setup. When we walk through the methodology it will be pretty clear how we can extend this approach for the asymmetric case. It's also a wise approach to slightly overestimate your maximum lateral acceleration and the speed this occurs at. It just gives you a bit more flexibility. Also g is acceleration due to gravity, which is 9.8m/s^2.

The first point of this discussion is to estimate the maximum tyre loads. This will be given by **Equation 3.**

Saving the reader the arithmetic, our max loads are 7157.7 N at the front and 8376.8 N at the rear. As a further factor of safety I'm going to multiply these loads by 20 per cent. This is going to cover us if we decide to go really crazy with downforce. Consequently our final tyre load estimation will be as **Table 4.**

To get us going for the max tyre force curve I'm going to assume a function of load only. The function we're going to fit is the following – **Equation 4 –** where L is the load of the tyre in N and F_{max} represents the traction circle ellipse in N. This curve is a simple parabolic fit to ensure we get max tyre force at the specified peak load and k_a represents the initial coefficient of friction with no load applied to the tyre. Going on from our values in **Table 3,** the k_b values for our tyre model are:

k_b	Value
Front	5.82×10^{-5}
Rear	4.97×10^{-5}

Now we have this we can now estimate the k_a values. By using **Equation 4** and applying a force equilibrium for the front axle it can be seen that – **Equation 5.**

Similarly for the rear, see **Equation 6.**

Doing the arithmetic and solving for k_a it is seen that:

k_a	Value
Front	2.72
Rear	2.56

What we have just done is that by using some basic equations and working for the arithmetic, we have come up with an initial estimate of a tyre model. While this is by no means perfect, you can see by using hand calcs that we've begun to inform ourselves with a great deal of data about what these tyres are potentially capable of. Also for the interested readers, please don't take the numbers here I've presented at face value. Use Table 3 and work through Equations 3-6 and prove the results to yourselves. It's really not that hard – you just have to pop the numbers in and it should be pretty obvious where this all goes.

The case studies we have discussed are all well and good, but what happens when you get something that's a bit out of the ordinary? Believe it or not, it's not as hard as you might think. The road map was given to me by my high-school physics teacher, Phil Bailey, a very long time ago. It's as simple as this:

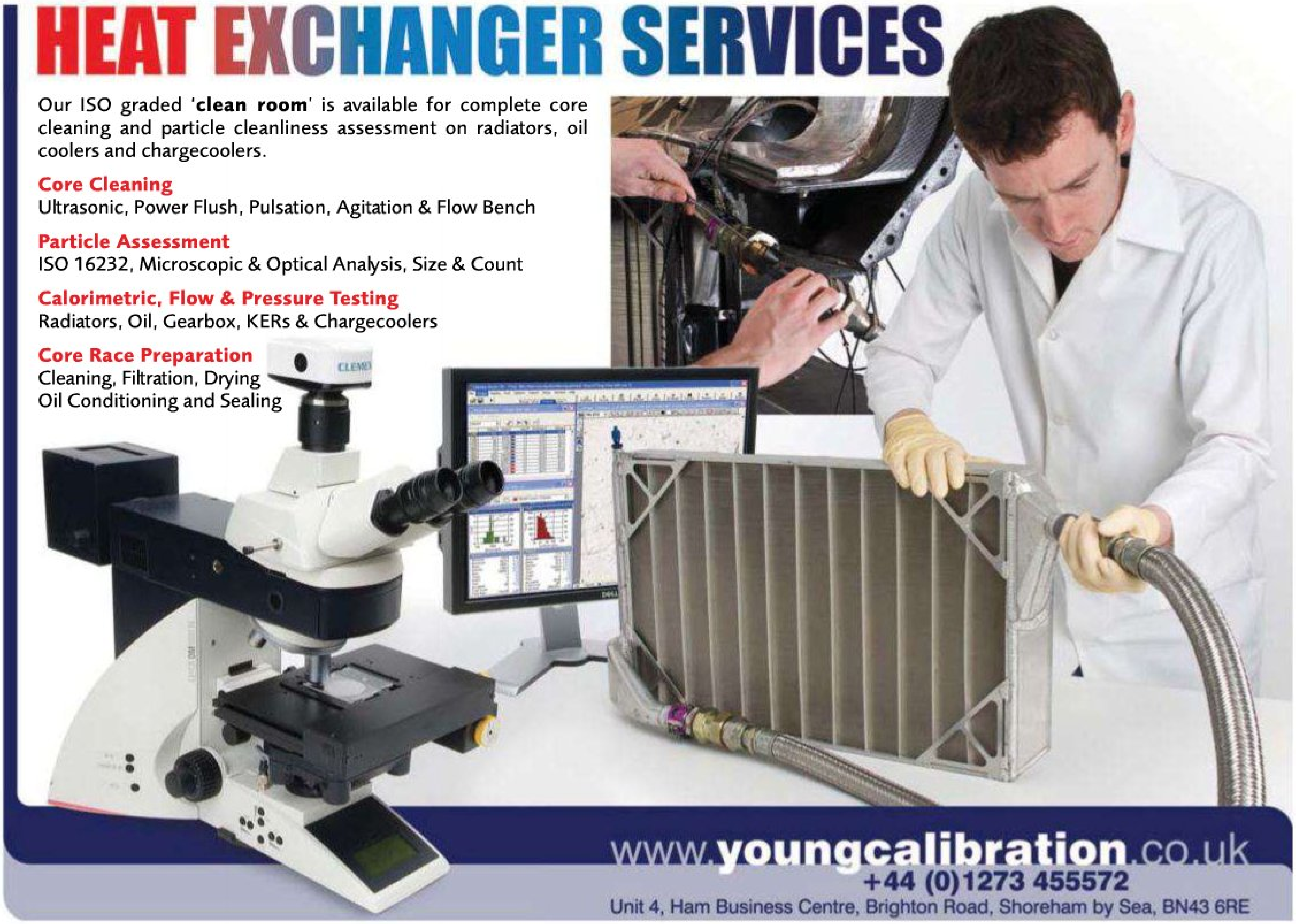
1. **State all the known variables**
2. **State the unknown variables**
3. **Sit back and think what class of problem this is**
4. **Write out the equation**
5. **Solve the equation and state the answer clearly**

Hand calcs won't tell you the whole story, but they force you to think about the problem

This problem-solving technique serves as the backbone of everything I do, and is one of the most valuable lessons I have ever learnt. Mr Bailey also taught me two other things as well: firstly memorise all the kinematic equations of motion, and secondly, work everything in SI units. He taught me this when I was an impressionable 16-year-old boy and so I did what I was told. This has served me well many years later and if you're a student reading this I would strongly suggest you do the same.

IN CONCLUSION

Summing up, as we have seen here, doing hand calculations provides some very valuable insights into what the racecar is doing. While hand calculations don't tell you the complete story, they force you to think about the problem and you learn an awful lot in the process. They also make your time on the computer far more valuable because once you have done your basic sums you start to develop an instinct about what to expect when you do your CFD and FEA. This helps to build up your skills to the point where they become instincts, and give you that edge you need to make quick decisions that can win or lose a race. This is why hand calculations are a must-have skill for any serious race engineer.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Declassified information

The DeltaWing had an eventful second race at the Petit Le Mans in Atlanta. Next year, it will be formally accepted into the American Le Mans Series

BY ANDREW COTTON

The calls at Road Atlanta for a 500kg, 300bhp category in the American Le Mans Series, or indeed at Le Mans, were deafening following the debut of the DeltaWing on US soil in Atlanta. It is hardly surprising – Porsche's 997 GT3 Hybrid attracted similar calls, but there was little doubt that the DeltaWing has touched a nerve with the tech-savvy crowds.

There were still those in the press room who wondered how the other drivers would cope with the unusual light clusters at night, and predicted accidents. There were those who, rightly, pointed to the design as a contributory factor in driver Gunnar Jeannette's roll on Wednesday evening. One of those was Ben Bowlby, who designed the car. Yet the momentum is building behind the DeltaWing, and the car will next year be recognised in qualifying and in the race. At Road Atlanta, the car qualified in the top half of the field, and finished sixth overall.

It is interesting to note that, while discussing the 2014 regulations, both Audi and Aston Martin pushed for a 700kg weight limit for non-Hybrid LMP1, although according to Peugeot – which was also involved in the negotiations at the time – it was Audi that finally voted against the limit. The limits are set at 850kg for hybrids and 830kg for non-hybrids run by privateers.

'Essentially the car is almost untouched [since Le Mans],' said Bowlby. 'We did bring an updated front upright, increased the caster to 12 degrees which was its original design spec, but the steering was so heavy that we had to back it out to 8 degrees, but that messed up the geometry and everything was pissed.

'We now have a nice clean upright with an offset caster to reduce the trail, and a longer steering arm. The only other thing was that we updated the right rear hub to change the bearing nut handing, because it was tending to undo itself. We had it symmetrical, like the wheel nuts themselves.'

EXPERIMENTIA

The car raced at Road Atlanta still missing the torque steer system as the team didn't have time to design or build new parts following the decision not to race with the system at Le Mans following a failure in testing.

'We had tested the torque vectoring, but we blew up the bits that we ran, so didn't have any left over,' says Bowlby. 'We are still running the Michelin tyres that we ran at Le Mans. The fundamental aero package is the same although we took away the DRS and put a fixed Gurney on the back, mostly because around here we don't want to be messing around with DRS. We extended the vortex generators, which is a real piece of hairy-arsed engineering. We whopped it on, looked at the data, and saw about two per cent shift forwards, which allowed us to run a taller wicker at the back. That gives us a bit of range at the back if we need it. It's not like we have a lot of races under our belt and just know what to do.

'We have a car that is, from a driver's perspective, as we expected, superb aerodynamics, and an excellent braking system now that we have worked out how to get air out of the brakes. That was the saga of our lives. It was Friday before the race at Le Mans when we thought we should just change the reservoir position. We were sucking air through the reservoir into the braking system. So basic, they were standard parts.'

"There is probably a more refined and reliable car inside this one"

A new front suspension layout, some 'hairy arsed engineering' with vortex generators, and a larger wicker at the rear were all updates introduced at the Petit Le Mans, Road Atlanta, in October

THE CRASH

It was daylight and dry when American driver Gunnar Jeannette exited turn 10b in the DeltaWing and ascended the hill towards the pits. Ahead, Peter LeSaffre in the Green Hornet Porsche GTC car encountered power oversteer and as he turned to correct, the DeltaWing was already alongside and the rear wheel clipped the trailing edge of the Porsche's exposed front. The car rode up, and rolled down the hill, hitting the wall backwards before righting itself.

'No question, the design of the car contributed to the response from the impact,' says Bowlby. 'It was a perfect storm. The leading edge of our left rear contacted the trailing edge of the Porsche's right front. The impact was 4.5g, which was a big spike. We climbed, and because we don't have an opposing diagonal wheel, there is a propensity to do what it did. That is not unexpected.

'What was pleasing was that the car never left contact with the road, even though the Porsche was underneath it and pushing it for quite a while, it couldn't come back down, and didn't go into any vertical instability which was bloody lucky because you're coming under the bridge at -0.5g. We also didn't spin through 180 degrees and shoot down the hill backwards, which would have caused a potential problem, but we did have our flaps, which did deploy when going backwards. His head didn't touch the ground, peak force was 8g so it didn't really get subjected to a high load. There was scratching on the tub, but that was it. Essentially we could put the car back together. It is easy to say "what if...?", but in reality the car didn't fly, didn't land on a wall and didn't hit the bridge. It did get inverted, but that is a Highcroft tradition here apparently.'

THE FUTURE

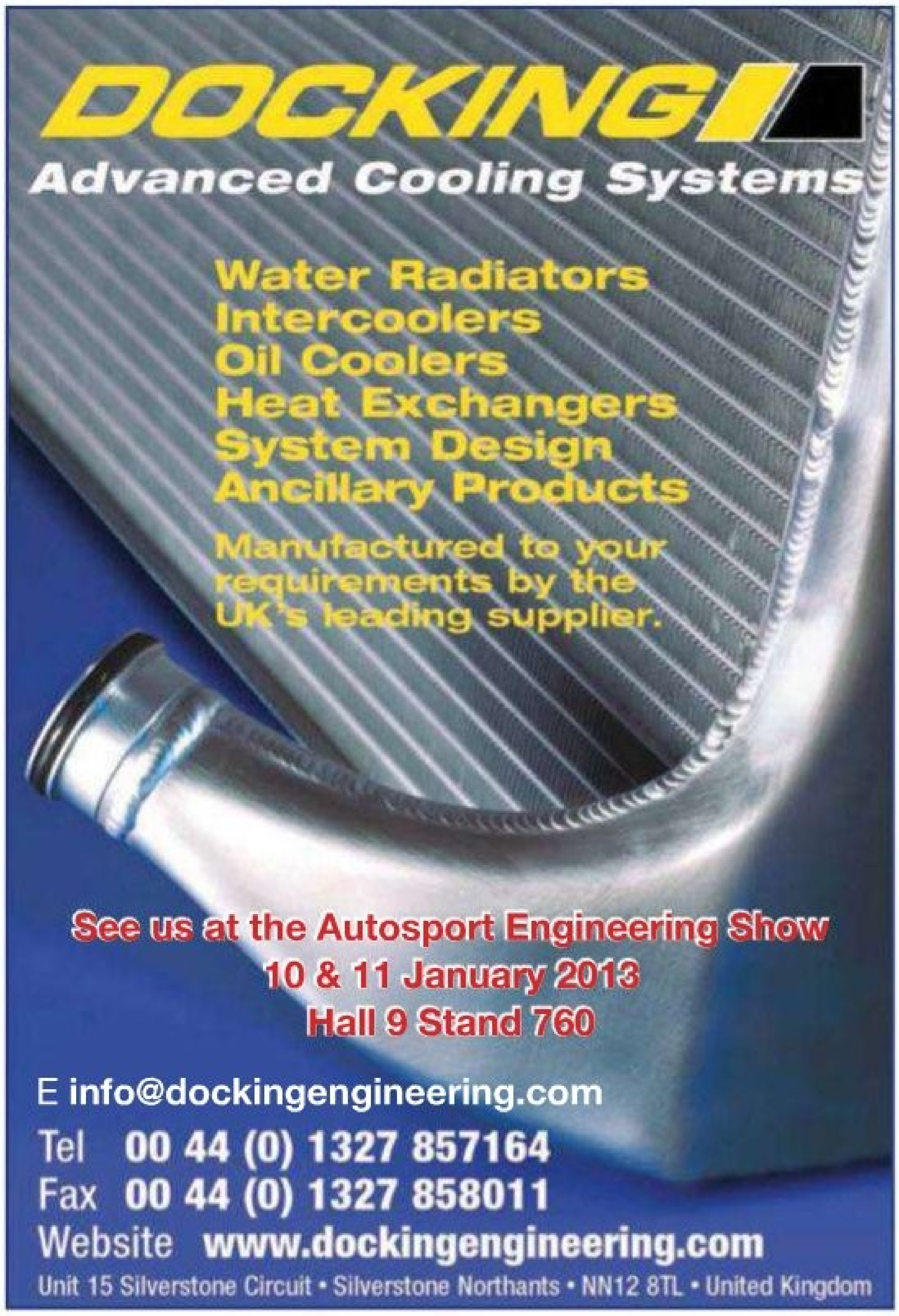
'What we did in the time [ahead of Le Mans] was the first car, there wasn't a lot of resource and there are lots of things that we look at and say "If we had another go at that, we could make it really nice." There is probably a much nicer, more refined and reliable DeltaWing inside this one. How is that going to happen? I don't know. Now, there is somewhere to race it, and that makes the viability better.'

