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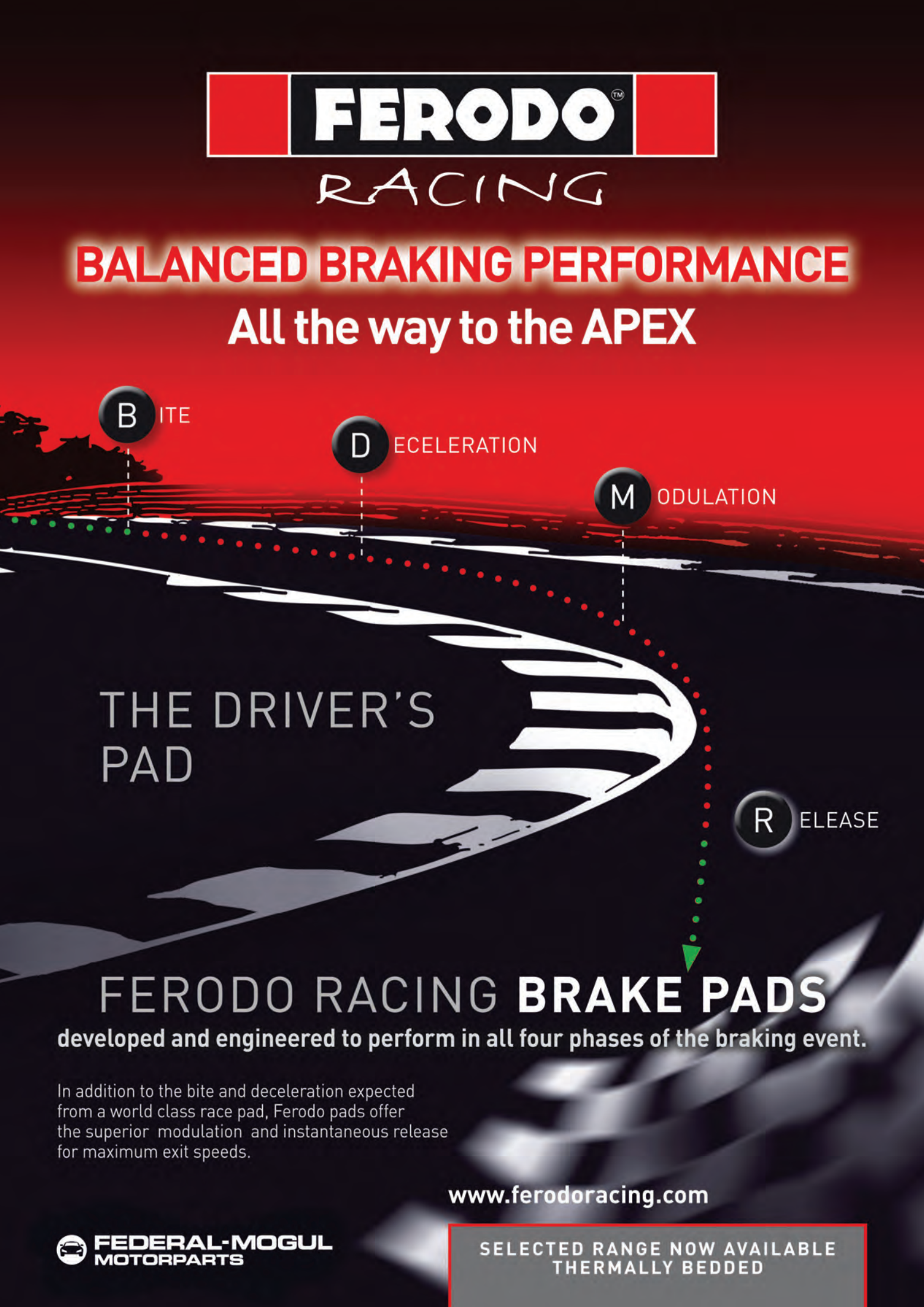
Le Mans technical debrief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WHY REFUELLING PLAN BLEW UP IN F1'S FACE

Dominic Harlow explains why controversial plans to introduce three-second refuelling stops were always doomed

COVER STORY Page 18

"Comparing the mass-saving cost gradient if a similar gain was to be found from the car, at maybe £50-100,000 per kg, it looks like the fuel mass saving is potentially worth considering"

DRIVING TECHNOLOGY INTO POLE POSITION
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A pipe dream comes true

Well, I can't quite believe it. In the December 2013 (RT157) my editorial was headed "Another pipe dream?" where I was reacting to the news that Ford had announced that it was developing a 3.5 litre V6 rather than a V8 for sportscar racing, specifically for the TUDOR United SportsCar Championship in the US. It was being installed in a Riley Technologies car with the press picture showing a white car with a blue stripe running the length of it that was so evocative of Ford's glorious GT40 era. I then surmised that with Ford and RoushYates' engineering skills it was not beyond the bounds of possibility that the Dearborn manufacturer could return to Le Mans to celebrate its 50 anniversary. I did write, though, that it would be a car in the Prototype class rather than in GTE, but I finished the article with the phrase "Now that's a pipe dream".

I am no way a clairvoyant or even clever, I was just expressing a hope as a fan that such a thing could happen. I did not dream for an instance that it would turn to reality, but it has. Furthermore, by coming into GTE, it is entering a fiercely competitive class as we saw at this year's race, especially coming up against the mighty Corvette Racing team. On a side note, personally I was deeply pleased that the lone Corvette won this year. I visited GM Powertrain last year and took an instant liking to everyone there. They might be wearing the corporate GM logo, but they are first and foremost racing guys – gasoline really does run through their veins and it was so good to see them come through what had been a tough week.

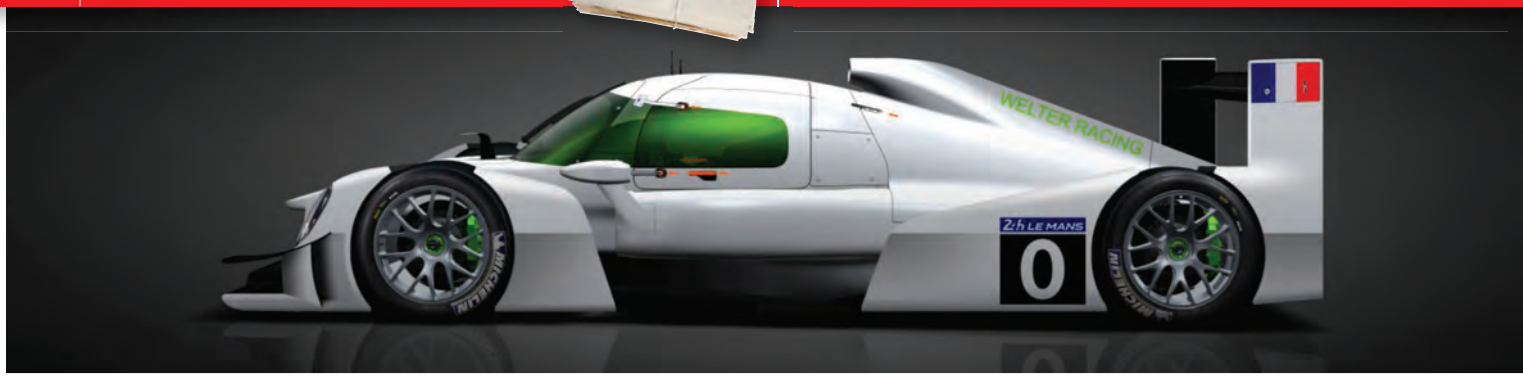
Lest you think that a rookie Ford team doesn't have a chance against the Corvettes, Astons, Porsche and Ferraris, one thing very much in its favour is that its four cars will be run by Chip Ganassi Racing. This is a crack team that not only runs NASCAR and IndyCar teams with considerable success having notched up 17 major championships, including four Indy 500 wins, in its 24 year history, but it has won the Daytona 24 Hours five times, so it knows a thing or two about endurance events.

Nothing compares to Le Mans, though, as everyone who competes there in any capacity will know. To expect the unexpected doesn't even begin to describe what will be encountered over the 24 hours, which is why it ranks as one of the best races in the world.

While Ford has elected to go into GTE, why don't Honda and Renault, and possibly even Ferrari enter teams in the World Endurance Championship? This was a question I was asked more than once at the race. The basic rationale it is that they could use it as free test sessions for their Formula 1 power units, albeit with some slight modifications. Of course, there's a budget and resources to consider and that would run into the tens of millions of dollars, even for a single car team, but in the overall scheme of car company budgets where developing a new production car model costs well over a billion dollars, it's not exactly big bucks. Some of the costs could also be alleviated with sponsorship.

I'm sure there must be reasons why we are not seeing an Acura taking on Audi, Porsche and Nissan, but it would be good to see if one was. It would also be good to see Renault return to this form of racing after such a long time being away. Ferrari? A Ferrari-Porsche dual similar to the one I witnessed at the first Le Mans I attended in 1970? No way, now that's a pipe dream. RT

William Kimberley
EDITOR



Will bio-waste car be a hit for the fans at Le Mans 2017?

By Anthony Peacock

LE MANS, France: The Le Mans 24 Hours will eventually become the world's first waste-neutral race, according to Automobile Club de l'Ouest president Pierre Fillon and former Peugeot style director Gerard Welter.

Welter is the man behind a new project to bring a car entirely powered by liquid methane to the 2017 Le Mans 24 Hours, under the auspices of the event's famous 'Garage 56' initiative, for experimental or new technologies.

Welter's team, WM Racing, already has an illustrious history at La Sarthe, with 25 participations under its belt and an all-time speed record set in 1988 when Roger Dorchy's WM-Peugeot topped out at 405 km/h (253 mph) on the Mulsanne Straight.

"Mastering new challenges has always been what has inspired me," said the 72-year-old Welter, based in Thorigny-sur-Marne, just to the east of Paris, "and that's why we have embarked on this latest project at Le Mans."

The man who is widely credited for having saved Peugeot when he designed the iconic 205 in 1983 – which turned the company's fortunes round – has now turned his attention to saving the planet – a task that is probably a bit easier.

"One of the biggest threats to the ozone layer, and therefore our life as we know it currently, is methane," he pointed out. "So if we can harness that methane and put it to good use, then we end up with a genuinely virtuous circle – recycling that cleans up after itself. Potentially, the world's waste could power every car in the world."

Biomethane fuel has been used for several agricultural applications, especially in China, but this is the first time that it will ever be seen in a competition car. If the technology is extensively adopted, Fillon and Welter hope that all the methane gas released from the waste produced by Le Mans can be offset by the equivalent usage to power the cars in the race.