In order to build the car in time for the 2012 Le Mans 24 hours, and at the request of the ACO, coupled with the sudden and unexpected closure of the Aston Martin Le Mans project, the DeltaWing project took on the Aston Martin AMR-One tub, and was forced to make compromises.

'I would like a tub that suits the car because we threw away 20-30 per cent of downforce,' says Bowlby. 'When we dumped the tub into the shape we had it hurt us. It is too wide and too far back, and it would be nice to sort that out. Just the shape of the tub, where it meets the engine, we could sort out. There are two hard corners that completely change the shape of the underbody. We might do some re-enforcement, so more anti-interlock. It is an excellent tub, it isn't at all heavy, I doubt that we could make it lighter than that, we would just be more appropriate and we would save weight in the junction into the nosebox.'

With the decision taken that the car can compete in the ALMS, the chance to make customer cars – and fit them with other engines – is a real possibility. Although Nissan has produced an engine for the car and benefitted from the project with its association, the car is capable of taking multiple Global Race Engine configurations, and Bowlby is keen to see that happen. Don Panoz, founder of the ALMS and Panoz cars, is known to want to create customer chassis for his series, although with the uncertainty regarding the future direction of American endurance racing, it may not be viable.

'The more you make, the less money it costs,' concludes Bowlby I completely don't know the plans or the partnership, but I believe that Don is keen to sell cars.' So, DeltaWing may have chassis for sale in 2014.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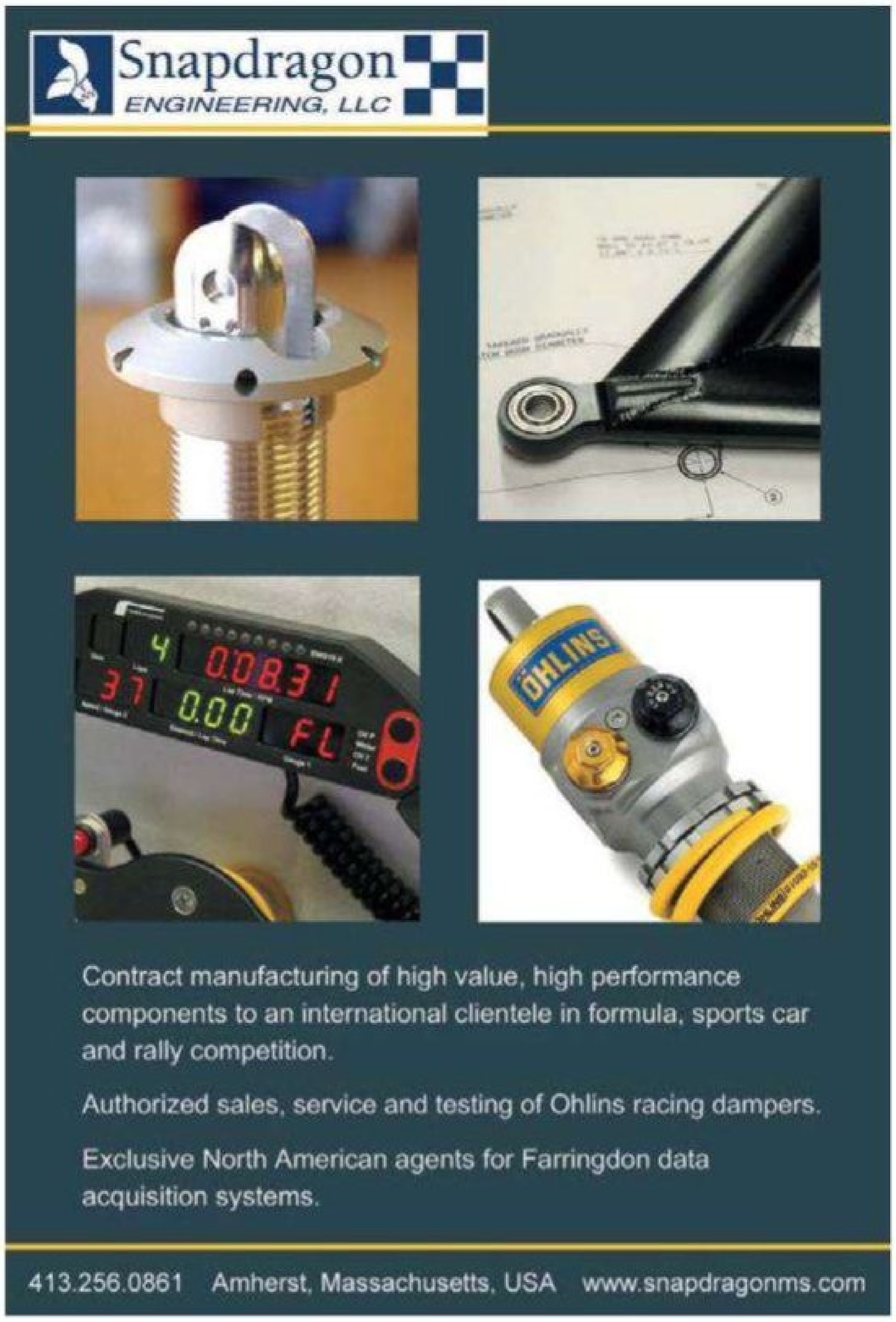
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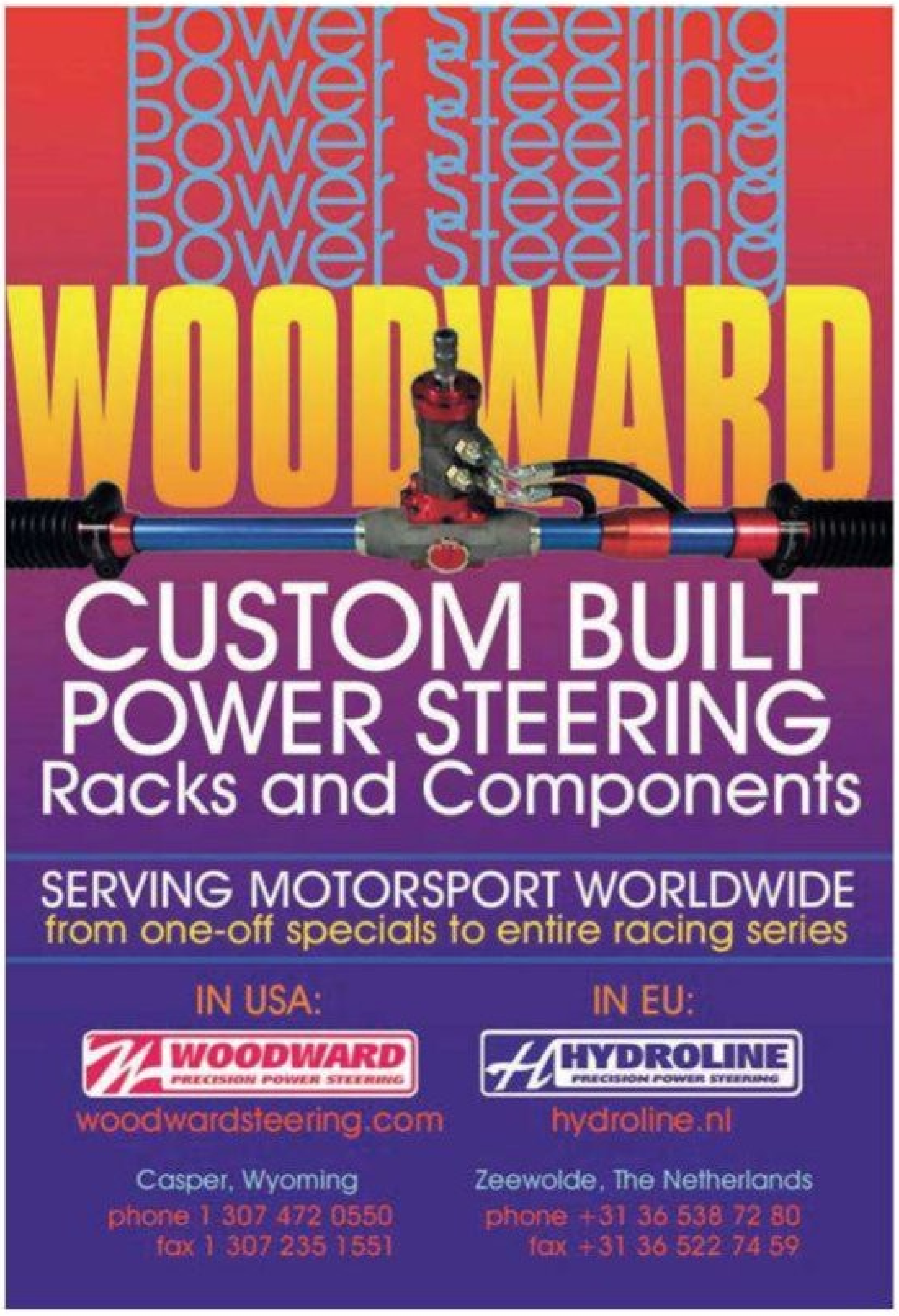
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Winged wonder

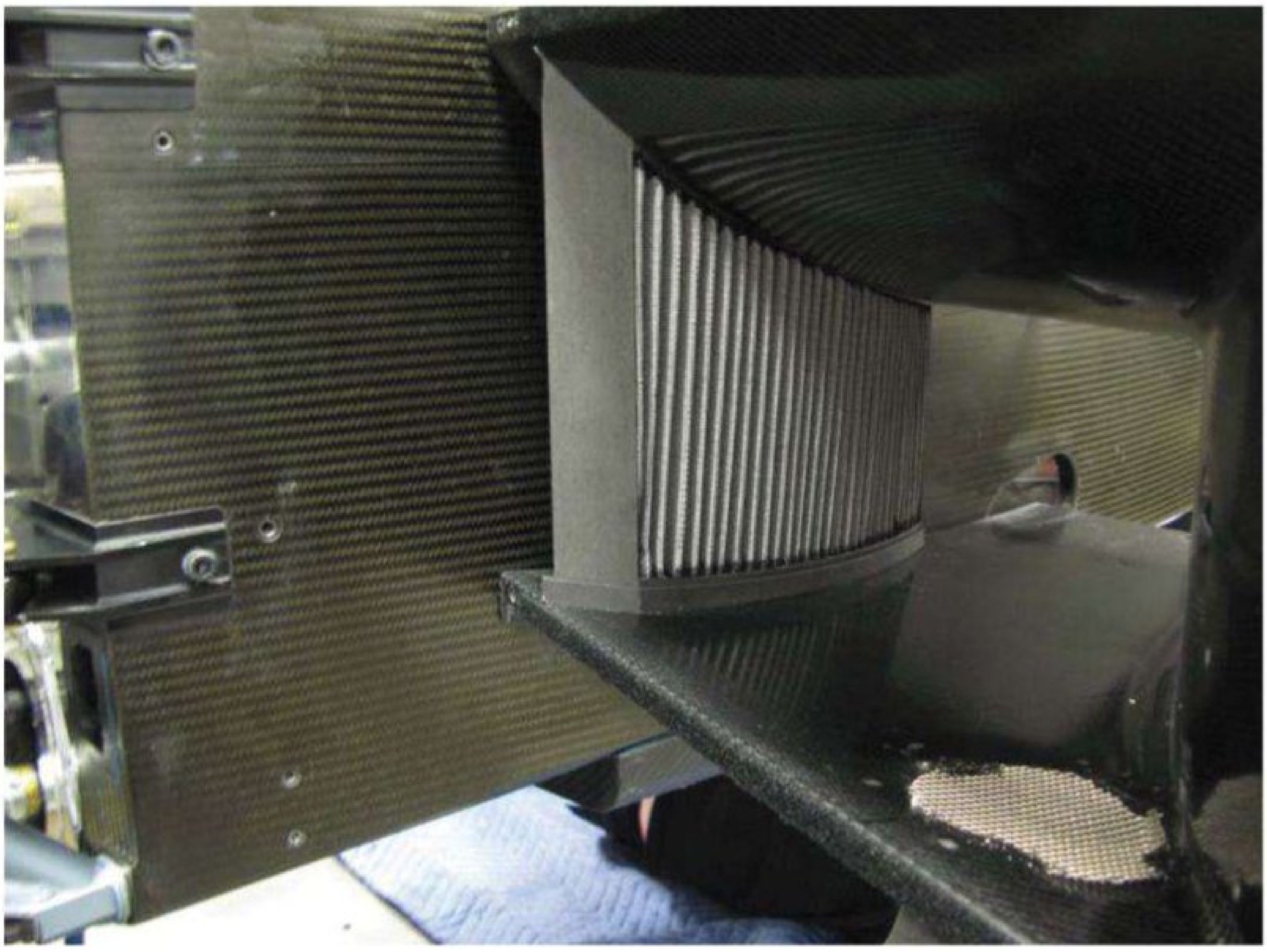
3D printing techniques aren't just being used to develop the innovative DeltaWing car – it's racing with printed parts

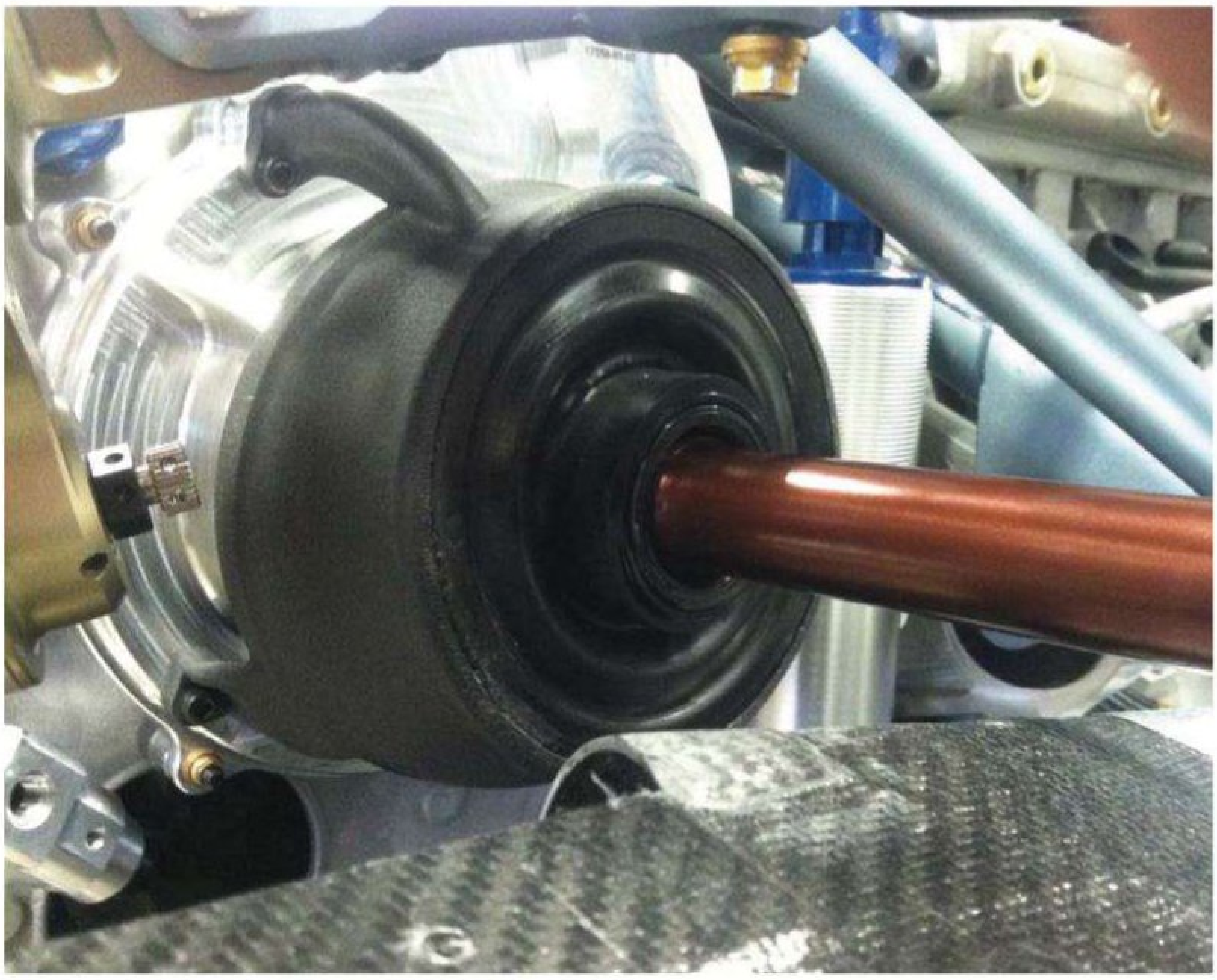
The unique design and construction of the Deltawing car relies heavily on a cleaner aerodynamic shape that achieves a low drag coefficient while still creating enough downforce to turn competitive lap times. This improvement requires less power to push the air at higher speeds, and significantly improves the efficiency of the vehicle operation.

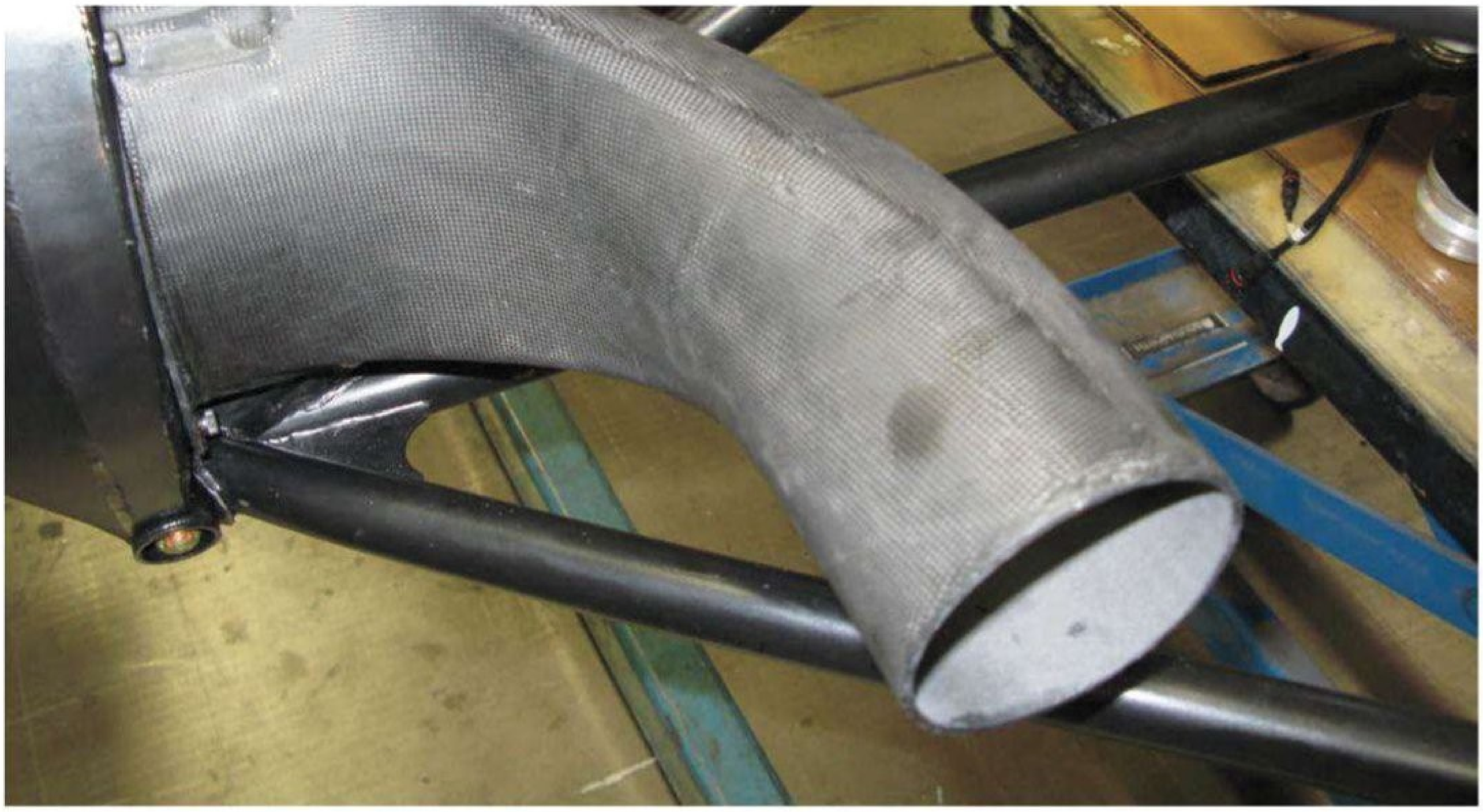
But aerodynamic advantage was far from the only goal of the DeltaWing team. Accelerating the car from low speed corners with only half the available power means the car can only weigh half as much, so an extreme weight-loss programme was key to making the car work.

To compound the challenge, there was a very short seven months from design to the first track test. So the team decided to use 3D printing technology together with the Windform high-performance materials where applicable to cut down the manufacturing time and save every bit of weight they could. In September 2011, they started to build the car at All American Racers (AAR) in Santa Ana, California. In March 2012 Alex Gurney, test driver and son of DeltaWing constructor Dan Gurney, became the first man to test the car at Buttonwillow Raceway in South California.

During this process, Laser Sintered Windform XT 2.0 was used not only in prototyping and testing, but in mission-critical applications on its truncated appearance at Le Mans, as well as during a successfully completed outing at the Petit Le Mans in the US. The DeltaWing team are moving the bar for both racing and Additive Manufacturing applications forward.







Windform parts raced on car:

- **Bespoke electronics enclosures**
- **Electrical breakout boxes**
- **Tow hook plinth**
- **Transmission seal covers with integrated pressurised oil feed passages**

Windform parts utilised in prototyping, tooling and testing:

- **Brake inlets and ducting**
- **Air inlet ducting and filter enclosure**
- **BLAT – Underbody extension flange (five-foot long bonded assembly)**

The carbon fibre reinforced Windform XT 2.0 was used to construct the gearbox side covers: The DeltaWing utilised a non-"stressed member" engine and gearbox to reduce the structural requirements of the assembly as well as reducing the vibration loads introduced into the lightweight car. The gearbox, with integral bellhousing, came in at a svelte 33kg, a fraction of the transmissions it shares the track with. Zack Eakin was the DeltaWing engineer responsible for the design of the gearbox and had this to say about the role Windform played in the design: 'Once we realised that we could use Windform XT as a race-able part at the elevated temperatures and pressures we run the gearbox oil at, it opened up a big possibility for us that would otherwise have been cost and time prohibitive. We went for a design that put the output seal on the halfshaft rather than around the outside of the Tripod joint which represents a big reduction in parasitic losses. But this design means that you have a seal that moves with suspension travel – a non-rotating CV boot that will react with the seal drag – and that you need to somehow get oil into the tripod cavity.

'Creating a metallic part that would orient the CV boot perpendicular to the average halfshaft angle, with integral oil drillings, was a Five Axis machining job that still would be heavier than what Windform gave us. With rapid prototyping technology, we were able to make a very complicated geometry, keep gentle radiuses in the oil passages, and get rid of all unnecessary material without introducing great cost or lead time in the parts. We were able to bond the CV boots directly to the Windform, seal directly to them with an O-Ring, and run the part at temperatures as high as 135 degrees, and pressures over 1-bar gauge without any issues. Windformwas a real home run for us on these parts.'

ENCLOSURE ENCOUNTERS

Eakin also believes the electrical enclosures were another very good fit for RP technology. 'We designed a number of our own electrical controllers for things like the DRS and differential that we needed enclosures for,' he says. 'All an electrical enclosure needs to be is waterproof, durable, and have sufficient heat dissipation for the circuit it houses. We found that we couldn't make an aluminum housing that was as light as a Windform one, let alone cost or time competitive. Often we would make a simple aluminum lid that the PCB would mount and heat sink to, which screwed into a windform box via some tiny threaded inserts.'

Windform XT 2.0 was the material mostly used for the manufacturing of parts, as it represents the top-level material for its mechanical and thermal characteristics. The use of 3D printing and Windform materials were fundamental to shorten the timing of car construction. In this case CRP Technology and CRP USA worked with the technical staff of the DeltaWing team step by step in order to help them finding the best solution.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Ecclestone pushes for Formula 1 budget cap

Bernie Ecclestone is arguing for a budget cap set at close to £150m in place of the current F1 Resource Restriction Agreement (RRA).

The reason behind the campaign is believed to be as a way of breaking the deadlock over the RRA, which places limits on teams' resources and has proved difficult to police. It is thought that this issue is behind the failure to agree a new Concorde Agreement, the covenant between the teams, governing body and the commercial rights holder (represented by Ecclestone) under which F1 operates.

By setting the cap at a relatively high level it is believed the top teams are more likely to accept it. Previous suggested budget caps have been around the US$50m mark but a top level of £150m (around US$250m) is close to what the front-running teams are already believed to be spending.

The proposed budget cap is set relatively high to encourage teams to sign up

Indeed, Red Bull's recently lodged accounts for the 2011 season reveals that the team's turnover was £176,844,000 with a profit of £641,000, which shows a spend of £176,203,000. Meanwhile, Mercedes GP shows a turnover of £114,853,000 with a loss of £10,568,000 for the same period, equating to an expenditure of £125,421,000.

While many of the teams would favour a realistic budget cap, there still remains the problem of restricting the spending of the engine manufacturers. For instance, Mercedes also has an engine arm which operates separate to the team. This is something which Red Bull team principal Christian Horner believes to be a huge problem with the RRA and any future cost restriction.

Horner said: 'We are fully in favour of costs being controlled in the sport, we just disagree with the mechanism at the moment and how they are presented to control those costs. Our concern is that entities and organisations are treated differently in what is proposed so far. It doesn't include the engine, for example, so at the moment there's freedom to spend on the engine, particularly the new power train in 2014.'

Despite the continued argument over costs the FIA has said that there has been real progress with the new for 2013 Concorde Agreement in the wake of a meeting with the teams and Ecclestone in Paris in late October. 'A further important step has been achieved today to secure the future of the F1 World Championship,' they said in a statement, 'which should lead to a final settlement to be reached between the FIA, the commercial rights holder and the teams in the coming weeks.'

Ford to give M-Sport tech support despite WRC pull-out

Ford will continue to give its erstwhile works operation technical assistance in 2013 despite the recent announcement that it's to quit supporting the M-Sport team's Fiesta RS WRC campaign next year.

The company, which has had a factory squad run by M-Sport in the WRC since 1997, shocked the rallying world with the news of its departure in October, but has said the decision was due to the current economic climate and its need to 'deploy its resources into other areas'.

But Ford's European motorsport chief, Gerard Quinn, has said that while there will no longer be a budget in place, it will still help M-Sport where it can. 'We will give them a large amount of technical and engineering support,' he said. 'I will keep our resources open so they have the best technology available.'

Meanwhile, the reason for Ford's departure from the WRC has been brought into sharp focus with three plant closures across its European operation, resulting in up to 1400 redundancies in the UK and 4300 in Belgium. The company has also made a commitment to cut spending by up to US$US500m a year.

The WRC pull-out came on the back of hugely disappointing sales figures for Europe for August 2012. They showed that Ford had sold 17,000 fewer cars than the same month the year before, a 29 per cent fall in sales. The decline in European sales has led to Ford reporting that it expects its full year loss in Europe to exceed US$1bn this year at a time when sales in its US heartland are on the up.

On announcing its departure from the WRC, Ford of Europe said that the decision had been taken following a major review of its marketing activities. Roelant de Waard, vice president, marketing, sales and service, said: 'Ford has a long and proud history in the WRC and this was not an easy decision. At this time, however, we determined that it was better for the company and the Ford brand to reduce our commitment to the WRC and deploy our resources in other areas.'

M-Sport, which has garnered 52 wins since 1997, scooping the manufacturers' world championships for the blue oval in 2006 and 07, aims to continue in the WRC with the Fiesta in the coming years.

There has been speculation that the state of Qatar might be close to signing a deal to take over the Ford rally effort by signing up as M-Sport's primary sponsor.

Cosworth searching for extra investment

Formula 1 engine builder and renowned motorsport technology provider, Cosworth, is seeking to sell equity in its business and admits a full sale of the company could be on the cards.

The firm, which is currently the engine supplier to HRT and Marussia in F1, has been the subject of speculation in the national press in the UK recently, with newspapers linking Rolls Royce, GKN and Prodrive to the purchase of the company.

A spokesman for Cosworth told *Racecar*: 'We are looking for new equity partners in the business, for some or all of the equity in the business. It's about finding investment so that we can continue the momentum of the growth that we've delivered to date.' He did agree that this could result in the sale of the complete company.

Cosworth had hoped to float on the stock market 18 months ago, but abandoned its plans for an IPO due to adverse market conditions. Tim Routsis, Cosworth's chief executive, said: 'We have been paused for the last 18 months and the board has decided that we cannot wait any longer. Otherwise, we risk losing momentum.'

The company says that the process to sell off equity has only recently begun: 'The thing to get across really is that at the moment we're in a fairly early stage of the process and we are looking at as wide a section of the buyer universe as possible,' said the spokesman. 'It is all about finding the right fit in terms of the new equity partners – they have to understand the culture of our business and

A spokesman says the company could be sold on in its entirety

understand what we do, what we've already achieved in terms of our diversification.'

Cosworth was bought by US-based Gerry Forsythe and Kevin Kalkhoven from Ford eight years ago and has since expanded its business into defence and aerospace as well as automotive consultancy. It was founded in 1958 by Mike Costin and Keith Duckworth (hence the name) and it has scored 176 F1 wins, mostly with its iconic DFV engine.

Its future in F1 beyond 2013, when the new turbocharged engine formula is introduced, depends on it clinching a commitment from three teams, but its general manager of F1, Kim Spearman, has said the company is keen to stay in the sport. 'If we can find a commercially sustainable way to provide a competitive platform for some potential customers, we'd like to do that,' he says. 'We are in useful negotiations with customers and hopefully we'll find a way to be in [F1].' Spearman added that the company has been working on its 2014 engine for a year and half.

PEELING BACK THE STICKERS. NUMBER 9: EADS

While it's not too difficult to imagine someone purchasing a can of energy drink after seeing a Red Bull F1 car, unless you're extremely rich – and even if you are – you're unlikely to buy an airliner after seeing the Airbus logo on a Caterham. So what is the partnership between Caterham and Airbus-owning aerospace and defence giant EADS all about?

The link between Caterham boss Tony Fernandes and Airbus was already very strong before the deal was announced in the late summer of 2012. Fernandes is Airbus's biggest customer through his Air Asia airline, having placed a record order for 200 planes last year, so a tie with Caterham was natural. 'We know Tony Fernandes very well through Air Asia so it was natural to be associated with his F1 team,' said an EADS spokesman.