The biomethane needed to power one car for the 24 hours could be produced from the waste that 160,000 people leave behind at Le Mans in one day. With 263,500 spectators who turned up to Le Mans this year, the target is well within easy reach.

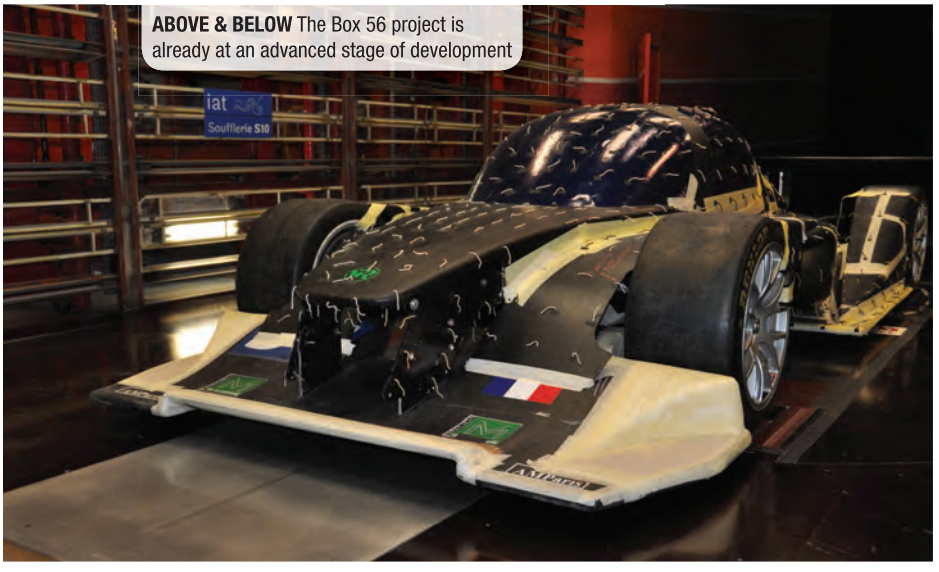
"On paper, this technology is not too complicated," said Welter. "The biggest challenge is making sure that our liquid biomethane gas remains at minus 180 degrees centigrade, which is the temperature required when it is injected into the engine. For this you need the right materials and the right design. It's really an exercise in thermodynamics."

To help maintain this temperature, the gas tank will be directly attached to the 1.6-litre, three-cylinder, turbocharged engine, which puts out 450 horsepower. At Le Mans, the tank will go from full to empty in the space of around 20 minutes, meaning that it will be relatively easy to ensure that the gas remains liquid. A road car application would be considerably more challenging, requiring a miniature version of the full-scale cryogenic tank that the fuel will be stored in before it is put into the car at Le Mans.

The engine itself is a bespoke WR unit, with the only production-derived component being a modified cylinder head from the PSA Group.

Welter was previously involved in the GreenGT H2 project, which was due to make its debut from Garage 56 at Le Mans two years ago. This was a hydrogen-powered electric car that produced drive directly to the wheels from a hydrogen fuel cell. WM Racing designed the chassis, with the rest of the technology coming from the GreenGT company in Switzerland. It did not make it to the grid in time for Le Mans 2013, withdrawing its entry before the test day, but has since run successfully at circuits such as Paul Ricard and Lurcy-Levis.

"That was an incredibly ambitious project and the timescale was just too



ABOVE & BELOW The Box 56 project is already at an advanced stage of development

short," said Welter, "but it worked in the end. It's a very valid technology. My personal vision of mobility in the future is small electric cars for urban and suburban environments, with hydrogen and biomethane for longer journeys."

The lessons learned from the GreenGT H2 project will primarily be translated into the chassis design – Welter's area of particular expertise – and he has promised "a radical aerodynamic concept", on a vehicle that will be slightly smaller than the current LMP cars.

However, he stressed that: "It will still be recognisable as a car, with four wheels located at each corner. We just wanted to take advantage of the extra freedom that running under the Garage 56 rules allow us."

The project is already at an advanced stage of development, with the monocoque completed and the engine on target to run within a completed car early next year. The only potential cloud on the horizon is finance.

"Up to now, this has all been our own investment," said Welter. "None of this is technology that you can buy commercially. Of course, it's come at considerable cost, so we are actively looking for partners. We're in discussions with a few companies – some very large firms and other more bespoke specialists – although we aren't in a position to announce anything yet. There's no such thing as certainty in this business, but I feel confident we will be on the grid at Le Mans in 2017."

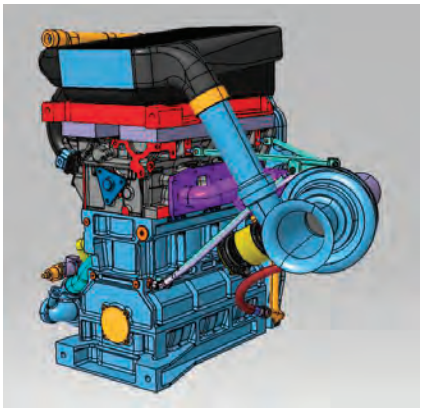
The very last item on the shopping list will be the drivers, not seen by Welter to be a priority. No special technique will be required to drive the BW Biogaz Le Mans 2017 and from the outside it will sound like a normal petrol-powered sports prototype. The car will be the star rather than whoever is behind the wheel.

Approximately 30 people are currently working on the project, under the direction of Welter – who describes himself as 'very much hands-on' – and technical chief Vincent Soulignac, a long-time associate. Former Peugeot Sport engine guru Jean-Pierre Boudy, who was responsible for the Peugeot powerplants that won Le Mans in 1992 and 1993, heads up engine development.

Welter talks a compelling argument, but it begs the question: if biomethane is as straightforward and logical a power source as he claims, how come it hasn't been more widely adopted, both in competition and the automotive world as a whole?

"I can answer that as somebody who has been in the car industry all my life," he said. "The industry is a juggernaut, an oil tanker. Once it's set on one course, it's very difficult to stop it or make it change direction. There are very few big companies out there who are willing to take risks. You need the smaller companies to do that, and showcase what is possible." RT

ABOVE & BELOW The 1.6-litre, three-cylinder, turbocharged engine is a bespoke WR unit. The only production-derived component is a modified cylinder head from the PSA Group



Ford returns to Le Mans

Scotty Whitelaw

LE MANS, France: Ford has announced that it is returning to Le Mans in 2016, the 50th anniversary of its first win with the landmark GT40 in 1966. It will compete in the GT Endurance class for professional teams (LM GTE Pro), rather than the top tier Le Mans Prototype 1 (LMP1) category in both the World Endurance Championship, of which Le Mans is the key race, and the TUDOR United SportsCar Championship. It will make its race debut at the Daytona 24 Hours in January.

The GT race car shares the production supercar's focus on advanced aerodynamics and lightweight composite construction with much of the development work having been carried out by Multimatic. Like the 2015 Detroit show car, the GT race car relies on a 3.5-litre EcoBoost V6 engine that has been developed by RoushYates that made its race debut in 2014 in the Riley that competed in the TUDOR United SportsCar Championship, winning that year's 12 Hours of Sebring and also the 2015 Rolex 24 at Daytona.

"As we developed the Ford GT, from the outset we wanted to ensure we had a car that has what it takes to return Ford to the world of GT racing," said Raj Nair, Ford's group vice president, global product development, and chief technical officer. "We believe the Ford GT's advances in aerodynamics, light-weighting and EcoBoost power will make for a compelling race car that can once again compete on a global stage."

The cars will be run by Chip Ganassi Racing, the crack US team that has won the Daytona 24 Hours on many occasions as well as winning many races over the years in NASCAR and IndyCar. "We've won races and championships, but we've never run Le Mans," said team owner Chip Ganassi. "When presented with the opportunity to compete with the all-new Ford GT on the world's biggest sports car stage, and on the 50th anniversary of one of the most storied victories in racing history, how could any race team not want to be part of that?" RT

BELOW Fewer spoils: Denny Hamlin's Toyota Camry, seen here at Kansas on 8 May, will have a much smaller spoiler at Kentucky in July

Matthew T. Thacker/LAT Photo USA for Toyota Racing

NASCAR acts again to improve show with 'race test'

Andrew Charman

DAYTONA BEACH, FL: NASCAR is to 'live-test' aerodynamics changes expected to be introduced for the 2016 season in the Sprint Cup Series race at Kentucky Speedway on 11 July. The changes follow on from a package developed for the start of the current season, and according to NASCAR racing with them has been brought forward after consulting teams and the industry.

NASCAR had been known to be working on further changes to the 2015 package, which included spoiler reductions and a cut in horsepower, and it was widely rumoured that the non-points Sprint All-Star Race at Charlotte on 16 May would be run to the 2016 rules as effectively a race test. In the event the race ran to current rules with Sprint Cup officials hinting that the 2016 package might not be any different to the current one.

However, the changes have now been revealed to be significant. The height of the rear spoiler, cut for 2014 from eight to six inches and which was said to reduce rear-end downforce by 300 lb, is to be further reduced to 3.5 inches. The front splitter extension panel or radiator undertray, previously cut from 43 to 38 inches, will now be 25 inches, and its overhang outside the body will be cut by 1.75 inches.

A softer compound tyre with more grip will also be employed at Kentucky, though in announcing the changes NASCAR's chief racing development officer Steve O'Donnell emphasised that the tyre has not been specifically designed for the new aero package.

He added that the development has an obvious aim. "We certainly want to see more lead changes on the race track. We'll evaluate not only that but a number of different factors coming out of Kentucky and see what we can learn and potentially what we can implement down the road."

While the current plan was to revert to the 2015 package following the 11 July race, O'Donnell said, "Any options are on the table coming out of Kentucky". The track has been criticised for processional racing ever since joining the Sprint Cup calendar in 2011.

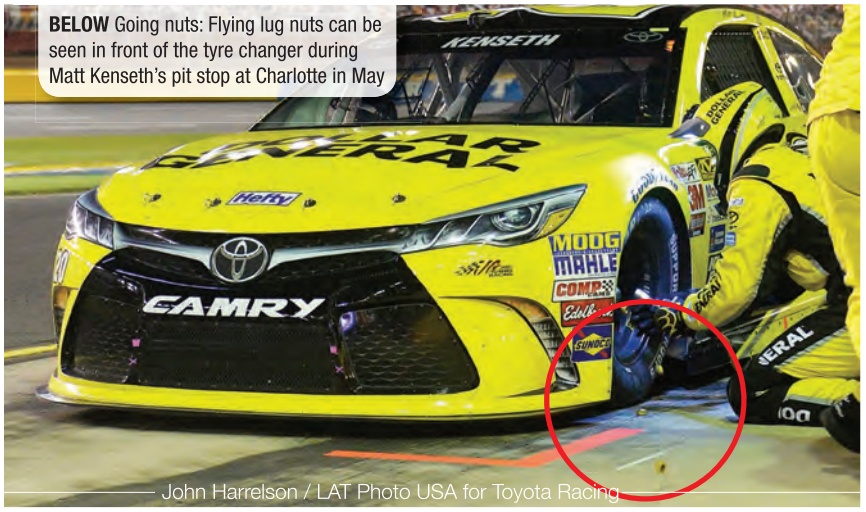
He also revealed that teams have been working on the proposed package for some time, and have enough data to race with it at Kentucky. "This is not a test; this is a race – this is the Kentucky package, and we have tested this over the last 18 months," he said.

Teams that have tested the package in the wind tunnel have suggested the resultant downforce reduction will be between 825 to 1,000 lb, with side force cut by 50 to 55 lb. One engineer has described the package as a "real game changer" suggesting that the effects for drivers will be equivalent to 110 extra horsepower.

O'Donnell has also revealed in other interviews that the sport could be moving towards track-specific aero packages – currently only the superspeedways of Daytona and Talladega use a different setup. He emphasised that this would likely take the form of different packages for low and high-downforce tracks, "not to have it at 36 individual packages."

The changes have brought praise from some drivers, not least Joe Gibbs Racing's Carl Edwards, long an advocate of less downforce. "NASCAR wants to make this the best sport they can for the fans, they want to make it the most fun for the drivers," he said. "Taking downforce off and making the cars hard to drive, in my opinion they're a third of the way where they need to go – they need to keep taking it off and keep making it better." RT

NASCAR problem is nuts

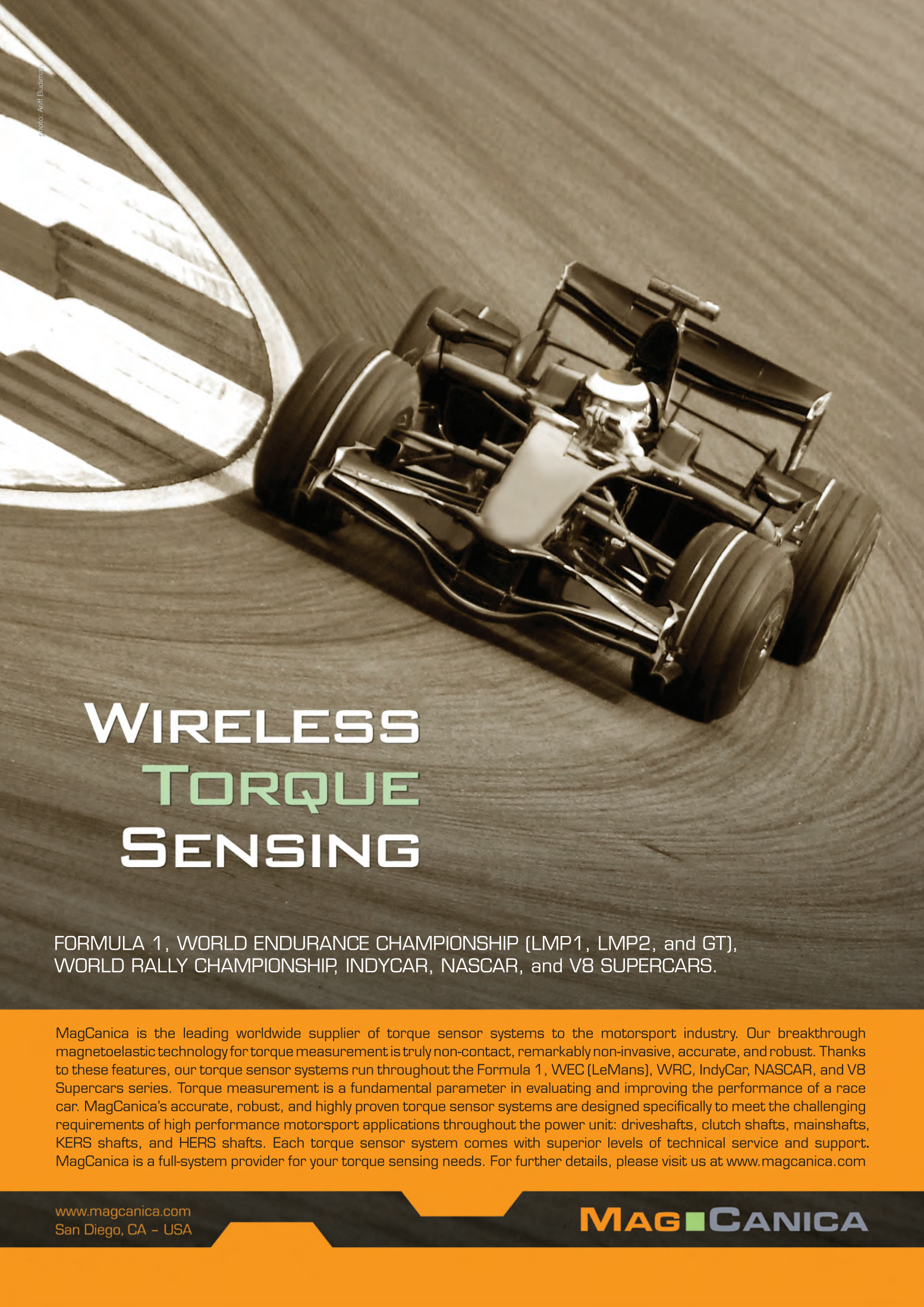


BELOW Going nuts: Flying lug nuts can be seen in front of the tyre changer during Matt Kenseth's pit stop at Charlotte in May

John Harrelson / LAT Photo USA for Toyota Racing

CHARLOTTE, NC: Concerns are growing in the NASCAR pit lane over recurring instances of flat tyres caused by the valve stems being knocked off by the lug nuts flying off the wheel during pit stops. When teams pit and the tyre changer replaces the five nuts on each wheel, the loosened nuts are allowed to fly free from the air gun, being swept up by pit crew after the stop is completed.

There appear to have been instances of the flying nut knocking off the tyre valve stem – the cars of Carl Edwards and NASCAR Sprint Cup points leader Kevin Harvick both having recently been afflicted by the issue. Teams suspect that the problem lies not with the nuts but the means by which the stem is mounted in the wheel. Crew chiefs questioned admit they are at a loss how to solve the problem. RT



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NASCAR warns teams to be by the letter

Andrew Charman

DAYTONA BEACH, FL: NASCAR's continuing problem of Sprint Cup teams pushing the limits of the technical regulations and requiring several passes through opening-day scrutineering has seen another raft of written warnings being issued.

The Hendrick Motorsports team of Dale Earnhardt Jnr, Joe Gibbs Racing's Carl Edwards and Kyle Busch, and the Josh Wise car run by Phil Parsons Racing were all issued the warnings following the race at Michigan International Speedway on 14 June. Earnhardt's car needed three runs through the inspection process before being passed to compete.

Earlier in the season, teams requiring multiple inspections caused significant delays to weekend schedules with some cars being unable to take part in qualifying as a result. While a written warning is not significant in isolation, a team receiving two warnings during the same or two consecutive events can suffer sanctions including last choice in the pit selection process – at some tracks certain stalls can make it easier to achieve faster pit stops – having their track time in practice or qualifying cut, going to the back of the line for pre-race inspection or being selected for post-race inspection.

Teams receiving six or more warnings during a six month period will have the penalty level increased to P2 on NASCAR's sliding scale, which can result in losing 10 championship points, fines between $10,000 and $25,000 and even crew member suspensions. Since NASCAR introduced the written warning system at Richmond in late April, 44 have been issued.

Meanwhile veteran team owner Jack Roush has questioned the consistency of the laser-measuring platform that NASCAR uses in the inspection process. Speaking on Sirius FM Radio, Roush said that the platform does not produce the same results 100 per cent of the time. "It is off… we don't know why," he said. "The temperature may have something to do with it. It does not always give you the same answer for the same set of circumstances on the car dimensionally."

He added that such variances sometimes resulted in NASCAR officials increasing permitted tolerances. "So if you've got something that varies and they give you a tolerance to take care of the variance and you're a racer, then you try to use the tolerance in your favour to make your car better." RT

New car issues force TCR calendar changes

Andrew Charman

THE new-for-2015 TCR International Series has abandoned the South American leg of its inaugural championship to give some of its new teams more time to develop their cars. The eighth round of the series was due to be held in Argentina but has been replaced by a round at the Red Bull Ring in Austria on 12 July, supporting the European Le Mans Series. The other planned South American round in Chile was cancelled in March when changes needed at the brand-new Codegua International Circuit made it unavailable for the planned August race date.

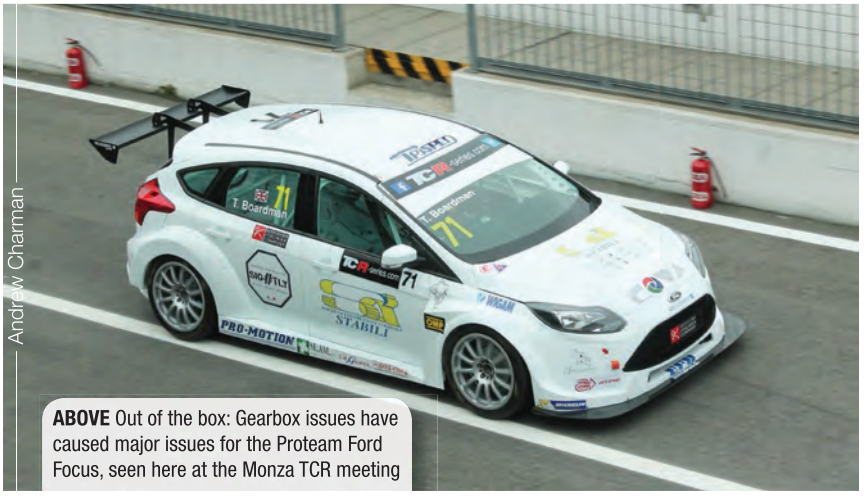
Marcello Lotti, CEO of TCR organiser WSC, said that the decision had not been easy. "We had to be realistic and consider that the technical development of the new TCR cars is taking more time than expected and going overseas would have forced some brands to skip the event. Rescheduling the event in Europe will give them the opportunity to complete the development steps without further delaying their participation in the races."

The move is seen as particularly aiding the Italian Proteam outfit, which has endured a very difficult introduction of its Ford Focus cars built by UK Ford specialist Onyx.

The Onyx design had chosen to use a production gearbox and Torsen differential, which had significant weight advantages over a racing sequential transmission. However, the production unit proved unequal to the stresses of competition, and respected Touring Car driver Tom Boardman, called in to help develop the car at the Monza meeting over the weekend of 24 May, admitted to *Race Tech* his frustration at the unit's continuing failures. A subsequent decision to modify the Focus to use a sequential gearbox resulted in Proteam missing the two following meetings at the Salzburgring, Austria and Sochi, Russia.