The synergy between the companies was also attractive, says EADS, which as well as owning Airbus is also the group behind Astrium (space programmes), defence and security systems provider Cassidian and helicopter manufacturer Eurocopter, with a workforce of 133,000 across the group. 'In general, the tie-up also makes sense as high performance aircraft makers and F1 teams share many similar requirements such as the need for lightweight but strong composite materials,' says EADS.

Neither EADS nor Caterham would comment on how much was being spent on the 'multi-year' deal, though a position on the airbox where the Airbus logo sits of that size would normally cost a sponsor around US$20m – which with its revenues of €49.1bn in 2011 EADS could surely afford.

That said, this is more likely to be a quid pro quo arrangement. Fernandes has made much of the fact that he's looking to expand the Caterham Group into a technology provider, and the tie-up gives Caterham the chance to trumpet it's involvement with a hi-tech organisation like Airbus, and also that the companies have already started to work on projects together. 'Right now Caterham Composites and Caterham Technology and Innovation are involved in programmes that utilise the specialist skills that both companies have in composite design and manufacturing, including a revolutionary lightweight aircraft seat and an inflight entertainment system that will showcase the benefits composite materials provide on a global scale,' Fernandes said.

This cuts both ways: 'The Caterham Group and EADS are active in specific areas where there are obvious overlaps such as composite design and manufacturing,' said EADS.

But although there is obviously more to this deal than a logo on the car, EADS insists that the exposure is useful: 'We see F1 as a good opportunity to enhance our brand visibility, particularly in Asia. After all, this is the growth market for commercial aircraft.' While you might not buy an airbus after seeing its sticker on an F1 car, someone else might. Probably the person on whose car the sticker's stuck...

Multimatic and Haas set to keep Lola in LMP

Canadian motorsport company Multimatic was close to signing a deal to safeguard Lola's presence in LMP racing as *Racecar* went to press.

Multimatic, which already produced parts for Lola before the company's demise, was talking to Lola Group Holdings, which has recently purchased the assets of Lola Cars International, about supplying Lola teams in conjunction with Haas Auto.

The famed constructor went into administration in May but a buyer could not be found and the administrator, CCW Recovery Solutions, announced that it ceased trading in early October.

While not being able to comment on the progress of the talks, Sean Mason, motorsports manager at Multimatic, admitted they were ongoing, and also said that the Ontario-based company would certainly be up to the task: 'Absolutely - it would almost be seamless to the competitors I would have thought,' he said.

The deal will also involve Lola's North American distributor Haas Auto, but it will not involve Multimatic or Haas owning Lola, we have been told. Lola Cars is now the property of Lola Group Holdings - a separate entity from Lola Cars and Lola Composites, the companies that went into administration - which has retained Lola's intellectual property.

'Lola Group Holdings Limited is the owner of the Lola brand and all Lola intellectual property,' read a statement. 'Lola Group Holdings has reached agreement with the joint administrators, through participation in a sealed bid tender, to purchase the remaining Lola Cars International stock and inventory which includes current LMP stock and tooling to enable the continued manufacture of parts to service Lola customers.'

The statement also mentions the talks with Multimatic and Haas, though does not name them: 'Lola Group Holdings is also able to announce that it is in advanced negotiations with parties to form a partnership to service Lola customers in the future. Lola Group Holdings is making available a licence for the intellectual property and existing inventory.'

Multimatic has already hired a number of former Lola employees, including chief designer Julian Sole and business development manager Steve Charsley.

SEEN: FORMULA FORD 200

Formula Ford has confirmed that it's to race with wings from next year. The formula will now be called Formula Ford 200, which also highlights a boost in power from 165 to 200bhp. The car retains the 1.6-litre EcoBoost turbocharged engine that was introduced in 2012, but Ford will be hoping that the introduction of the new car will attracts more drivers to the UK championship, which suffered from thin grids in its first year with the new engine.

McLaren to get tax back from spy fine

McLaren will now be able to claim a corporation tax deduction on the £32m fine it picked up for its involvement in the 2007 'spygate' saga after a tribunal found in its favour.

In 2007 the Woking F1 team was found guilty of being in possession of Ferrari technical secrets and was subsequently hit with a staggering US$100m fine - £66m at the time, of which half was accepted as payment through the loss of TV and travel money that the team would have received had it not been excluded from the results of the constructors' championship that year. The exact cost of the fine to McLaren was £32,313,341.

But now McLaren's legal team has convinced an appeal hearing brought against the Commissioners for Her Majesty's Revenue and Customs (HMRC) that the fine was in fact a business expense as it was related to the team's trade.

HMRC had argued that the fine should not be tax exempt as it was the result of activities that were not directly related with the team's F1 programme. Akash Nawbatt, HMRC's solicitor, said that: 'The penalty arose from McLaren's interference with Ferrari's intellectual property: such interference was not part of McLaren's trade or incidental thereto.'

Nawbatt added: 'The legitimate gathering of information was part of its trade but the illicit gathering of information was not. McLaren had said as much in its submissions to WMSC [World Motor Sport Council] in the July [2007] hearing.'

However, only one of the two judges at the tax tribunal was convinced by Nawbatt's argument and ultimately the opinion of the presiding judge, Charles Hellier, decided the matter. He believed the fine was tax deductible: 'This cost was not one imposed on McLaren, but one which it was contractually obliged to pay under contractual obligations undertaken for the purposes of its trade ... The penalty was something which arose from its trade, was connected with its trade and was incurred wholly and exclusively for the purposes of its trade.'

The court ruling issued by the tribunal's judges revealed that in 2007 McLaren's turnover was £127m, but it made a loss of around £35m, the vast majority of which was down to the fine.

HMRC has the right to appeal the ruling, but would not comment on whether it would do so at the time of writing.


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Top factory award is made for measure

Well-known motorsport industry supplier Renishaw has been awarded a top award for its state-of-the-art assembly facility in Gloucestershire.

The precision measurement instruments manufacturer's Woodchester facility has been named as the UK's Best Electronics And Electrical Plant at the prestigious Best Factory Awards 2012.

Renishaw was up against some stiff competition for the award, including global names such as Sony and Siemens, but the judges, led by Cranfield University's Institute of Management, were particularly impressed with their set-up. The award citation said: 'Ultimately, the combination of astute supply chain management, strategic operations planning and class-leading automated technology make this stand-out OEM a worthy winner of the Best Electronics and Electrical Plant prize.'

Renishaw was also recognised for its global leadership in the field of industrial measurement: 'Some manufacturers are simply synonymous with their technology area – when it comes to metrology, they don't come any bigger or better than Renishaw,' said the citation.

The Woodchester facility carries out the design, development and assembly of components for a wide range of metrology products, including laser calibration devices, probe heads for co-ordinate measuring machines, laser tool setters for machine tools and optical encoders for precision position feedback.

At 15,000m² and with 348 employees working in manufacturing roles at the site, the Woodchester plant is the largest of four assembly facilities within the Renishaw Group. The facility includes a full electronics production capability, including printed circuit board (PCB) layout, assembly and test.

Gareth Hankins, director of Renishaw's Group Manufacturing Services Division, said: 'A tremendous amount of work has gone in to making Renishaw's manufacturing site at Woodchester the world-class facility that it is today. It is a testament to the quality and motivation of our employees at Woodchester that we have won this award and all of us are very proud to be recognised in this way.'

BRIEFLY

Super DTM

The organisers of the DTM and those behind the Super GT championship in Japan have struck a deal that will mean the Japanese championship will run to the DTM technical regulations from 2014.

Porsche quits ALMS

Porsche has announced it's to cease its factory involvement in the American Le Mans Series after 13 seasons, and it will instead develop the 991 GTE car in Europe, with a factory team and customer support. It's partner team in the ALMS, Flying Lizard Motorsports, says it's to remain in sportscar racing, but there is speculation this will be in GrandAm rather than the ALMS, a potentially smart move with a 2014 merger confirmed.

Name change for PFC

Performance Friction Brakes has rebranded and will now be known in Germany, Japan, Europe and America as PFC. 'For many in the racing markets worldwide, PFC is Performance Friction Brakes,' says Motorsports Director Darrick Dong. 'From the racing viewpoint, PFC is a brand already recognized as a leader in design, manufacturing capabilities, and service for race teams in many countries.'

NASCAR track division posts $1m loss

International Speedway Corporation (ISC) remains upbeat about the company's future despite falling attendance figures and a US$1m net loss in the third quarter of 2012.

The NASCAR-owned company reported a US$1m net loss in third quarter earnings in October, down from a US$9.7m profit for the same period in 2011. Revenues also fell from US$150.3m in fiscal third quarter 2011 to US$115.9m in the same period in 2012.

Lesa France Kennedy, CEO at ISC, says some of the blame for the poor results are down to changes in the NASCAR race calendar: 'Adjusting for the schedule changes, primarily related to the timing of the NASCAR weekend at Kansas Speedway and a NASCAR Nationwide series event we no longer promote, total revenues for the quarter were down only slightly, approximately three per cent, from the comparable period delivering core business results within our range of expectations.'

The ISC has also seen a large drop-off in the number of spectators attending NASCAR events since 2009, a decline that's continued this year. According to NASCAR's own crowd figures, attendance at Sprint Cup counters fell by 8.5 per cent from 2009 to 2011, and has dropped another 2.4 per cent thus far in 2012.

France Kennedy says the low attendance numbers are down to the poor economic situation in the US, but she insists there are encouraging signs for the future performance of ISC: 'We remain encouraged with many aspects of our business despite the ongoing effects of the sluggish economy, which continues to impact on our attendance-related revenues. Corporate partner support for the industry remains robust. The sports media rights landscape is strong, as evidenced last month [September] by Major League Baseball extending its television contract on favourable terms. And, we are seeing certain consumer trends moving in the right direction. These consumer trends need to translate into increased attendance at our events before we can see growth in attendance-related revenues.'

CAUGHT

NASCAR Camping World Truck Series crew chief Ted Walters was fined and placed on probation until the end of December after the No 57 Norm Benning Racing Chevrolet he tends was found to be running with an unapproved weight on its truck bed. The transgression came to light during scrutineering at the Talladega Superspeedway race.

FINE: US$5000

Fox signs $2.4bn rights deal with NASCAR

NASCAR and Fox Sports Media Group (FSMG) have signed an eight-year extension to their ongoing TV deal, which will now run through to 2022.

The new deal, which will come into play in 2015 after the current contract has run its course, will net NASCAR an average of US$300m a year from Fox, amounting to US$2.4bn over the life of the contract.

Under the terms of the deal, Fox – which has been involved with the sport since 2001 – will continue to hold the exclusive rights to NASCAR's flagship event, the Daytona 500, plus the races which make up the first third of the NASCAR Sprint Cup.

NASCAR chairman and CEO, Brian France said of the deal: 'NASCAR has been in very good hands and has enjoyed tremendous success the last 12 years, in large part because of our fantastic partnership with Fox and Fox Sports Media Group. We are thrilled to be able to extend our relationship in such a significant way for our track partners, race teams, and – most importantly – our millions of loyal and passionate fans. This extension with Fox Sports Media Group helps position the sport for future growth as NASCAR continues to be an anchor with one of the world's largest and most influential media companies.'

From 2015 FSMG will retain the television rights to 13 consecutive NASCAR Sprint Cup Series races, beginning each year with the prestigious Daytona 500. In addition, FSMG retains the rights to the NASCAR Sprint All-Star Race, the Daytona Shootout, the Duel at Daytona, the entire NASCAR Camping World Truck Series season and practice and qualifying for both the NASCAR Sprint Cup Series and the NASCAR Camping World Truck Series races that FSMG broadcasts.

'We're extremely happy to have worked closely with Brian and his team at NASCAR over the last few months to expand and extend our relationship for what is without question the most popular motorsport in the country,' said FSMG co-presidents and CEOs Eric Shanks and Randy Freer. 'NASCAR has been a staple at Fox for more than a decade and we consider it one of the signature sports we cover. With our commitment renewed, we look forward to presenting NASCAR thoroughly, professionally and creatively for many years to come.'

NBC F1 is on, but NJ F1 is postponed to 2014

Formula 1 continues to make great strides in the United States with the news that top US broadcaster NBC has won the right to air the sport for the next four years, although its coverage in 2013 will not now include the inaugural New Jersey Grand Prix, which has been postponed until 2014.

NBC has agreed a four-year deal with Formula One Management (FOM), which will see the well-known US TV company replace Speed as the sport's exclusive broadcaster. Speed has been airing F1 races in the US for the past 17 years.

The NBC Sports group will broadcast all 20 races of the 2013 season, four of them on NBC and 16 on NBC Sports Network, as well as the practice sessions and qualifying.

FOM boss and Formula 1 ringmaster Bernie Ecclestone said of the deal: 'NBC and its various media assets, have a huge profile throughout the United States and I am obviously delighted to have concluded this agreement. I feel that they will promote Formula 1 to a level not seen before in the United States.

'I very much look forward to working with NBC. Together, we will endeavour to broaden the scope of Formula 1 coverage available to US viewers incorporating additional digital content in particular that has not been available before.'

Jon Miller, president of programming at NBC Sports and NBC Sports Network, said the sport was ideal content for the broadcaster: 'We are thrilled to add the top international open-wheel racing series to our already-strong motorsports portfolio. Formula 1 is a perfect fit for the NBC Sports Group as it provides content across three platforms – broadcast, cable and digital – for nine months a year with more than 100 hours of premier programming annually.'

Meanwhile, the New Jersey Grand Prix has been dropped from the 2013 schedule. The inaugural running of the race, which was to be the USA's second grand prix after Austin and was to feature the backdrop of the Manhattan skyline, will now take place in 2014, Ecclestone has confirmed.

The reason for the postponement is that the organisers are behind on road repairs and on acquiring the necessary permits for the street race, while Ecclestone has said the promoters are also still seeking extra investment. It now seems likely that the French Grand Prix will return to the calendar to take New Jersey's place.

SEEN: NISSAN ALTIMA V8 SUPERCAR

Nissan has unveiled its all-new 2013 Nissan Altima V8 Supercar which will compete against Ford, Holden and Mercedes next season.

The Altima is the first all-new V8 Supercar model to be unveiled in two decades, as Nissan joins the V8 Supercars Championship from next season with the four-car, factory Nissan Motorsport team, run by Kelly Racing.

'Unveiling our Nissan Altima V8 Supercar, the first new V8 Supercar model in two decades, brings Nissan's special brand of "Innovation and Excitement" to the V8 Supercars Championship,' said Nissan Australia managing director and CEO William F Peffer Jr. '2013 will be an enormous year for Nissan, with several important new models set to launch next year. One of those will be the all-new 2013 Nissan Altima, the first time the Altima nameplate has gone on sale in Australia.' The Altima V8 has been designed and built to the category's new Car Of The Future regulations, which include 18-inch wheels, transaxle gearbox and independent rear suspension. Nissan Motorsport will use the production-based VK56DE engine in the Altima V8 Supercar, the same engine that powered Nissan to the FIA GT1 World Championship title in 2011. The VK56 engine also powers the 2013 Nissan Patrol that goes on sale in Australia from 1 February 2013.

INTERVIEW: PETER HUGHES

Q. What motorsport disciplines do FHS Motor Racing supply?
We design, manufacture and supply air and fluid hose systems for all sorts of professional motorsport. This includes every F1 team, as well as being actively involved with WRC and other series such as British Touring Cars.

Q. What sort of applications do you supply to motorsport?
Hydraulic and fluid controls. These have been used in Formula 1 for many years, and control everything from DRS to KERS. It really got going in the 1980s, though, when Lotus and others were starting to develop active suspension. They needed responsive, lightweight control systems to retain a consistent ride height. The precise control, flexibility and 'power density' of hydraulics – rather than electrical alternatives – resulted in widespread adoption, ultimately controlling the braking, steering, engine and gearbox.

Q. How difficult is this sort of technology to implement?
Hydraulics require meticulous cleanliness and, like many systems on an F1 car, have to operate in tight, hot and high vibration environments. We have specialised in designing and making systems to function reliably in these applications. In addition, the teams demand responsiveness. Our hoses are normally required in very short lead times, but to very high quality standards and cleanliness. Some have to withstand up to 3000psi and even higher in some applications.

Q. Do you supply any sectors outside of motorsport?
We supply a growing number of defence customers. We could do more; sectors such as oil and gas, and marine would be highly relevant to the materials and processes we have developed and proven in F1. For instance, we developed a joining process called Swagetite. Essentially it is a form of swaging that eliminates the need for brazed or welded joints. This enables us to have a smoother internal bore and reduces the number of joins, which are often the weak points of a hydraulic system.

Q. How are the hoses designed and produced?
We work closely with our customers and we are involved at the earliest stages, for packaging. For instance, we have been working on 2014 [F1] changes for over six months and we are already well on our way for 2013 installations. Customers provide the parameters from which we produce detailed designs for approval. Every year the bend radii seem to get tighter, but by working closely with the teams' engineers we can find a solution that works for everyone. We do our own rigid tube bending and assemblies are manufactured here in our workshops. Each one is 100 per cent tested before despatch and we recently purchased a CMM [co-ordinate measuring machine] machine to enhance quality assurance.

Peter Hughes is managing director of FHS Motor Racing
FHS designs, develops and manufactures air and fluid hose systems. Hughes started the business as a division of Flexible Hose Supplies, a company that supplied products to industrial sectors, around 20 years ago. Hughes wanted to concentrate on the motorsport sector so when the business was sold five years ago he retained this part of it to focus on this area as well as other sectors that needed reliable air and fluid systems in harsh environments.

Q. What other products do you manufacture?
We manufacture and supply filters, solenoid valves, high temperature ducting etc. We enjoy technical partnerships with other firms such as Pall Filters, so we can offer a one-stop solution that makes the most of each element. The teams like the fact that we are constantly pushing the envelope, whether that is in packaging, resistance to environmental conditions, or weight.

Q. What's new at FHS?
We are already heavily involved in the 2014 F1, where downsized engines will require more power dense hydraulics, something we are progressing well with. As KERS changes are also planned for 2014, we are preparing new products to meet the demands for higher output. We are also looking at small improvements in package size for DRS componentry. Generally we tend not to see step changes in hydraulic developments, rather a constant stream of evolution, each time delivering more performance for less weight or package space. Reliability is so crucial, though, and with limited testing we do not see a huge appetite for risk with hydraulics. But only once we are sure that we have absolute reliability would we consider introduction to F1.

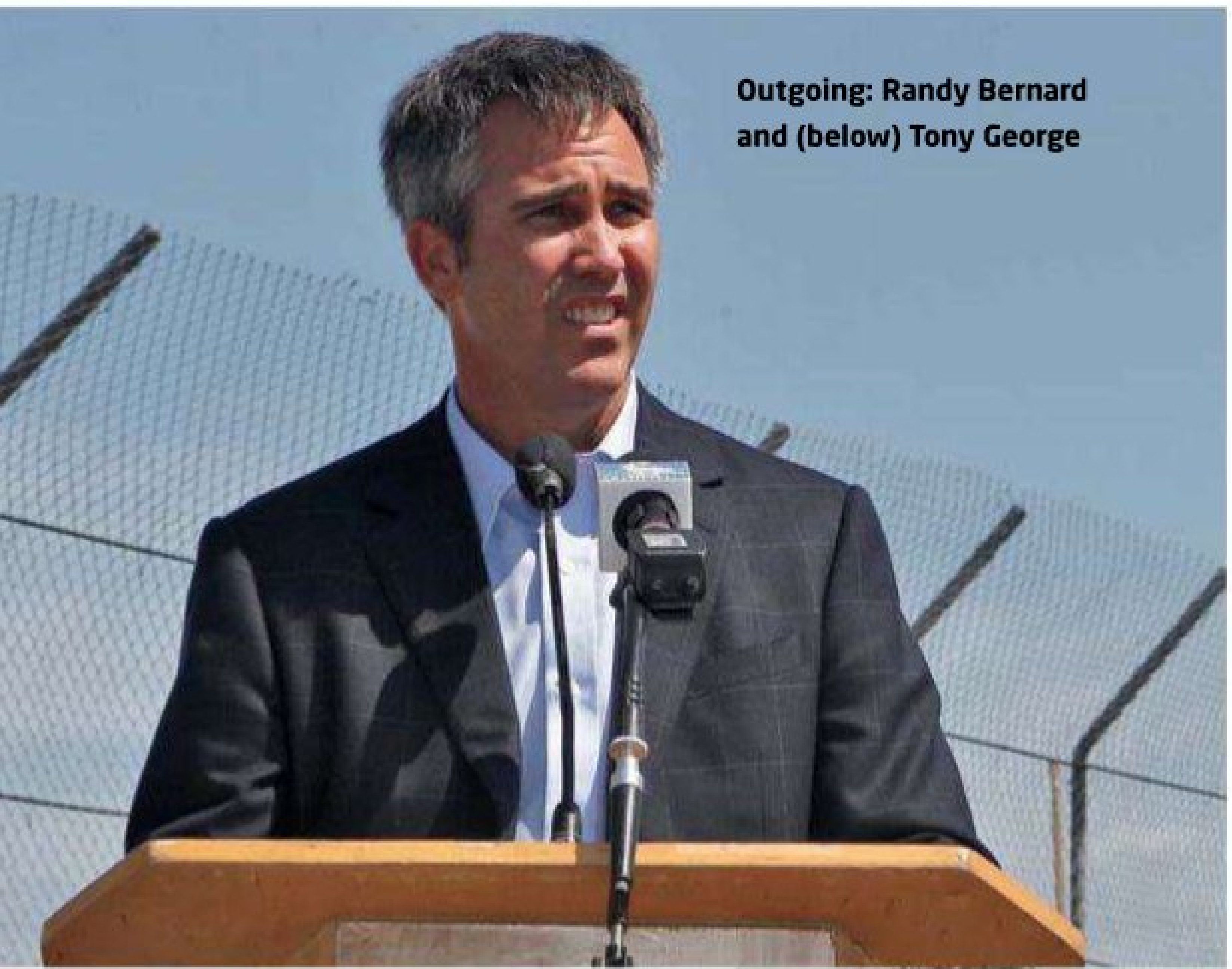
Q. How many people do you employ and what facilities are in place at your factory?
We employ 25 people at our dedicated site in Slough. We moved into this facility about five years ago. We have extensive assembly equipment, plus pressure rigs and measurement, all in-house. We can do rigid tube bending here and have a prototype machine shop, which we use a lot for developing ideas. As I've said, inspection is crucial and we have a boroscope and high magnification units, as well as the new CMM machine.

Q. Is it true that your factory is where the GT40 was assembled?
I heard that they were built on this estate from the developers when we were looking around. It's a nice story, so we believe it! I also understand that Frank Williams was based near our factory in the late-60s, when he was trading racecars.

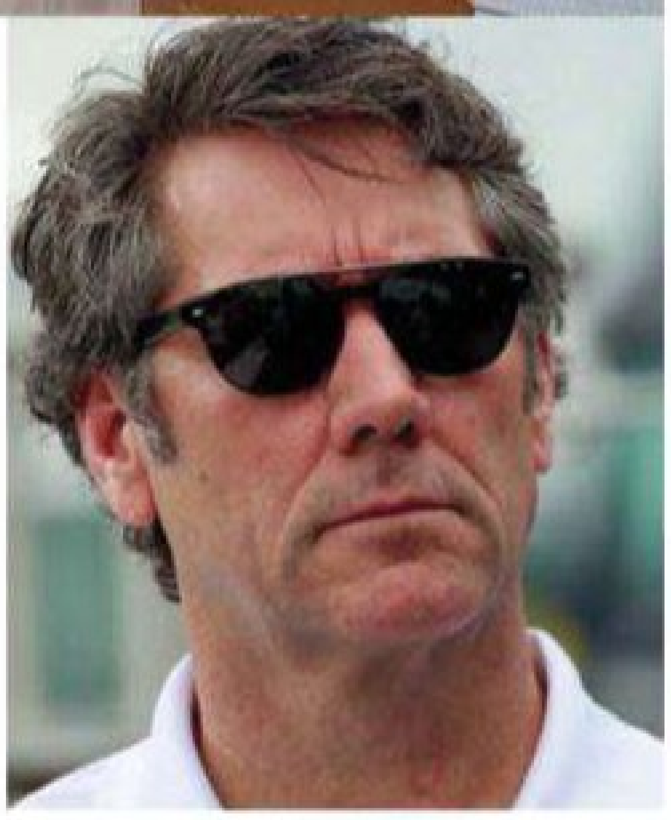
Q. What is the future for hoses in motorsport?
The use of good quality flexible hoses in motorsport is set to continue for many years. When done properly, it is such a reliable method for control. Recent changes in regulations such as KERS, DRS etc. ensure we always have something on the go.

Q. What is the future for FHS?
We would like to do more work in GT and WEC. What we do for other formulae is highly relevant and our ability to extract reliability from even the tightest package-restricted application could deliver benefits in the WEC. Our BTCC work demonstrates a capability to produce batch runs cost effectively, something that could also appeal to other series. We are also attending other trade shows such as The Boat Show to see where we could do things better in those applications. There is a lot of potential.

IndyCar boss Bernard quits the series



Outgoing: Randy Bernard and (below) Tony George



High-profile IndyCar chief Randy Bernard has stepped down from his role as CEO of the US single-seater series.

Bernard, who will remain on the board in an advisory capacity, will be replaced by Hulman & Company (the company that controls IndyCar) president and CEO Jeff Belskus in the interim. Belskus said: 'As both Randy and our organisation have reflected on the past season, and as we look toward the opportunities ahead and how to best take advantage of them, we agreed that the timing was right to pursue separate paths.'

The news came soon after the resignation of Tony George from the Hulman & Company board of directors. George, the founder of the series in 1996 in its original guise of the Indy Racing League, said that plans to acquire the series have led to the decision, saying he did not want there to be a conflict of interest.

Belskus says that there are no plans to sell the series.

Titan reflects and rebrands

Titan has launched new branding that represents growth in new and existing markets. The company is now a leading supplier of high precision engineering services to motorsport, automotive, marine, defence and aerospace companies.

Titan is a leading supplier of engine, steering and drivetrain solutions for racing teams, and for automotive companies.

Titan co-owner Oz Timms said: 'We have always needed to be flexible, in order to respond to our motorsport customers' needs, and this capacity has enabled us to successfully contribute to the prototype and development stage with customers in other industries.'

Titan is launching a new website that will provide online support to customers purchasing its products and which illustrates the services that Titan can offer to their increasingly diverse range of customers.

RACE MOVES

Chris Dyer has joined BMW's DTM project, taking over the chief engineer position from **Mike Krack.** Dyer is best known for his time at Ferrari, where he was race engineer to Michael Schumacher from 2001 to 2006, and went on to become the Scuderia's head of race track engineering, before he was replaced by **Pat Fry** last season. Dyer has previous tin-top experience, having worked for the Holden team in his native Australia in the mid-90s.

Monisha Kaltenborn has stepped up to the role of team principal at Sauber, the former CEO of the team taking on the position of team founder **Peter Sauber,** who has decided to relinquish his position at the head of the team. Sauber has always said he would step down from the top position when he turned 70, a milestone he will reach next year. The news means Kaltenborn, who joined the team in 2001 as head of its legal department, becomes F1's first ever female team principal.

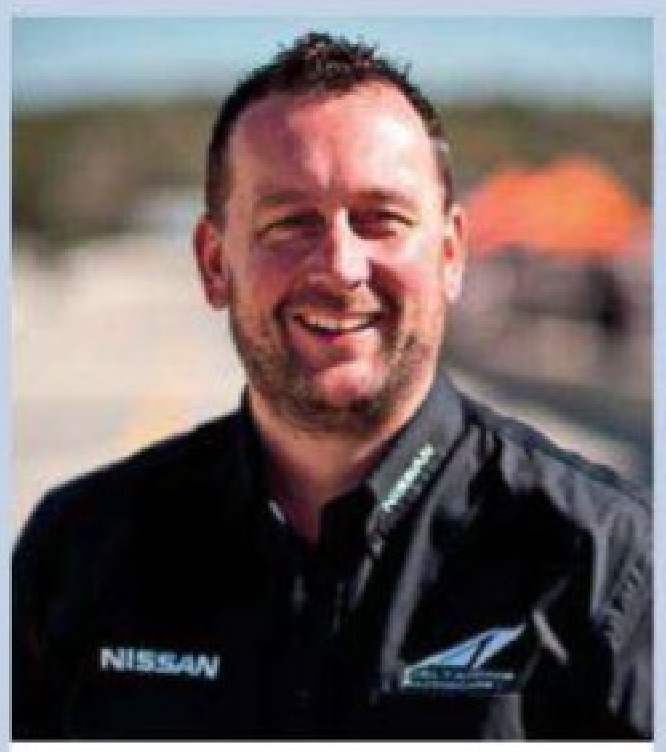
Pat Tryson has joined the BK Racing NASCAR Sprint Cup team. At the time of writing it was not known what position Tryson, who has been a crew chief with both JTG-Daugherty and Michael Waltrip Racing in the 2012 season, will take at the BK team.

Tony Gibson is to become crew chief for **Danica Patrick** in the NASCAR Sprint Cup in 2013, which will be Patrick's first full season in NASCAR's premier series with the new Stewart-Haas racing team. With Gibson and his crew moving over to the Patrick entry, SHR will now be hiring a new crew to tend the car of Gibson's 2012 charge, **Ryan Newman.**

Robert Newton, the founder of Hoosier Racing Tire, has died at the age of 85. Newton and his wife, Joyce, set up the famed US motorsport tyre company in 1957. Hoosier is now a successful business exporting to over 70 countries, but Newton was a racer before he became a businessmen and he developed his first tyres when he saw a need for better performing rubber in the sport.

Cecil Gordon, a former independent car owner and driver, and later in his career a crew member at Richard Childress Racing for the late **Dale Earnhardt,** has passed away at the age of 71. Gordon's last job in his 40 years in NASCAR was with Travis Carter Motorsports.

Tom Anderson has left his post as director of motorsports operations at IndyCar outfit Rahal Letterman Lanigan Racing. Anderson joined the organisation in November of 2011, when co-owner **Bobby Rahal** restarted the team. At the time of writing no reason had been given for Anderson's departure.