Also opting to miss the Russian races was the two-car Campos team of Opel Astras, cutting the manufacturer representation to only SEAT and Honda. Campos had endured a torrid previous round at the Salzburgring in Austria, both of its cars suffering engine issues.

Lotti emphasised that TCR's withdrawal from South America is only temporary. "South America remains one of our main areas of interest. We are planning to organise a press conference in Buenos Aires in the near future to announce our final plans of racing there next year," he said. RT



Andrew Charman

ABOVE Out of the box: Gearbox issues have caused major issues for the Proteam Ford Focus, seen here at the Monza TCR meeting

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IndyCar makes changes to speedway aero kits…

Andrew Charman

INDIANAPOLIS, IN: The IndyCar Series has mandated changes to the superspeedway aerodynamic kits of Chevrolet and Honda following the three airborne crashes that befell drivers Helio Castroneves, Ed Carpenter and Josef Newgarden during the Indianapolis 500 meeting.

As reported in last month's *Race Tech*, in all three accidents the cars, all equipped with Chevrolet's aero kit, flipped into the air after spinning backwards.

Chevrolet, Honda, car manufacturer Dallara and IndyCar have all been working together to try to isolate the causal factors in the accidents, and before the following speedway meeting at Texas, IndyCar mandated changes to the cars. These comprise 'closure panels' fitted to the rear wheel guards and preventing air from flowing through them. This helps to delay the point where lift occurs if a car is spun backwards.

IndyCar also changed the rear wing angle for cars at Texas, mandating an angle between -6 and -10.5 degrees, an increase in downforce compared to the 2014 event.

Chris Jones/IndyCar

BELOW Cover up: The new aero kit covers on Will Power's Chevrolet at Texas Motor Speedway on 5 June

Following the announcement of the package changes, Chevrolet's IndyCar programme manager Chris Berube said that they represented only a measure of controlling such accidents and could not guarantee such a crash won't happen again.

"There's no magic fix that's going to ever prevent it from happening – it's about better understanding when it might happen," he said. "The conditions that caused those cars to do what they did involved hitting the wall going backwards – the wall was definitely a contributing factor – and crash dynamics are very transient and very difficult to model – there are a million combinations for how a crash can proceed."

Berube said that Chevrolet's examination of the three crashes had not proven that its aerodynamic package was at fault, and he was confident that the factors in the crashes were not unique to the Chevrolet kit. IndyCar competition head Derrick Walker added that he had not seen enough evidence to convince him that the Chevrolet kit was to blame, particularly as a Honda-kitted car had not suffered a similar type of accident. He also praised the rival manufacturers for working together to try and find a solution to the incidents. RT

…while Dallara beefs up suspension

INDIANAPOLIS, IN: Higher loads produced by the new-for-2015 IndyCar aerodynamic kits have seen chassis manufacturer Dallara mandate new suspension components. Stronger pushrods have been designed for the right side of cars in time for the rounds at Iowa on 18 July and Pocono on 23 August. Both races see high loads on the right side of the car. The current pushrods will be permitted to be retained on the less affected left side at these races and on both sides at other road and street courses, but many teams are expected to switch to them full time.

On 18 May during practice for the Indianapolis 500 James Hinchliffe suffered a high-speed impact with the outside wall after the right front suspension rocker arm failed. In the crash the right front wishbone punched through the car's monocoque, and it is generally accepted that only the rapid intervention of IndyCar's safety team prevented Hinchliffe succumbing to his injuries.

As a result IndyCar and Dallara mandated new flat plates attached to the rear legs of the lower front wishbones. Approved two days before the Indianapolis 500, all cars were fitted with them for the race. Also made optional was the addition of an extra rod between the front and rear legs of the wishbone. A familiar component of previous IndyCar chassis, they have proven effective in cutting the instances of wishbone intrusion.

Team Penske's cars went into the Indianapolis race with the rods fitted while other teams fitted them before the next superspeedway event at Texas on 6 June. RT

No telling when IndyCars push to pass

INDIANAPOLIS, IN: IndyCar has made its 'push-to-pass' horsepower addition button secret – to encourage more overtaking in races. In the first part of the 2015 season when drivers have used any of the 10 push-to-pass activations they are allocated – each activation adding a 20-second long burst of 50 extra horsepower – the information has been immediately displayed on timing screens, along with how many activations each driver had left. According to series officials, though, the instant alerting to the activation has seen the driver being passed immediately activate their own system to match the burst and defend their position.

IndyCar competition chief Derrick Walker believes that such defensive measures defeat the intention of the system, so from the IndyCar round at Toronto on 14 June, access to the real-time information was removed. "We will limit the availability of that information, which will make things interesting, particularly late in the race," he said. RT

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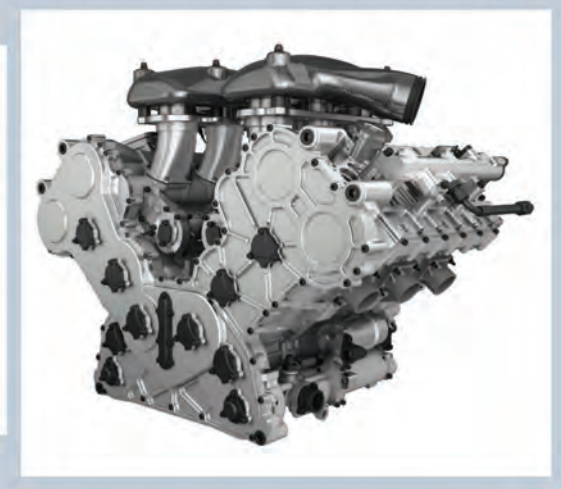

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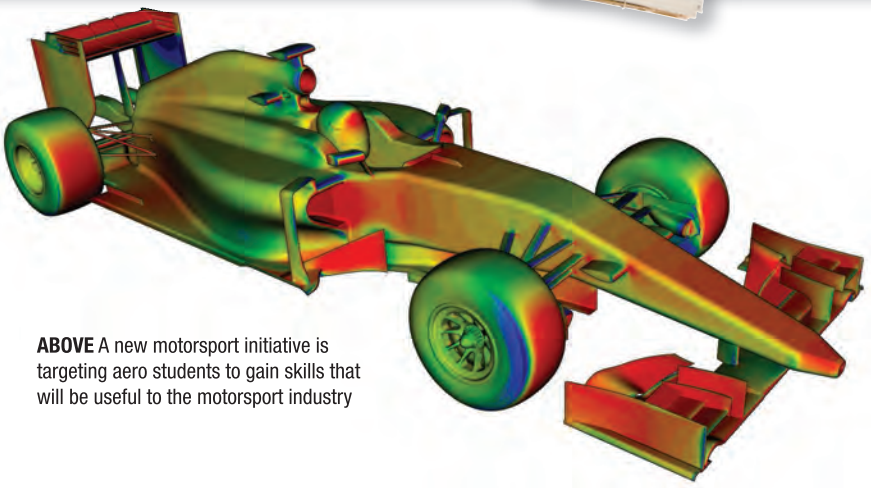

ABOVE A new motorsport initiative is targeting aero students to gain skills that will be useful to the motorsport industry

Aero course to help boost students into industry

William Kimberley

MORETON-IN-MARCH, UK: Tim Milne, head of aerodynamics at the Manor F1 Team, has created UniFi Motorsport, an educational initiative that is targeting students seeking a role within motorsport aerodynamics. Although the course is based on F1 design principles, the skills gained will provide an ideal platform from which to build a career in a wide range of aerodynamic design disciplines. A range of package options are available to suit the experience of the students and the supporting staff at each university. This can include dedicated training sessions prior to the commencement of the course or other direct support for the student team taking part.

TotalSim has joined the project and has developed a simple to use cloud based OpenFoam CFD code that will allow the students to focus on understanding the flow structures around an open wheeled racing car without the traditional barrier of learning a complex new CFD code and package. The software will not require any prior knowledge or experience of OpenFoam or indeed any CFD code. The aim of this approach is to ensure that during this course the students focus on adding performance to their race car and understanding the approach required to do that, rather than on the setup and settings required to run a successful CFD model.

SGI is providing access to a high-performance cluster which will allow all participating teams to run nominally unlimited development cases and compete their designs against other university teams.

The development project is then split into three main evolutions, aligned to the terms of an academic year. In the first term, the team's focus will be on producing their "Race 1 Car". In the second term the focus will be on evolving their design for a "Race 5 Update" and in the final term they will focus on a final update aimed at the final third of the F1 season. For each evolution, UniFi Motorsport will publish the results of the competition, and a student handbook aimed at arming the students with the information they require to continue successfully developing their designs.

By the end of the course, each student should have a detailed appreciation of the latest F1 Technical Regulations, an understanding of how the regulations will change for the following season, a thorough knowledge of how an F1 aerodynamics department works and how the different roles within it interact and experience of developing an area of an F1 car in CFD through a complete design cycle.

The top five teams at the end of the season will also be invited to prepare a presentation either based on their project directly, or on a related motorsport topic to the other competitors and invited guests.

"The discussions and meetings I've held with many of the universities in the UK and abroad have helped guide the setup of the project and we are now in a position to formally launch the programme," said Milne. "The key benefit to those students taking part in this project is highly sought after industry relevant experience, allowing students to develop skills usually only gained by those fortunate enough to secure rare placements in an F1 aerodynamics department." RT

Personnel

The Manor F1 Team has announced the recruitment of **Luca Furbatto**, a mechanical engineering graduate of the Politecnico di Torino, who has been involved in F1 since 1998 when he joined British American Racing as an assistant test engineer, in the role of head of design. In his career he has also worked at Toyota F1 and than at McLaren from 2001 to 2011 as head of stress analysis and materials but ending up as an assistant project leader on the MP4-26 under Paddy Lowe. Furbatto then moved to Scuderia Toro Rosso as chief designer for 2012 overseeing the design of the TR7, TR8 and TR9 projects. He will report to Manor F1 Team technical director John McQuilliam.

The Manor F1 Team has also recently hired **Gianluca Pisanello**, formerly head of engineering operations at Caterham F1 and prior to that at Toyota F1, as its chief engineer. The team has also taken on **Bob Bell** as a technical consultant for 2015. He is a long-established name in F1 having spent 15 years at McLaren before becoming technical director and then managing director at Renault F1 in 2003. He then joined Mercedes as technical director in 2010 until the arrival of Paddy Lowe.