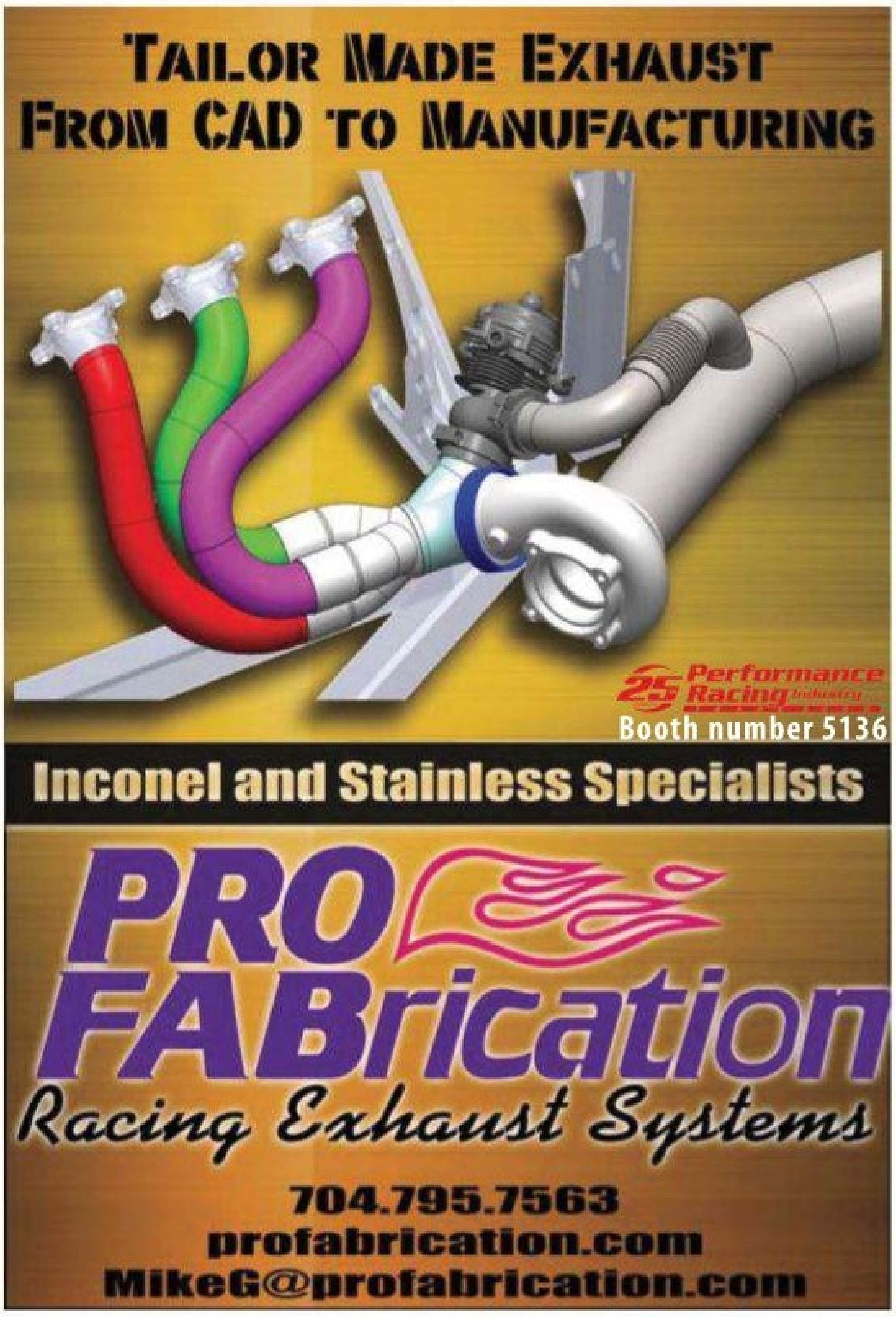


Darren Cox has been appointed as director of Global Motorsports at Nissan. Cox is widely acknowledged as the driving force behind two of Nissan's best known racing initiatives, the GT Academy and the 2012 Nissan DeltaWing Le Mans programme. In his new position Cox will expand existing projects as well as managing the strategy and activation behind the company's multiple racing programmes, which include the Super GT Championship in Japan and the V8 Supercar series in Australia.

Former FIA president **Max Mosley** has said he thinks that his successor in the position, **Jean Todt,** will have to become more confrontational if he wants to achieve his aims in Formula 1. Mosley, whose tenure at the top of F1 was marked by friction with the teams, told Sky Sports that Todt has got 'a completely different style' and that 'at the moment maybe he's a little bit too reluctant to confront'.

Jeff Wohlschlaeger has been taken on by NASCAR as managing director of its Industry Services department. Wohlschlaeger joins NASCAR from the Chicago Bulls basketball team, where for the past 18 years he served as senior director of game operations. In his new role he will work alongside track operators to help improve the fan experience at NASCAR events.

Chad Seigler has been promoted to managing director of team services at NASCAR's Industry Services department, where he will work wiith race teams within each of NASCAR's national race series, providing marketing tools, resources and advice. He will report to Jill Gregory, NASCAR's vice-president of Industry Services.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SPONSORSHIP

TaxSlayer.com, an online tax preparation service in the United States, has renewed its sponsorship deal with NASCAR Nationwide team **JR Motorsports**, an outfit with which it has had an involvement since 2011. TaxSlayer.com will be the primary sponsor of the team in 17 NASCAR Nationwide races in 2013.

Crack Australian V8 Supercars team **Stone Brothers Racing** has entered into a multi-year partnership with apparel brand **KooGa.** It is the well-known sportswear company's first foray into motorsport and it says it was attracted to Stone Brothers because, like KooGa, the race team is a family-owned company based on the Gold Coast.

Swiss F1 team **Sauber** has renewed its partnership with **Oerlikon** until 2015, and the logo of the company will now continue to appear on the upper portion of the engine cover, as well as on team clothing and equipment. Hi-tech engineering company Oerlikon, which is also Swiss, is a global player with more than 17,000 employees at over 150 locations in 38 countries, with reported sales for 2011 amounting to CHF4.2bn (US$4.5bn).

Jack Daniels has announced a new multi-year sponsorship agreement with **Nissan** motorsport for the 2013 Australian V8 Supercars Championship. While the deal is new, it does continue a long relationship with the team that is to run the works Nissans, **Kelly Racing,** which has been sponsored by the bourbon producer since its inception in 2009. Jack Daniels entered V8 Supercars in 2006, sponsoring Larry Perkins's team for three years before switching to Kelly Racing.

RACE MOVES

An arrest warrant issued against **Vijay Mallya,** the team principal of the Force India F1 team, was withdrawn after the Kingfisher Airways boss settled his differences with Hyderabad Airport. The dispute was over a US$2m unpaid bill for airport user fees.

NASCAR Digital Media has made four additions to its editorial staff in the run-up to the launch of its new website, due to come online at the start of 2013. The new members are: **Kenny Bruce, Holly Cain, David Caraviello** and **Alan Cavanna.**

Veteran UK race commentator **Andrew Wilkins,** best known for keeping spectators in touch with the action at MGCC meetings, has hung up his microphone. Wilkins's retirement from the commentary box comes after almost 20 years and 100 meetings with the club.

Hakan Samuelsson is the new president and CEO of the Volvo Car Group, taking the position vacated by Stefan Jacoby. Samuelsson has 35 years of experience in the car industry and between 2005 and 2009 he was chairman and CEO of MAN.

Jerry Hardcastle is now technical director for Nissan Global Motorsports, although he will also be keeping his former post of global chief marketability engineer for the car company. Part of Hardcastle's work involves helping translate customer requirements into technical specification. He is also the technical liaison to the Red Bull Racing F1 team for Infiniti.

Amel Boubaaya, formerly of Infiniti Europe, has been appointed European PR manager for McLaren Automotive, replacing **Lena Siep,** who has been promoted to global PR manager. Former global PR manager, **Wayne Bruce,** now fills the new position of head of communications and public relations.

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

Chief engineers on board for MIA race school

Whether you want to get into the industry, progress within the industry or broaden your knowledge of the industry, the MIA Winter Race School of engineering is an opportunity you do not want to miss.

The Race School offers a course that spans across the first two weekends of this December, which focuses on the work of a race engineer on the pit wall, rather than the driver's role. The course is divided into two sections to cover a wide range of essential topics, which include Real World Vehicle Dynamics, Data Analysis, Strategy and Simulation, among many others. Both courses take place in December inside the Lotus F1 HQ in Oxfordshire and Cosworth's manufacturing centre in Northampton. Each is taught by two, currently successful, chief engineers, Dan Walmsley, chief engineer at Strakka Motorsport, and Jay Davenport, chief engineer at MW Arden – GP3 Series.

As Walmsley explains: 'Our mission statement confirms that the course can only be taught by currently "active" race engineers. As constant changes to our race engineering challenges move very fast, we want to keep the content fresh and relevant. One additional benefit of the course is the networking we instigate, where pupils get access to current race engineers and can make an impression on them, to benefit their future. We socialise with delegates in the evenings, and invite special guests to share their tales of pitlane heroics, in a relaxed environment.'

'The MIA Race School is in its third year, and is continuing to bridge the gap between education and the motorsport world. 'The course was born out of a recognition that, when both Jay and I entered the motorsport industry, despite the good theory we had learnt at university, we felt somewhat under-equipped and needed more information from people who were currently working and applying their trade. Sadly, someone who has never stood in a pit lane simply has no understanding of the decision-making process which a race engineer has to go through.'

From the start, the Motorsport Industry Association was an important partner in the Race School, as chief executive of the MIA Chris Aylett explains: 'The MIA always highlights the importance to new recruits of the need to gain practical, hands-on and, most importantly, current race engineering knowledge and skills. The constant need for, and speed of, improvement, updating and incorporation of innovation makes it very difficult to pass this knowledge on to those wishing to enter motorsport. The biggest challenge was our determination that the course must be taught by the very best, currently successful, race engineers. These "teachers" are in demand at tracks all over the world.

'Graduates receive a diploma which explains what skills they have been taught and by whom. We know this helps to secure employment, and helps our industry prosper too.'

The pupils range from recent graduates looking to progress from technician to race engineer, to older engineers wanting to broaden their knowledge. Even suppliers come to see what products and services motorsport teams use and need.

The future of the Race Engineering School is looking extremely bright as it educates more people and its reputation grows, and it plans to add additional course modules to expand the school.

For further information, contact Zoe Chilton on +44(0)24 7669 2600 or email: zoe.chilton@the-mia.com

HARDWARE

Greaves 3D Engineering Fuel Rig & 360° Boom

Greaves 3D Engineering has added a new fuel rig to its range. It's identical to the one used to great success by its sister company, Greaves Motorsport, in 2012.

The rig can be customised to suit any specification, and combined with the Greaves 3D Engineering 360° Carbon Boom it provides the most versatile fuelling system on the market. Lightweight, and constructed with pitlane safety at the core of the design, the rig allows full access as a result of its low stance.

Wheels and pit tools can be passed easily and refilling the autonomous tank is safer.

Other features of the rig include: remote mounted regulators, capacity for three large air cylinders, as well as a fully rotational air line arm.

For more information visit www.greaves3dengineering.com

CLUTCHES

AP I Drive clutch

AP racing's latest development, dubbed the 'I' Drive clutch system, is designed to counter some of the problems inherent with traditional clutch designs. Conventional clutch designs typically feature external jaws around the outer edges of the steel intermediate and main pressure plates, which can distort and trap the legs of the aluminium cover, causing the clutch to drag. The 'I' Drive design features drive tenons, which locate into internal jaws in the lightweight aluminium clutch cover, eradicating the onset of clutch drag.

The 'I' Drive design has been proven via a program of extensive dyno tests, which assessed durability in challenging conditions. During the test, the 'I' Drive maintained optimum performance under arduous operating conditions for significantly longer than the conventional clutch design.

With up to 10 per cent less mass than conventional clutches, and with 15 per cent less rotational momentum, the design also features an innovative 'wear plate' to combat wear on the drive legs of the lightweight aluminium clutch cover, where they interact with the steel plates.

The new design is already in competitive use in the WRC and NASCAR, while another unit is currently undergoing internal testing for use in enduring racing and touring car

TOOLING

Webcon Carburettor Jet Drill Set

Experimenting with various carburettor jet sizes can rapidly become an expensive exercise, and result in a lot of unused jets going to waste. Now, Webcon have released a complete micro drill set to enable tuners to determine the correct size of jet needed. Having found the correct size, it will then be possible to order the appropriate jet from Webcon without trial and error guesswork.

See more at www.webcon.co.uk

AIR FILTERS

Pipercross coated air filters

Race and rally engineers constantly struggle to manage air intake temperatures, particularly in production-based competition vehicles such as British Touring Cars. The increased heat generated, and the restrictions on modifications, lead to the air intake temperatures rising with a noticeable drop in power. Now leading air filter manufacturer Pipercross believes it has solved the issue on its flagship C7000 filtration unit, thanks to the use of a ceramic coating from Zircotec.

Zircotec already provides a range of thermal management solutions to motorsport protecting both driver and car from the effects of heat, but applying the coating to an air filter housing was novel. 'The C7000 is a closed filtration unit with an aluminium housing,' says Zircotec's sales director Peter Whyman. 'We are able to plasma-spray the housing to prevent heat soaking into the filter itself. As the ceramic coating can lower surface temperatures by 30 per cent, it offers a significant reduction in air temperature inside the unit.'

Visit www.pipercross.net for more information

FASTENERS

Hydraflow coupling

Specialty Fasteners & Components claim that their new Hydraflow fluid coupling is set to be a breakthrough product in the motorsport fluid connector market.

The new Hydraflow 14J21 series features a unique safety strap for added security, as well as non-snagging latching pawls and integral electrical bonding wires.

Check out www.specialty-fasteners.co.uk for more details

PRI 2012

MACHINING

Hardinge MF

Machine tool manufacturer Hardinge has introduced an new small footprint/large capacity Quaser MF500C machining centre. The Quaser range of MF five-face machining centres bridge the gap between simultaneous and non-simultaneous five-axis machining needs. The latest addition to the range has an enlarged trunnion table to accommodate substantial sized workpieces.

The Quaser MF500C can accommodate up to a 500x300mm workpiece, with a table load capacity of up to 200kg, yet has only a 2.6x3.2m footprint. It's equipped with a BBT40 spindle taper with a maximum spindle speed of 15,000rpm.

The machine also allows the operator to machine with any four of the five axes. An idle axis can be altered at any point in the operation so that a first phase might use A, X, Y and Z while the second operation may not utilise A – the tilting axis – but bring in C, the rotary axis. It should be stressed that on the MF500C each axis is a full CNC with contouring capabilities. As standard, the UK Quaser MF500C machines are equipped with the Siemens 828D controller although a Fanuc option is available on factory order.