Veteran NASCAR crew chief **Richard 'Slugger' Labbe** has taken over the Sprint Cup Series Richard Childress Racing Chevrolet of Austin Dillon. **Gil Martin**, who has been acting as crew chief to Dillon, moves into "a leadership role within the RCR R&D Department", effectively swapping duties with Labbe.

NASCAR Sprint Cup team Richard Childress Racing has bolstered its engineering department with former Williams F1 engineer **Javier Marcos Padros** and simulator engineer **Lawrence Hodge**, who has previously worked with the Ferrari and McLaren F1 teams. RT

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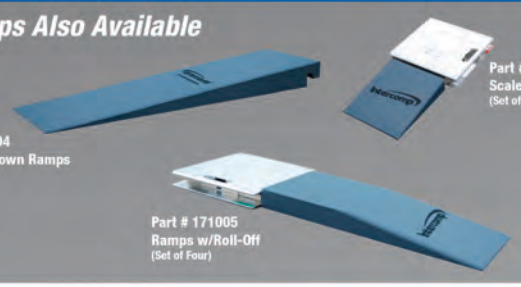

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Torque speaks louder than words

William Kimberley

VENTURA, CA: Californian company ARP, the manufacturer of fasteners found in engines ranging from upgraded OE replacement parts to specialty hardware for racing applications has just acquired two Schatz-Analyse torque tension machines.

With the quality of the bolts and nuts used in assembly having an enormous effect on the quality of assembled joints, performance tests are the most important type of analysis for use in assembly processes. They determine the mechanical properties and tolerances of the fastener components in order to ensure that they fulfil their performance requirements.

"The acquisition is the result of a process we began over a year ago but it became apparent when we reached the shortlist stage that one company stood out above all others and that was Schatz, a German company located in Remscheid just outside Cologne but which also has a US operation based in Holy MI, outside Detroit," said Chris Brown, ARP's director of specialty products who himself spent a few days being trained on it.

"The company has focused on the software side of what the machines can do, so compared to the one we've had for some time, these new ones provide us with so much more data. For example, we can now identify all the components of friction – thread friction and bearing friction – the amount of friction generated under the head or underneath the face of the nut against the washer and the friction against the flanks of the thread, all of which we can isolate and provide data while also looking at the total. Furthermore they also use the same software platform we use to run our fatigue machine, so we are acquainted with it."

The two machines will be used both in a quality control function and more research and development, said Brown. "Where a manufacturer of mass produced bolts would use a machine like this to qualify batches to different specifications and then ship them out, essentially what we do is research and develop a part so that we understand the pre-load, the thread friction and how it behaves when torqued. Typically when tightening down a cylinder head or a set of main caps, you don't go to the full torque but do so in steps, so what we want to do is drill down in between those steps to understand the thread friction and the pre-load."

Brown said the next stage was to develop some programmes in-house while for the customer it means more accurate and in-depth data. "Some of our customers have always wanted as much as we can give them anyway but now we can really drill down and give them much more detail. It's a really exciting time." RT

LEFT ARP has just taken delivery of two Schatz torque tension machines

IN BRIEF

JAPANESE premium car manufacturer Infiniti has withdrawn its support to the Support Our Paras Racing British Touring Car Championship team headed by Derek Palmer Sr. The team has endured a troubled start to the BTCC season. The first car, driven by Palmer's son Derek Jnr, had its initial test only days before the season-opening rounds at Brands Hatch, and the other car for Richard Hawken did not debut until the second meeting at Donington Park. Recurring power-steering issues have also afflicted the cars, keeping at least one of them out of several practice sessions at a time when accumulating mileage is essential. Meanwhile the team's works status effectively pitched Infiniti directly against front-running manufacturers MG, Honda and the West Surrey Racing constructor team running BMWs.

NASCAR chairman Brian France has revealed in a radio interview that the sport is still receiving enquiries from potential new manufacturers, and that NASCAR is committed to working with potential new entrants to determine if a programme would be right for them and the sport. However, he has not revealed which manufacturers are interested.

BOSCH Motorsport is currently working on the next-generation ECU for the 2017 DTM turbocharged 2.0-litre engine. However, as the series further converges with the Japanese Super GTs, there is the chance that the Cosworth Pectel ECU, which is the spec unit in the Japanese series, may be selected.

CHEVROLET gained 50 points over rival Honda in Indycar's engine manufacturer championship following the race at Toronto on 14 June, for reasons that had nothing to do with results on the track. The Japanese manufacturer was fined 20 points each for changing the engines on the cars of Marco Andretti and Carlos Munoz before the units reached the designated lifespan of 2,500 miles, while Chevrolet earned 10 bonus points when Simon Pagenaud's engine passed the mileage mark.

GINETTA has confirmed that it plans to submit an expression of interest to the Automobile Club de l'Ouest with a view to become one of the licensed chassis manufacturers for LMP2 from 2017. Its in-house CAD team has already begun design work and will build a modified version of an LMP3 chassis in order to explore the feasibility of a P2 project while a Ginetta-Nissan LMP3 has been crash-tested to the same standards as that of an LMP1 car. RT

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WHY REFUELLING PLAN BLEW UP IN F1'S FACE

ABOVE The iconic image of the last refuelling era: the Benetton crew are engulfed in flame at Hockenheim in 1994. An investigation found that a filter had been removed to speed up fuel flow


Tee/LAT

Dominic Harlow explains why F1's controversial plans to reintroduce refuelling were always likely to hit the buffers

THE reintroduction of refuelling was, some hoped, to become part of the vision for a reinvigorated 'best of the best' Formula 1.

The ambitious objective, discussed in the Strategy Group's meeting at Biggin Hill, was set to make the fuelling happen in the same time as the tyre changes currently do. In other words, some two to three seconds. This was clearly a challenging technical brief, and no blank cheque came with it.

The catalyst for the overhaul was the group's conclusion that lap times should be reduced by between five and six seconds, typically 6%, to improve the sporting spectacle in 2017. The plan had the support of some of the sport's most influential figures. Yet many of the engineers who worked in F1 during its last flirtation with refuelling, myself included, were surprised by the proposal.

The teams were quick to make their feelings clear in discussions at the Canadian GP. There, despite some of them having supported it initially, their opposition effectively left the scheme without support. Indeed this kind of reaction clearly demonstrates how it was always going to be a difficult call.

It had been acknowledged at that original meeting that in the past race refuelling was banned primarily on grounds of cost. But there was also a second reason: it was deterministic in terms of pit stop times and strategy, drawing the spotlight away from the skill of the strategists and pit crew.

VICTORY AT A COST

Race refuelling using means other than a gravity feed – even today no other major series uses true pressurized systems – in order to reduce total race time through a reduction in vehicle mass, was first used in the Austrian Grand Prix of 1982 by the Brabham team. Most attribute the germ of this idea to the innovative designer Gordon Murray.

Even in these pioneering days, though, costs were a big issue. After early attempts to copy the procedure, the technique was widely adopted the following season in various similar guises. There were some teams, notably Williams, which opted for cheaper and slightly slower systems, and who ultimately were disadvantaged (despite using a more fuel-economical naturally aspirated engine). Perhaps in part for this reason it was banned for the 1984 season.

When refuelling returned, in 1994, it harnessed a standard system for the first time. The equipment was supplied by aircraft fuelling specialist Intertechnique – now part of Zodiac Aerospace, the same group that produces the iconic French rubber-hulled speedboat – which had pioneered the first systems with Brabham. It remained a feature of Formula 1 for 16 years until the cost squeeze at the end of 2009.

During this time two generations of the standard race fuelling systems were employed. The first used a pre-set amount of fuel forced into the car by compressed nitrogen; then, from 2001, a more advanced system used a PLC controller and motor-driven pump. The main feature of the latter was the ability to vary the amount of fuel until the last moment, and to collect far more data on the nature of the fuelling process.

The issue of cost control, as well as the interests of parity and safety, dictated that the fuel rigs had to remain as supplied by the manufacturer with the exception of minor changes. These required specific permission from the FIA in consultation with Intertechnique. A frequent example related to tailoring the nozzle handle to fit within the confines of a car's bodywork (see Figure 1). Another was the replacement and relocation of the light pod that indicated the progress of the fill to the handler. ▶

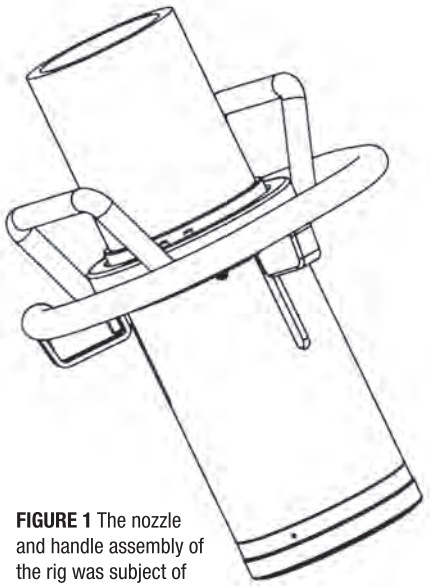
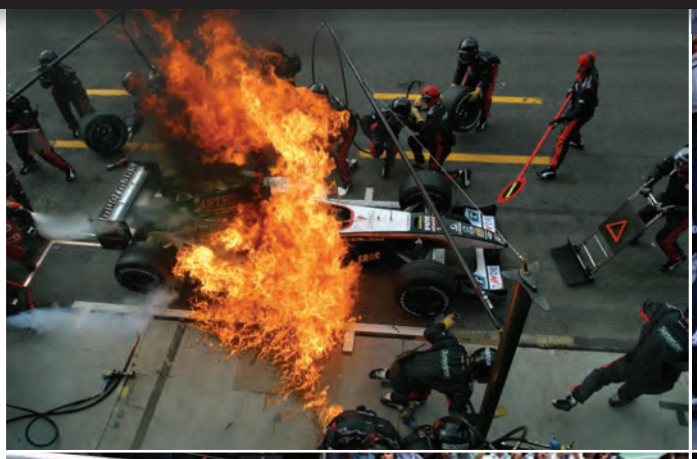
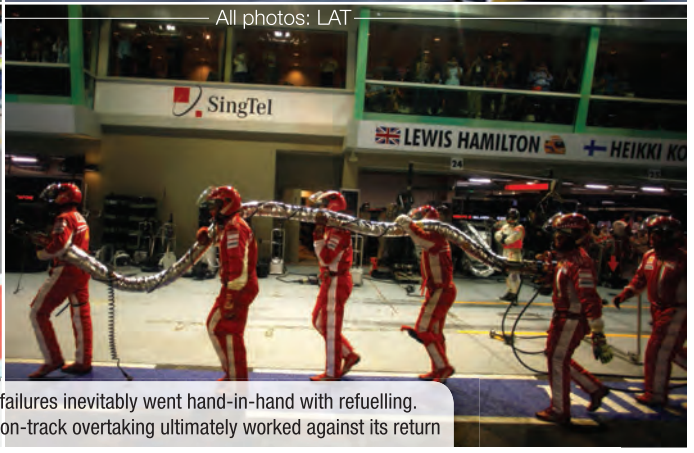


FIGURE 1 The nozzle and handle assembly of the rig was subject of considerable modification





All photos: LAT

ABOVE A succession of incidents and failures inevitably went hand-in-hand with refuelling. Worries over safety, cost and reduced on-track overtaking ultimately worked against its return

Nevertheless, there was still occasional controversy when changes were knowingly or unknowingly made without full disclosure. Even with the very simple original rigs that used an orifice plate to limit flow rate, teams like Zakspeed were known to have engineered complex flow conditioning solutions in the fuel tank upstream of the restrictor in order to minimize its effect. It would have been incredibly difficult to contain the inevitable arms race that would have been inspired by the quest for two- or three-second refuelling stops had it been reintroduced for 2017.

NEED FOR SPEED

In refuelling's last era, a maximum fuel flow rate of 12.1 litres per second was defined in the Sporting Regulations; the rigs could only be used in the sterile pitlanes of qualifying or race sessions for reasons of safety. With a typical fuel density in the region of 0.725 kg/litre that was practically limited by the composition dictated in the technical regulations, the maximum mass flow was just below 9 kg/s.

If this figure were to be input to a race strategy calculation in an attempt to determine the optimum refuelling strategy, however, it would have given the wrong result because of the connection and disconnection time and the flow starting and stopping. A pit stop would be too short and therefore too favourable. The data available from the rigs showed a true breakdown of the refuelling time (see sidebar below).

We will refer to this point again when considering the feasibility of the decreased pit stop time required by the 2017 brief.

Because the control system gave an indication of the state of the fuelling operation, it was possible to predict the final completion of the delivery and pre-empt nozzle removal. The time into the fill was observed by some means and usually a light system or oral alert used to indicate to the nozzle handler that he should disconnect the rig. With his reaction time of 0.25s followed by the physical act of shutting and disconnecting the nozzle, the time could be built into that required for the fuel pump to stop and outlet valve to close. Clearly average mass flow achievable increases with fuel mass required, meaning longer fuel stops were more efficient.

The rig control itself worked from a closed loop around the flow meter with some valve characterization, and so fuel density was a necessary input. The FIA also connected into the system at this point with a remote logger to monitor both the fuel temperature and maximum flow rate of the rig during the race.

The rigs rested on triangulated load cells which, although not a control input, allowed the flow meter system to be calibrated and the final fuel mass delivery to be measured instead of calculated. With this data a good deal of effort went into chasing down and ▶

Every Second Counts

The anatomy of a pit stop in refuelling's last era

• Car stop to nozzle connection & pump start	0.2s
• Pump start to maximum fuel flow	1.1s
• Maximum fuel flow (pump speed 1100 rpm)	3.7s
• Start of nozzle disconnection process	0s
• Concurrent pump stopping/valve closing	0.8s
• Completion of nozzle disconnection	0.3s

TOTAL TIME 6.1s
FUEL DELIVERED 40.0 kg
AVERAGE FUEL MASS FLOW 6.5 kg/s

BACK TO THE FUTURE?

Environmentalism in motorsport - a quest for the impossible?

Society may demand 'green' motorsport while industry benefits from the development that takes place, but what about the fans who are voting with their feet and fingers on TV remote controls and being turned off at virtually all levels? So should motorsport go BACK TO THE FUTURE to the time when men were men and cars were cars?

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eliminating the errors within the system, be they due to the controller, measurement accuracy, or physical effects of tolerances on components like the ball valve actuator or a large assembly like the nozzle.

The fuel rigs were not without problems. Although the flash fires are memorable, there were more instances of unexpected rig shutdowns or incorrect deliveries that cost teams results. Since the rigs were electrically-powered from a 415v three-phase supply, clearly any loss of power would be a disaster. Redundant generators were therefore needed at all times to back-up local facilities. Typically the demand on a grand prix venue's electrical capacity peaks during a race, with hundreds of tyre blankets, IT and other systems drawing power, increasing the chance of an issue and compounding the risk.

A picture is beginning to emerge of the amount of infrastructure and support that the refuelling rigs absorbed. It was certainly not trivial, although one might argue that recently this same focus has been expended on the wheel changing side of the pit stop.

In the recent past two fuel rigs, one per car, were almost always used for reasons of redundancy and for fuel capacity. Each one held about 180 kg, which was marginal to refuel two cars in some races. To setup and operate these rigs during an event would be an almost full-time task for a team truckie. Then an engineer or operator would be needed to look after the IT side. He would have to run calibrations regularly and purge the rigs before zeroing measurements, setting the required fuel amount and arming it. In the pit stop itself there was a greater number of personnel involved than is currently the case, with the following additional roles required:

ABOVE & BELOW By the last era of refuelling the infrastructure and cost involved had escalated to a level nobody could have imagined back in the carefree days of 1983 (below)

> *"The cost of spares can be extremely high, for example some 200 Euros for an 'O'-ring!"*

- Fuel nozzle handler
- Hose carrier (the hose weighed around 35 kg)
- Spare nozzle handler (for the other rig and ready to step in if the first one failed)
- Spare nozzle hose carrier (a combination of balletic footwork and brute force was required when a swap became necessary mid-pit stop)
- Deadman's handle operator (to hold open a spring-loaded last line of defence valve and also operate the 'E' stop should the worst happen)
- Control desk operator
- Fireman
- Car steady (holds the roll hoop one side to react the force of the nozzle connection)
- Disconnect helper (also FL or FR wheel-off)

This increased the numbers involved in a pit stop to close to 30.

Back at the factory there would also be input required from engineers, designers and the inspection and purchasing departments.

The rigs were relatively costly hardware – a key contributor to their demise. A new rig itself would be more than £100,000, but the maintenance cost could be the same order of magnitude yearly. Airfreight, at some $250 per kilogram/season, would equate to another similar amount and road transportation would add further cost.

Handling fuel in an explosive environment is subject to safety regulation and certain standards known as ATEX. This requirement means certification of the rigs is necessary in addition to obvious steps like the earthing strips that would be bolted to the pit lane in the pitbox position. Since the refuelling equipment has its origins in the aviation sector, the standards incumbent on the suppliers generates cost, and spares prices can be extremely high, for example some 200 Euros for an 'O'-ring! ▶

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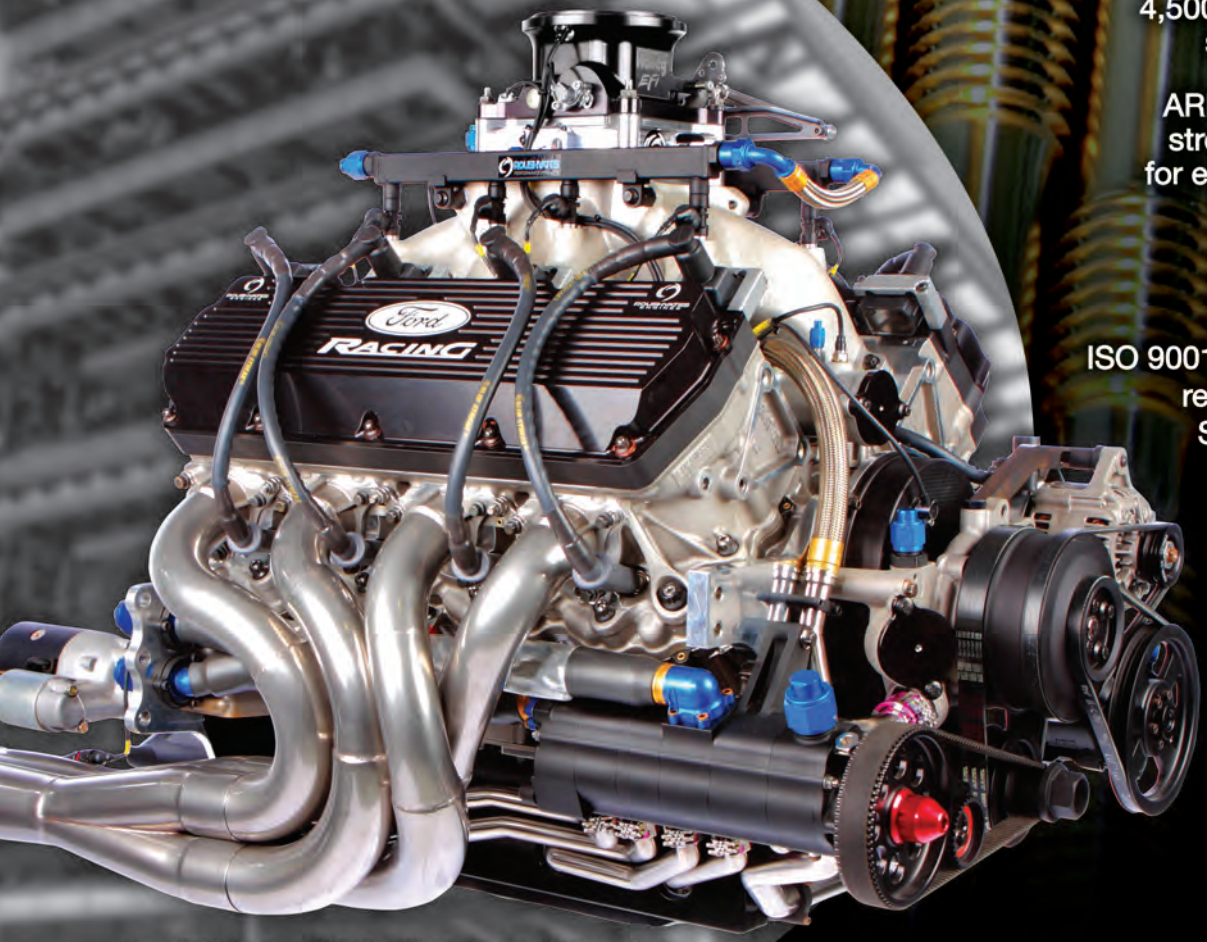

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ABOVE Would the pits become the main focus of overtaking moves?

ABOVE Locating the refuelling valve at a height and angle to best suit rapid nozzle connection is a tricky aspect of chassis design that spawned a good deal of work in the past

An interesting development that only saw service during the final refuelling season in 2009 was a nozzle interlock protection that used proximity sensors to check for the location of the nozzle on the car connector. If the sensors indicated the presence of a ferrous collar around the fuel nozzle, the clutch could be held disengaged to prevent the kind of dangerous pit stop release that happened to Massa in Singapore in 2008, for example. A similar method was adopted around the same time in IndyCar, with an optical sensor arrangement in the nozzle aperture or 'buckeye' as it is known.