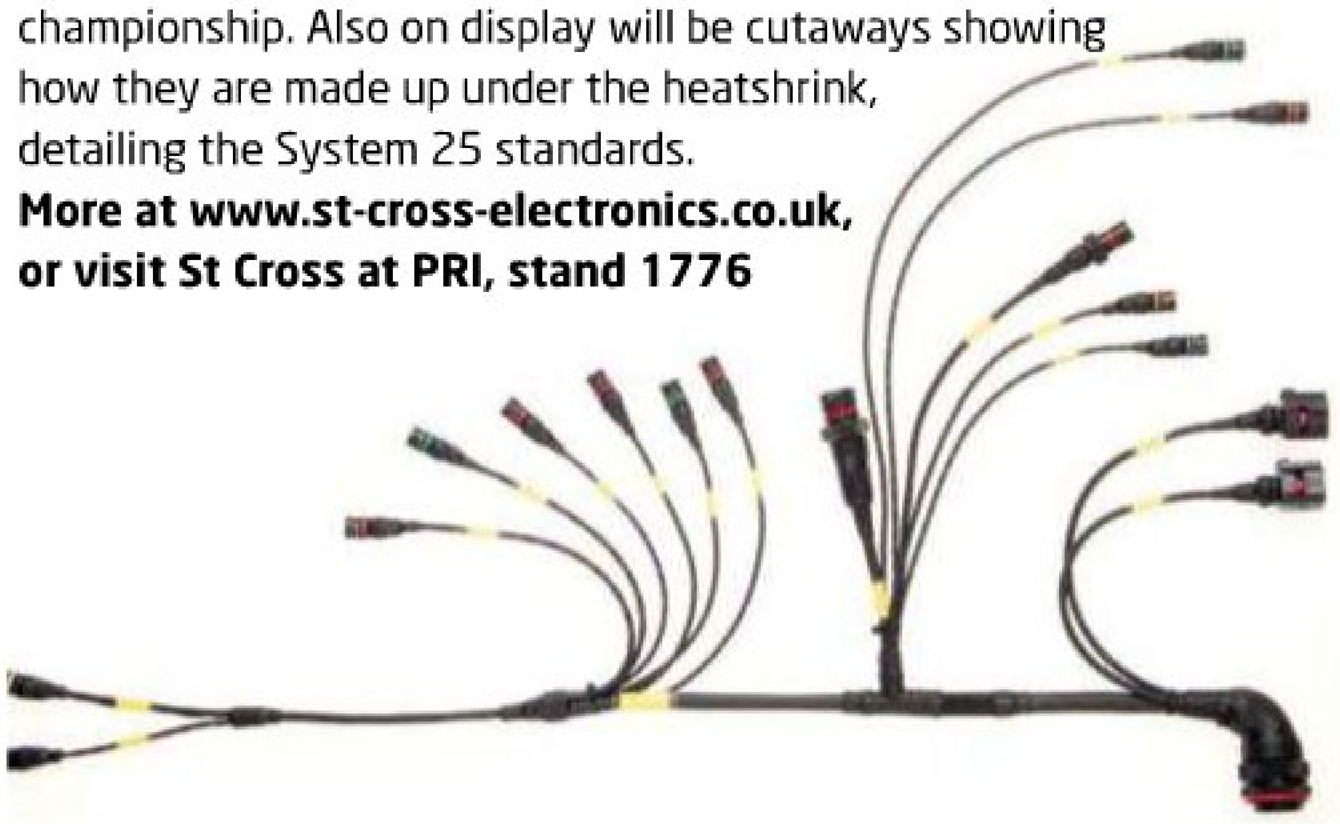
See www.hardinge.com for more information

ELECTRONICS

St Cross Electronics

UK-based St Cross Electronics will be showcasing a range of EFI NASCAR cable looms similar to ones that have made it to victory lane in this year's Sprint Cup championship. Also on display will be cutaways showing how they are made up under the heatshrink, detailing the System 25 standards.

More at www.st-cross-electronics.co.uk, or visit St Cross at PRI, stand 1776

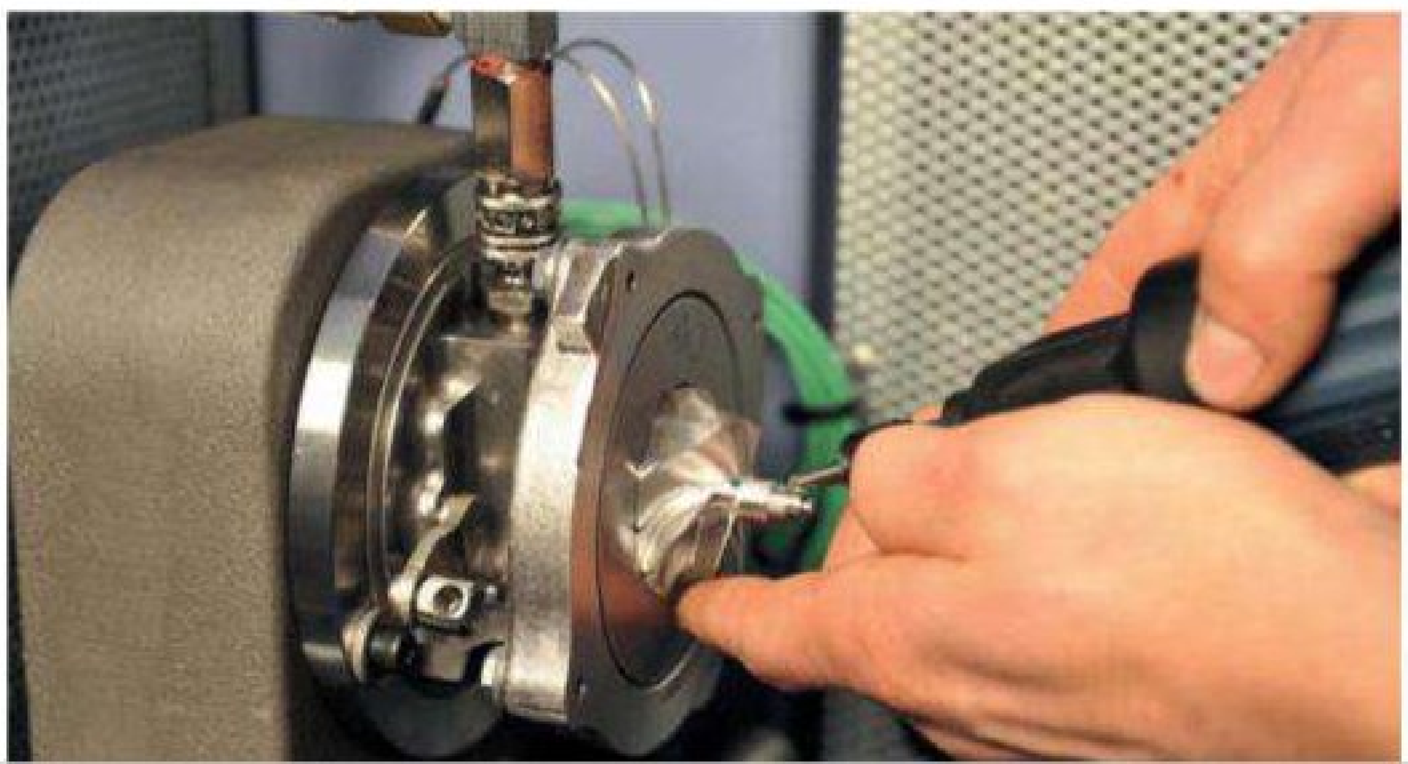


HARDWARE

Breuer Technical Developments

Belgian firm BTD is looking to partner with customers on the development of a range of racing products, including high performance and series production engines, competition engines (GT1, GT2, GT3, LMS, WRC), single components and engine sub-assemblies, supercharging systems, turbo charger development and new state-of-the-art balancing equipment.

For more information visit www.btd.be



HARDWARE

Lifeline Zero 360

The new Zero 360 fire suppression system is an endorsement of Lifeline's innovative approach to research and development. Quicker to install and even more efficient at deploying its highly effective 3M Novec 1230 gaseous extinguishant, this represents Lifeline's most significant breakthrough in driver safety technology in the company's history.

Visit www.lifeline-fire.co.uk for more information

SEALANTS

Gregseal F-Types

Seal manufacturer Gregseal now has full racing approval for both of its F-Type seals, for Big Block Chevy and Small Block Chevy Race Engines. The F-Type seals are a unique one-piece design offered as an upgrade from the regular two-piece items and will seal successfully to 25.0"Hg vacuum without leakage. It is reported that extra power and torque are being achieved from the seals and reduced shaft surface wear is extending the life of the crankshafts, reducing the cost of engine rebuilds. Gregseal says that the F-Type seal principle could be easily applied to most two-piece seal applications such as Ford, Chrysler, etc.

For more details check out www.gstracing.co.uk

FASTENERS

Racetech

Racetech tube connectors and fluid couplings are designed specifically for motorsport use with strength, weight and pricing as a priority. The connectors are made from 7075 aluminium to the highest standard, with an easy-clasp action for quick removal. Up to 15 per cent lighter, stronger and smaller than existing products and compatible with other manufacturers weld ferrules.

See www.racetechdesign.com

SENSORS

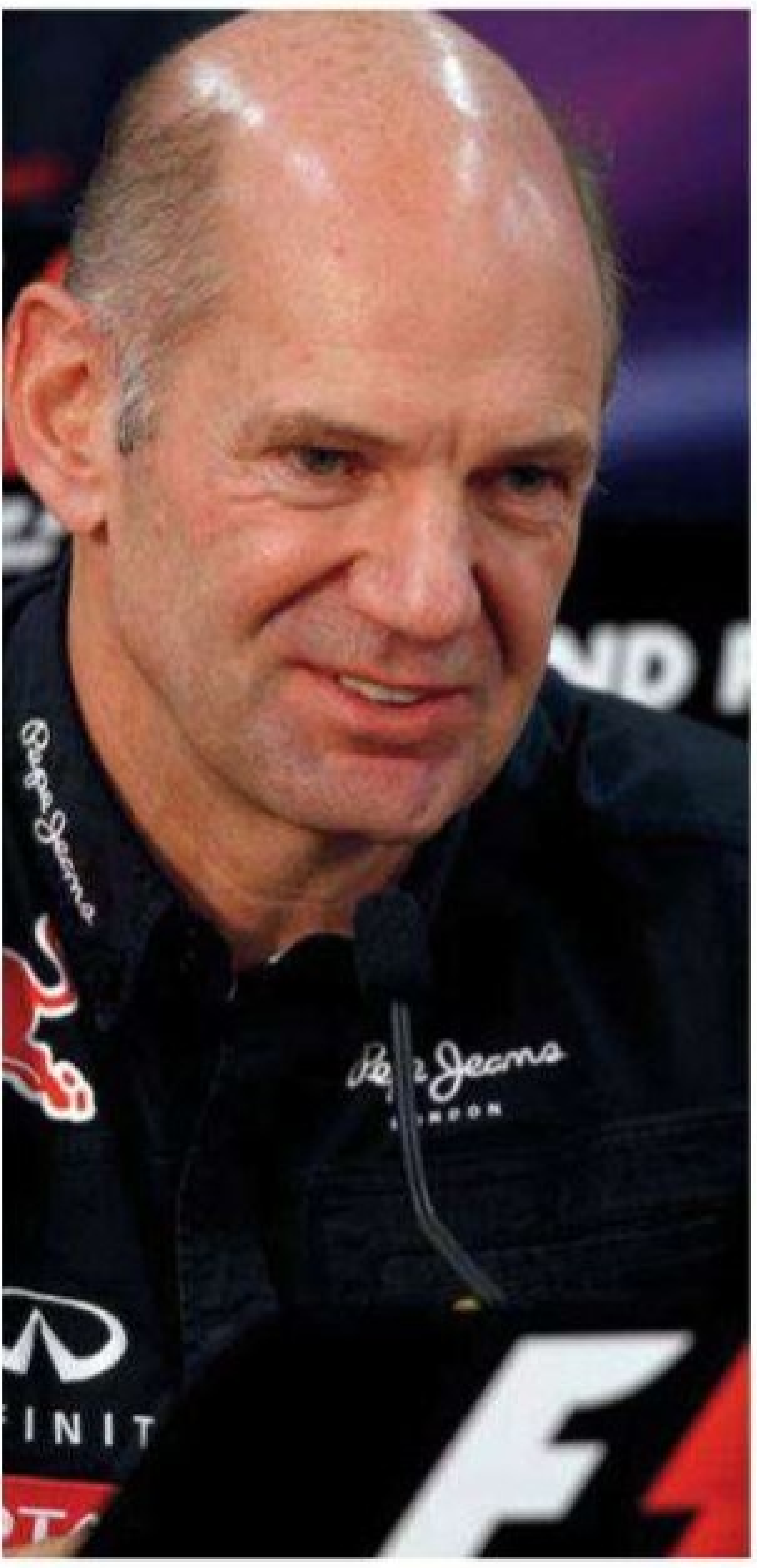
Gill Sensors

Gill Sensors has developed customised non-contact throttle pedal and clutch actuator position sensors for a number of leading Formula 1 race teams. The sensors have been formally homologated by the FIA and provide race engineers with critical feedback regarding throttle pedal position and clutch wear during a race weekend.

For more information visit www.gillsensors.co.uk

Technology transfer

Without doubt the most successful Formula 1 designer of the past decade, Adrian Newey offers his nomination for the Technical Excellence award for innovation in motor racing – technology transfer



Motor racing is a service user, taking technology that has been developed in other industries, and make the best use of them to allow a competition vehicle to travel faster within a set of regulations.

As an inventor, motor racing does not excel, according to Adrian Newey, the most successful Formula 1 designer in the past 20 years with designs that have won eight constructors' titles, and nine drivers' titles, not including the 2012 racing season.

'Motorsport as an industry is a user of technologies that have been developed in other industries, aerospace in particular,' says Newey. 'So CFD programmes, aerodynamic understanding, simulation tools software and hardware – all are developed outside motor racing, and we apply them because we are not big enough to invent them. I think for the application of those, I would agree with [other nominations from] Peter [Wright] and Ross [Brawn], but I wouldn't say that they were motor racing inventions.

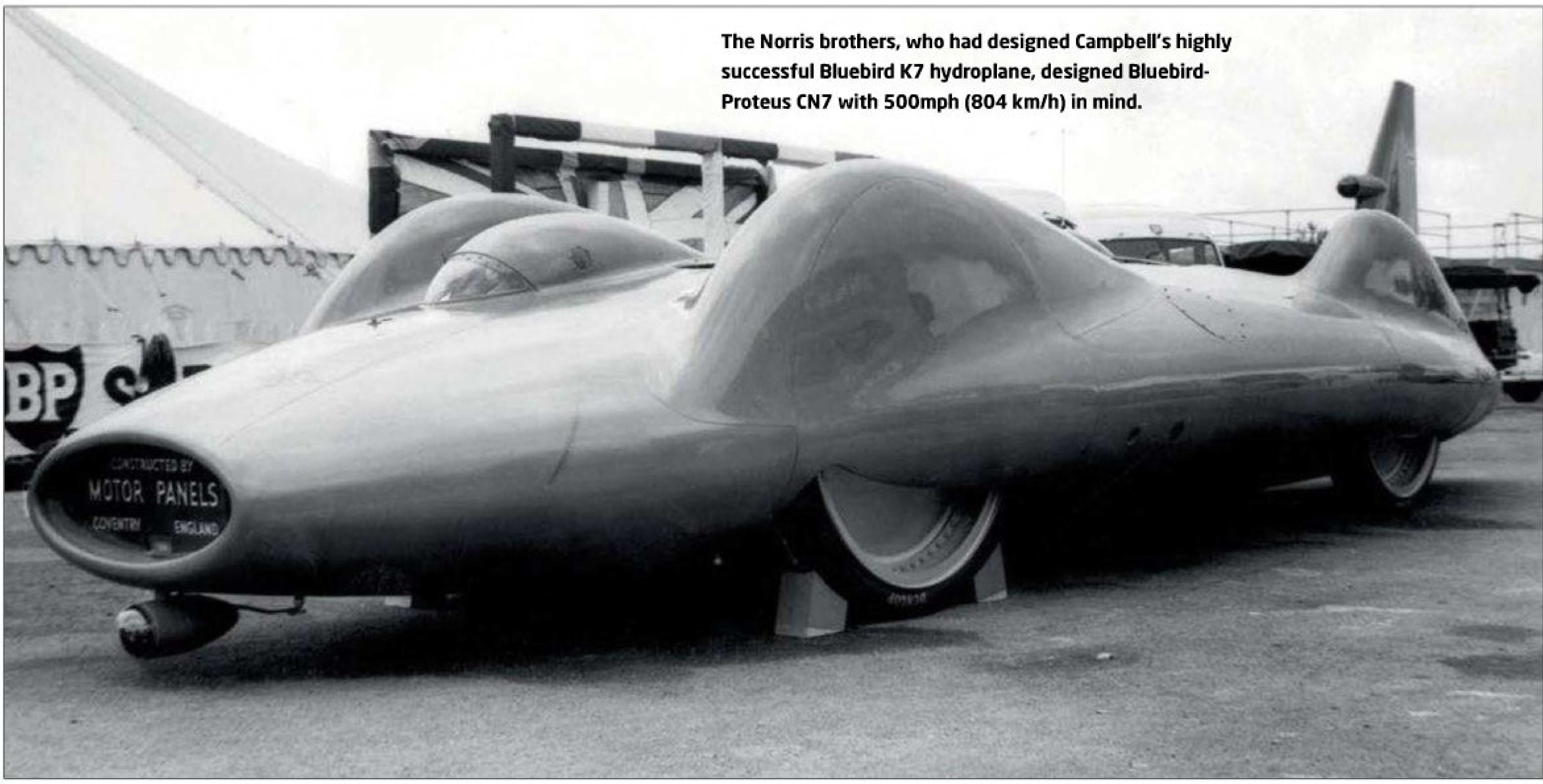
'I think in terms of one of the biggest advances made, although it was not strictly speaking a racing car, was Bluebird. Arguably for its time it was the most advanced vehicle.'