PROJECT 2017

Returning to the objectives set out for a possible reintroduction of race refuelling, it is easy to ignore the sub-heading relating to lap time reduction. The cars are currently substantially slower in the race than in qualifying for multiple reasons and hence a reduction in fuel load at the earlier stages will serve to reduce lap times and potentially promote attacking driving. The question would then become about how much faster is possible with refuelling and how the cost of this compares to other measures to increase performance, as well as the potential impact on the sporting side.

Figure 2 shows some simple calculations for the reduction in race average lap times using various fuel strategies.

It is perhaps not entirely the same thing but just comparing the mass-saving cost gradient if a similar gain was to be found from the car, at maybe £50-100,000 per kg, it looks like the fuel mass saving is potentially worth considering. This is the strongest qualitative argument in favour of a reintroduction.

There would likely be some inherent increase in mass and complexity of the car for refuelling though, making weight ▶

FIGURE 2 2015 v 2017

Average Lap Fuel Load & Relative Laptime				
2015	2017 With refuelling			
Current	2-Stop Typ.	2-Stop Min.	3-Stop Min.	
51	18	17	13	kg
absΔ:	33	34	38	kg
Laptime Advantage Typ.				
ref.	-1.2	-1.2	-1.3	S/Lap

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BELOW Analysis suggests that on-track overtaking could diminish with the return of refuelling

BELOW Completing refuelling in the time taken to change the tyres would pose considerable technical challenges

reduction even more difficult. The benefits of a slightly smaller fuel cell and chassis (being sized around the longest stint needed to comfortably one-stop Monza) would be offset by the refuelling valve (+1.5 kg), a fuel flap actuator and assembly, either pneumatic or hydraulic (+0.5 kg) and modifications to enable a quick connect valve to be fitted to either side of the car with garage refuelling also available (+0.5 kg).

In fact, this is a bigger design issue than it sounds. The requirement for the refuelling valve to be located at a height and angle that would best suit rapid nozzle connection was a tricky aspect of chassis design that spawned a good deal of work in the past. It was also necessary to provide clear space on the surrounding bodywork. Nowadays, with the much simpler fuelling connectors, this part of the chassis has been considerably reworked to provide a smooth area for radiator exit flow and minimal aerodynamic obstruction. This is something designers would not be keen to sacrifice.

The most challenging element technically is to reduce the time taken for a typical fuel fill such that it can compete with wheel changing and therefore not become the determining factor in pit stop time. Using the data presented above and assuming a stop of three seconds (very average in today's terms), this would require a flow rate of at least 20 l/s or more assuming a two-stop race. This is then something approaching double the old fill rate.

To add a further perspective this is the kind of fuelling rate that would be typical of one of the four hoses used when filling a Boeing 747, which can take up to about 150 tonnes of fuel from a 40-tonne bowser. Clearly handling this in a pit stop with such a large bore hose and powerful pump would be extremely difficult, as would coping with the tank ventilation needed at the same time as fuelling. This would require complex internal ventilation snorkels and a large diameter vent hose to limit backpressure. The Intertechnique rigs were set to cut out when experiencing a backpressure of more than 200 mbar.

There are few suppliers worldwide who produce this kind of specialist equipment for commercial airfield operators. Zodiac Aerospace in France is one example, Fluid Transfer Systems in the UK another.

SPOILING THE SHOW?

Whatever is done, there would remain the issue that once a fuel stop had been timed it would be simple to predict the next pit stop lap, and this would reduce tactical variation in races. It never made sense to pit earlier than fuel on board would allow due to the time penalty incurred for carrying the additional mass. This is mitigated by a lower consumption now

> *A stop of three seconds would require the kind of fuelling rate that would be typical of one of the four hoses used when filling a Boeing 747"*

ABOVE Coming soon to a race near you?

but it still remains unlikely, so the use of an undercut diminishes, and of course the overrun is ruled out.

The teams' analysis of historical overtaking statistics revealed that the seasons during the refuelling era of 1994-2009 had fewer on-track overtaking moves than any other year since 1980. Although it is difficult to eliminate the significant effects of increasing car reliability and the coincident change of tyre supplier, it suggested that overtaking actually improved in 2010 as a consequence of a ban on refuelling.

From a more subjective angle, race refuelling could be seen to run contrary to the efficiency message of the current engine formula. There is a danger that it could draw attention to the delivery and use of relatively large quantities of hydrocarbon fuels. It was, after all, one of the plans of the Powertrain Working Group that over time the 100 kg race fuel allowance would slowly be reduced to drive even greater efficiency.

After a relatively cool reception for the proposals it will be interesting to see where Formula 1 chooses to head next. Refuelling is exciting in its own way, there is no doubt, and it would improve lap times in a race. But the capital, operational and development costs could outweigh the potential upsides.

After the initial spike in interest that would be generated by such a change has subsided, would the practice offer a long-term benefit or a burden? My preference would probably align with the engineers. I think that rapid refuelling has had its chance and should be left to the airlines, and that F1 might choose to deploy its finite but powerful technical resources and ingenuity to other areas this time around.

BELOW With as many as 30 people involved, a fast refuelling stop requires a combination of brute force and balletic footwork

BALANCE? THE ANSWER'S UNDER YOUR NOSE!

With the role of the front wing so vital, our **Expert Witness** suggests the key to Formula 1 isn't the 'balance of power' – it's the power of balance

WHERE do you start with racing car aerodynamic flow structures and behaviour? Perhaps, not surprisingly, at the front!

To qualify that statement, when you think about the potential of the air – clean, undisturbed (I will come back to this) – the start of the car, the first devices that encounter this initial situation, have to maximise this opportunity. By definition they have the most ideal conditions in which to perform, which means they will be important and need to make the most of it; at the same time, they must do so as efficiently and responsibly as possible as they will then influence the wake and conditions that the rest of the vehicle must utilise downstream.

By location and legality the loads that will be generated will be ahead of the front axle line and can utilise the power of ground proximity. Therefore they have to operate in the required window of behaviour the car and driver need, often being adjustable. Add in some of the spectacular challenges of the open-wheel, single-seater categories and today we will be dissecting the complex problem that is the front wing.

FLOW FIELD

Sometimes described as 'global', this is a good analogy to explain a fundamental principle of aerodynamic design: there is a circular interaction of the individual components, most profound when operating in a coupled upstream or downstream position. For a front wing that can be at times the full legality span of the car and the first device the free stream sees. That means the vast majority of the vehicle must utilise the outcome of its influence, good or bad. To try to give a simple example, front wing part design historically could adversely affect rear brake temperatures, perhaps three metres away. Once you take this key principle on board, the way you approach development and evaluation changes.

GROUND HUGGING

Wings perform by accelerating air around a more cambered surface, reducing its pressure. This situation can be enhanced exponentially further by moving this racecar lower surface in proximity with a flat plane, in this case the track. This condition for the front wing profile, its endplates and fences has long been a known benefit, but being mounted to a sprung platform that pitches, rolls, steers, yaws and slips is the first issue. The geometry therefore needs to be robust to these changing criteria, delivering high performance while having a low sensitivity to these changing parameters.

BELOW With as much as 35 per cent of an F1 car's total downforce currently generated by the front wing, this has become a crucial aero battlefield for teams

Mercedes GP

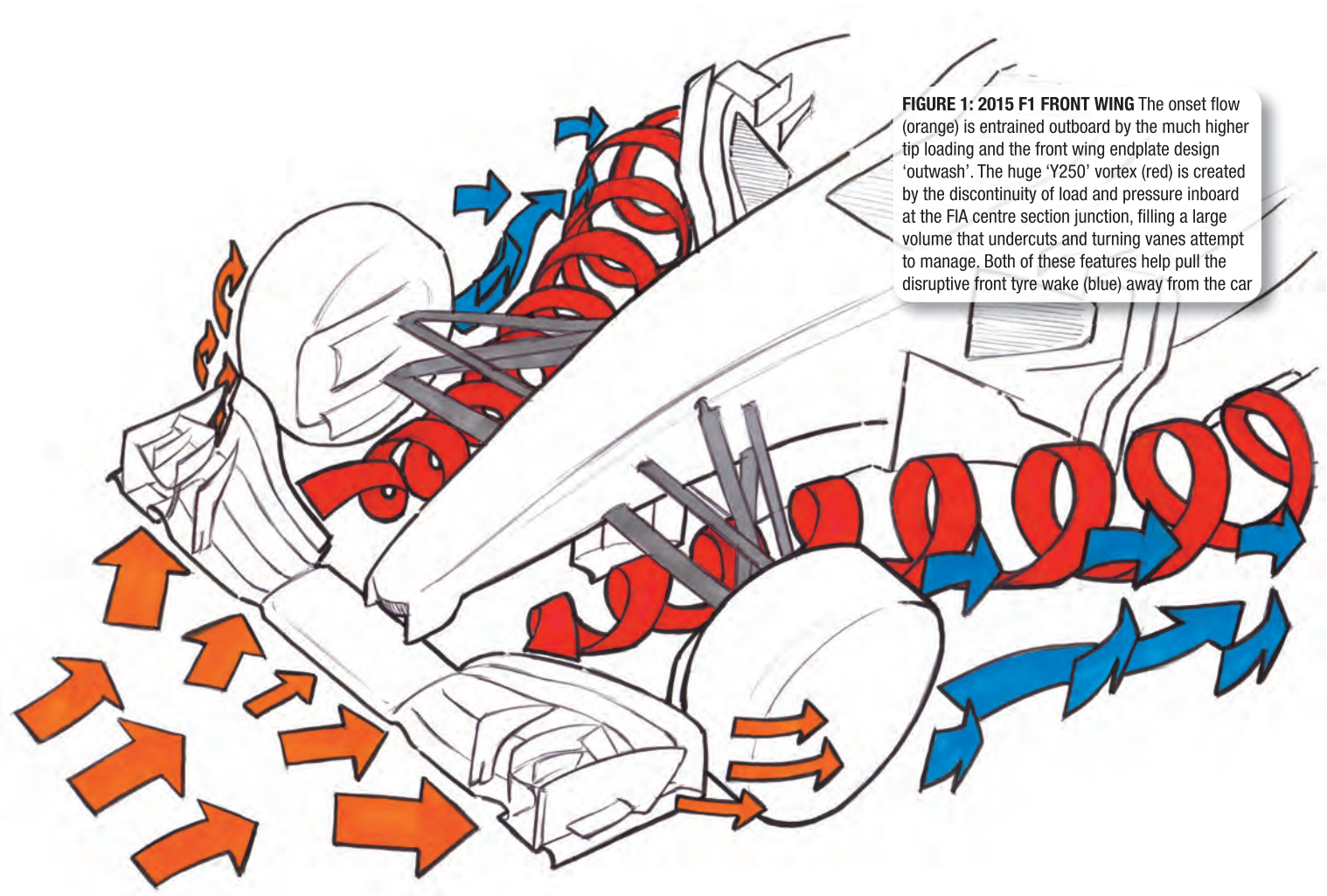

FIGURE 1: 2015 F1 FRONT WING The onset flow (orange) is entrained outboard by the much higher tip loading and the front wing endplate design 'outwash'. The huge 'Y250' vortex (red) is created by the discontinuity of load and pressure inboard at the FIA centre section junction, filling a large volume that undercuts and turning vanes attempt to manage. Both of these features help pull the disruptive front tyre wake (blue) away from the car

How low can you go? As the phenomenon is well known, usually as low as you are allowed; sometimes rather more… As someone famously once said, "Our car passes all of the FIA tests." (Static, by practical necessity.) Yes, I am sure it does, but those front wing endplates seem to have metal inserts in the tips to prevent them wearing away on the ground; how can that be, given the current minimum legality height requirement…?