The Bluebird Proteus CN7 was the car that Donald Campbell used to set a record of 403.1mph in July, 1964, the last outright land speed record car that was wheel driven. It was a revolutionary car that featured an advanced aluminium honeycomb chassis, featured fully independent suspension and four-wheel drive. It also had a head-up display for Campbell.

'It was the first car to properly recognise, and use, ground effects,' says Newey. 'The installation of the jet turbines is a nightmare, and it was constructed using a monocoque working with a lot of lightweight structures. It was built in a way that you build an aircraft, but at the time motor racing teams weren't doing that.'

The car featured a Bristol-Siddeley Proteus gas turbine engine that developed over 4,000bhp. It was a two-spool, reverse flow gas turbine engine that was specially modified to have a drive shaft at each end of the engine, to separate fixed ratio gearboxes on each axle.

It was designed to do 500mph, but surface conditions, brought about by adverse weather in 1963 and 1964, meant that its fastest recorded time was nearly 100mph short of its hypothetical capability. It is interesting to note that, should an exact replica be built today, and it did achieve its potential, it would beat the existing record of 470.444mph set by Don Vesco's Vesco Turbinator in 2001, and still be the fastest wheel-driven car today.



The Norris brothers, who had designed Campbell's highly successful Bluebird K7 hydroplane, designed Bluebird-Proteus CN7 with 500mph (804 km/h) in mind.

World of motorsport heads to Birmingham

The 2013 Autosport International show will yet again host another strong lineup of international exhibitors at Birmingham's NEC, on 10-13 January. As exhibitors continue to commit to Europe's largest dedicated motorsport trade show, which starts with Autosport Engineering on 10-11 January, more than 15 per cent of the currently confirmed companies are based outside of the UK.

Including 12 first-time exhibitors, so far more than 70 international businesses from 14 countries have confirmed their presence. The United States leads the way with 15 exhibitors, followed by Italy with nine, and Germany with seven. Beyond Europe, multiple companies will make the journey from Australia and China, while transmission experts MFactory Competition Products will be Autosport International's first ever exhibitor from Hong Kong.

'Autosport International is the best place in Europe for us to meet people from both the motorsport engineering industry and the general public,' said Ola Lennström, marketing communication manager for Swedish suspension experts Öhlins. 'Appearing across all four days of the show allows us to meet a vast range of new customers, from those involved in world championships to national racers. We haven't found an equivalent show in Europe.'

Across the four days of Autosport International 2012, over £800m worth of business was generated.

'Over the last two decades, Autosport International has cemented its reputation as the place the motorsport industry does business,' commented Autosport International show director Ian France. 'It's a European hub for both the British and global motorsport communities to interact and do business on the eve of a new season.

'International interest is again strong for January's show, with new exhibitors booking their presence all of the time, we're looking forward to hosting them all at the NEC.'

Autosport International will also attract industry decision makers from around the world. Last year's show saw 28,500 trade guests attend, including 5,100 overseas visitors from more than 60 countries.

'Radical has exhibited at Autosport International for over a decade and, yet again, the 2012 show was an overwhelming success, generating approximately a quarter of a million pounds of business,' said Will Brown, marketing executive for Britain's Radical Sportscars.

'It was the perfect platform to launch our new road legal SR3 SL to the UK audience, with visitors from all over Europe and as far afield as Latin America and Asia expressing an interest in purchasing the car.'

Autosport International runs from 10-13 January 2013, with the opening two days dedicated to trade visitors. Adult tickets are available from £26, with discounts for group bookings. To register call +44 (0)845 218 6012, or visit www.autosportinternational.com.

IN BRIEF

RICHARD BURNS

A tribute to 2001 World Rally Champion Richard Burns will be celebrated on the rally feature at Autosport International 2013. Headlining the stunning seven-car display at the annual motorsport show is the factory Subaru Impreza WRC-S7SRT used by Burns in 2001 to become only the second British driver to win the World Rally Championship.

Also featured will be the Impreza WRC-W25SRT taken to victory at Rally GB in 2000, and the Legacy models from his title-winning 1992 Group N National and 1993 Group A British seasons.

Bookending Burns's WRC career, three Peugeots complete the tribute. The Group N 205 GTI driven to the 1990 and 1991 Peugeot Challenge titles will appear alongside his Group A 309 GTI from Rally GB 1991, and a Peugeot 206 WRC used by Burns in 2002 and 2003.

A Tribute To Richard Burns will feature at Autosport International 2013 through the assistance of the Richard Burns Foundation. Created following Burns's passing in 2005, the Richard Burns Foundation raises funds to help people who are affected by serious illness or injury gain access to the best possible care.

BLADDER CONTROL

ATL Racing Fuel Cells will exhibit a Formula 1 fuel cell for the first time as part of its Autosport International 2013 presence. Having supplied cells to every F1 team for almost 20 years, ATL has manufactured a cutaway bladder specifically to exhibit at the show.

Following the popularity of Sauber F1 Team's cutaway chassis video, which has been viewed over 1.5 million times since it was posted to YouTube in May, ATL's stand in Hall 9 will go one step further, giving visitors a rare opportunity to view the intricate technology first hand.

THEY HAVE THE POWER

AT Power have developed a 'fly-by-wire' variant of their unique, 'shaftless' throttle body for the FIA World Touring Car Championship and FIA World Rally Championship. The Electronic Throttle Control (ETC) throttle body will form part of the forced induction system on a new, 1.6 litre WRC engine, likely to launch in 2013. The shaftless throttle body design delivers more power and better torque than conventional throttle bodies, by removing turbulence-generating restrictions of the shaft. The motorsport performance experts will launch several new products at Autosport International 2013, including fly-by-wire throttles for a range of high-performance Japanese models; Toyota's GT86, Nissan's GT-R and the Subaru BRZ. AT Power will be based in Hall 9 on 10-11 January.

INDUSTRY CONFERENCES

The GRAND-AM Racing Group, Northamptonshire Enterprise Partnership and the CRP Group are among the industry leaders to announce they'll host exclusive workshops during Autosport Engineering, in conjunction with the Motorsport Industry Association.

One-hour workshops are available across the two trade days, 10-11 January, as the ideal platform to launch a new product or promote existing products and services alongside an Autosport International stand.

Following recent news of its merger with the American Le Mans Series, the GRAND-AM Racing Group will brief guests on the series and its future plans, while the Northamptonshire Enterprise Partnership will outline the county's economic opportunities. Featuring six companies, the CRP Group will host a free presentation, detailing its application of motorsport technology in the automotive and aerospace sectors.

HOOSIER AND FUCHS JOIN ASI

Consumable giants Hoosier and Fuchs are among the latest companies to confirm their first attendance at Autosport International. The UK arm of American tyre supplier Hoosier will appear on all four days of the show in Hall 8, while Fuchs Lubricants UK will also feature in Hall 6.

Among the international contingent, American safety and racewear brand Simpson Performance Products will be present on 12-13 January, one of over 40 new exhibitors confirmed.

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Money matters

At school, I very quickly realised that economics was not a subject at which I could ever excel. As such, my understanding of finances to this day is a little off-kilter, and as far as I am concerned, the International Monetary Fund might as well make its policies out of syrup. I hope that, should the ice-caps indeed melt, they will reveal that the polar bears and penguins have been guarding three buttons which, when pressed simultaneously, will reset the entire global financial system. The national debt for every nation will be wiped out, and we can talk about profit for every country instead of how to manage vast interest payments.

Now, someone with a beard will explain that this is not how the world works, and that countries somehow rely on debt to function. Just as war breeds innovation (Northern Ireland, apparently, has the best knee surgeons in the world following the Troubles, where a bullet to the kneecap was a favoured form of punishment), so running countries in debt is profitable.

Last month I wrote that the cost of fuel has to rise to encourage innovation. Discussions with various people who have shaved off their beards, but still know what they are talking about, suggest that stretching fossil fuels further is the cheapest and most likely short-term solution to our travelling costs. Alternative fuels and electronic hybrid systems are not as clean as first thought, and are spectacularly expensive, as Formula 1 and sportscar racing has already found out.

"If more can be done to recoup what gets spent, the cost of racing reduces"

Meanwhile, the ACO's decision to reduce the cost of GT racing by introducing a set of technical regulations to a category that currently didn't have a set of technical regulations, but which was balanced by a driver telling the scrutineers how the car felt at a particular set of circuits.

As barmy as this sounds, it worked just as well as the FIA's new policy of mapping each car aerodynamically and mechanically, and then applying science to the whole process. Despite extensive research and expense, in the first year it was no more accurate than previous attempts. I will make the concession that previous attempts took several years to get it right, but melding GT3 cars into GTE, particularly with turbos involved, is no mean feat. And no cheap feat either.

Nevertheless, this is a plan for the future. The confusing bit for me is that the ACO and the FIA have constantly criticised the costs of GTE racing. Yet look at the ALMS, or the FIA World Endurance Championship. Ferrari, Porsche, Aston Martin, Corvette, BMW, and Lotus have all built GTE cars. Corvette will build the new C7 into a contender in 2014, McLaren too out of its MP4-12C, while BMW is rumoured to be building a Z4 for 2013, competing against Porsche's 991, that the factory will race 'with customer support', according to its head of motorsport, Hartmut Kristen.

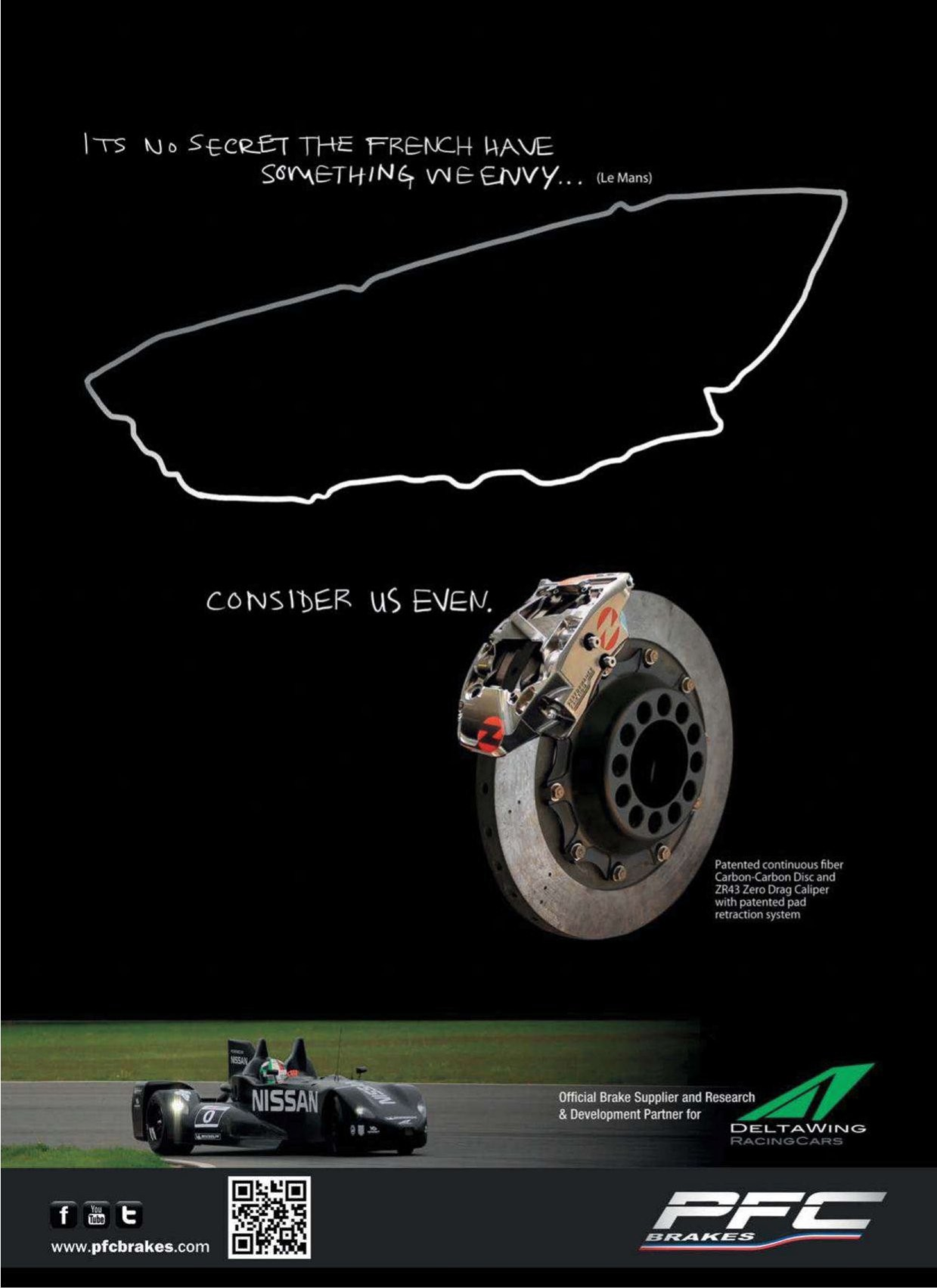
Is there really a need to cut costs? Can't we take these existing cars, those that are one or two years old, turn them into GTE-Am cars, and sell them around the world into the various series? Cue interjection of man with beard – GT3 is enormously successful as a privateer class. Indeed, a man with wavy hair and a beard, Stephane Ratel, says just that. GT3 is all about balance of performance and technical innovation is actively discouraged. Sure, Ratel made mistakes, including the change in regulation that permitted one update per year for each GT3 car rather than one in a product cycle, which rather affected costs, but the actual race results are still determined by the quality of the gentleman driver rather than the car technology. Therefore, his Blancpain series is something of a success.

Martin Whitmarsh has spoken out about honouring the RRA, and ensuring that smaller teams aren't priced out of the Formula 1, or indeed any other, market. The increase in engine and gearbox life undoubtedly helps, but the return must be there on investment. Motor racing is only expensive if the amount you recoup is vastly different from what you spend. If more can be done to recoup spent money, the cost of racing reduces.

From my rather basic grasp of economics, it seems that there are ways of cutting the cost of motor racing without mass change in philosophy and new glass ceilings. It just takes a little bit of thought.

EDITOR
Andrew Cotton

Correction; In the December edition of Racecar Engineering, we stated that the electronics for the Caterham SP300R were supplied by Cosworth. The wiring is made by St Cross Electronics, who also built the steering wheel. Ole Buhl Racing supplied the ECU.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