AERO ELASTICITY

Mechanical structures are not infinitely stiff. When you add into that the motorsport condition that you require them to be as light as possible, this magnifies the challenge. And if there was benefit from them distorting in a known and required way, then that would be even better. This is far from a simple problem to resolve as the inputs change and require iterations and convergence. Structures groups in teams work closely with Composites and Aerodynamics in order to create and develop these to not just hit legality, but also performance targets.

> *"The vast majority of the vehicle must utilise the outcome of the front wing's influence, good or bad"*

Front wings are a beam structurally, supported at the centre by the nose or mounting pillars, therefore they will bend and twist. How much will not just depend on how much load is being generated, but where it is acting in terms of mechanical advantage along its span. Remember this is not only constantly changing with speed and distance from the ground, but also due to the structural deformation itself because of that condition. This, then, is the interactive loop of changing parameters that needs to be solved.

This is highly topical, for the F1 FIA test on the front wing tip bending down:

> ***3.17.1*** *Bodywork may deflect no more than 10 mm vertically when a 1000N load is applied vertically to it at points 675 mm and 975 mm forward of the front wheel centre line and 720 mm from the car centre line… etc.*

and the front floor or bib bending up:

> ***3.17.5*** *Bodywork may deflect no more than 5 mm vertically when a 2000N load is applied vertically to it at three different points which lie on the car centre line and 100 mm either side of it. Each of these loads will be applied in an upward direction at a point 380 mm rearward of the front wheel centre line using a 50 mm diameter ram in the two outer locations and a 70 mm diameter ram on the car centre line…etc.*

have both been tightened up in recent years. The FIA felt it was necessary post-Monaco, this May, to introduce a further test to prevent the front flaps backing off with speed so much – a very desirable and long sought after characteristic, but one that became blindingly obvious on track from the frequent on-car nose camera footage. ▶


Dunbar/LAT

ABOVE Red Bull has been arguably the king of the front wing in recent seasons. This 2011 image captures the flexing, rake and low front ride height that have courted controversy – and proved very successful

The new front wing flap test is in essence:

When a load of 60N will be applied on the front wing flap trailing edge it may deflect no more than 3 mm.

BALANCE

Perhaps the most obvious but vital function is to provide a system of adjustable balance within the required team and driver range to operate the car best across a variety of tracks and weather conditions. This is useful adaptability, but leads to extra parts, weight, complexity and potential leakage paths.

Equally there is, or was, opportunity there too as some adjustment systems can be less stiff than others. With a legality period after the Overtaking Working Group (OWG) survey (of which more later) of having driver-adjustable front wing flaps, this remains one of the few car tuning variables now still available to teams under *parc ferme* and during the race.

Distinctive features

Each period of regulatory stability normally generates initial diversity as teams and R&D departments experiment with solutions, but soon distinct families of components emerge. Sometimes this is by innovation, but often as a direct result of the rules framework. I want to look at a few of these trends and try to explain the mechanisms around how and why the front wing went in the directions it has.

STEP CHANGE

In 2001 all but the centre area of the front wing assembly minimum height was lifted, losing the valuable ground proximity and creating leakage under the now very high front wing endplates. From a period of designs that were largely flat and quite two-dimensionally simple, through a brief period of quite stepped assemblies, a new phase of highly complex three-dimensional designs was born.

The challenge here was to try to recover the loss of performance from the high tips by increasing the load of the remaining volume ▶


Pirelli

BELOW The instrumented rake, or 'pigeon catcher', gathers information to help teams understand tyre wake and the Y250 vortex, the two dominant structures in modern F1


Etherington/LAT

ABOVE In 2001 teams recovered the loss of performance from the newly-mandated high tips by increasing the load of the remaining volume in the centre

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Griffiths/LAT

ABOVE Ferrari's ducted central nose in 2008 highlighted the extremes that were reined in by the Overtaking Working Group for the following season

in the centre. How hard, low and cambered that solution could get even gave rise to armoured protection on the lower surface, to prevent kerb damage, and ducted nose designs to allow the centre wake to remain less impeded.

SPAN & CENTRE

2009 was a bit of a watershed in terms of huge rule change for F1 and our area of focus did not escape lightly. The OWG was established at this point: Pat Symonds (Renault), Rory Byrne (Ferrari) and Paddy Lowe (McLaren), with the help of Jean-Claude Migeot's FondTech aerodynamic consultancy, tried to solve the challenge of aero performance when running in proximity to – or, more accurately, the wake of – other cars.

The problem with reliance on complex front wing geometry is two-fold. Firstly, it is developed to a peak in optimum flow conditions and if it becomes disrupted its underperformance results in a severe loss of forward balance, giving aerodynamic understeer. Secondly, in conjunction with track design, this can lead to processional racing and lack of overtaking, with the pace to catch the car in front, but the inability to run close to it.

With the OWG's collective input, full-span front wings arrived, with a neutral, symmetrical and flat FIA-prescribed section in the centre 500 mm. The planform shape and area of the package was also controlled.

FRONT WING ENDPLATES

With lifted or full width tips on a front wing, you are always trying to control and even harness the tip flow or mixing created by the pressure differential. In simple terms this is vorticity, a three-dimensional rotation of airflow in the volume. The footplate outboard and closest to the ground is where one of these main vortical structures forms, spiralling underneath and downstream as high speed leakage and mixing at the wing tip is formed.

In 2002 a team realised that if instead of a flat shape, you arched the footplate to ▶

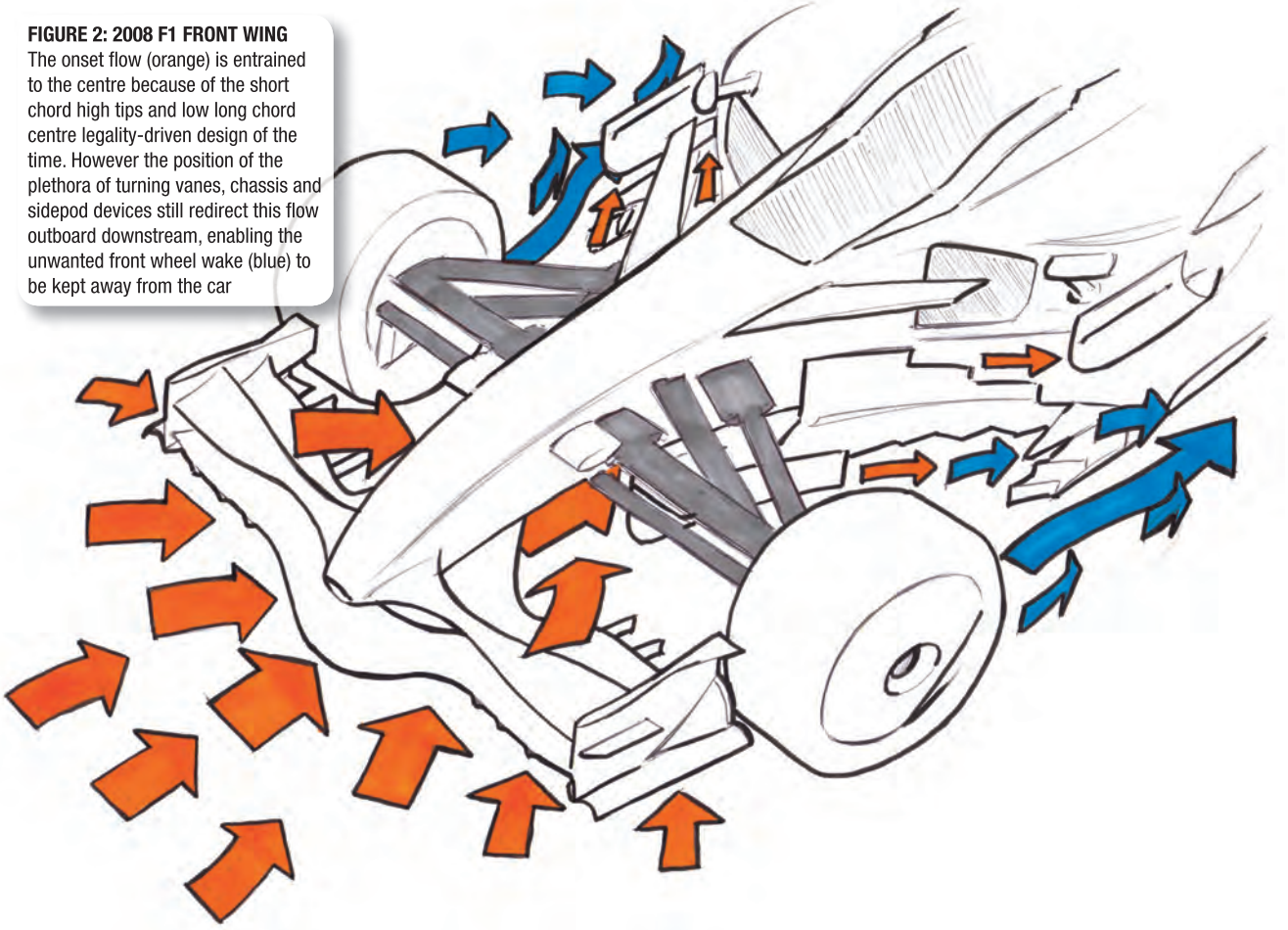

FIGURE 2: 2008 F1 FRONT WING
The onset flow (orange) is entrained to the centre because of the short chord high tips and low long chord centre legality-driven design of the time. However the position of the plethora of turning vanes, chassis and sidepod devices still redirect this flow outboard downstream, enabling the unwanted front wheel wake (blue) to be kept away from the car

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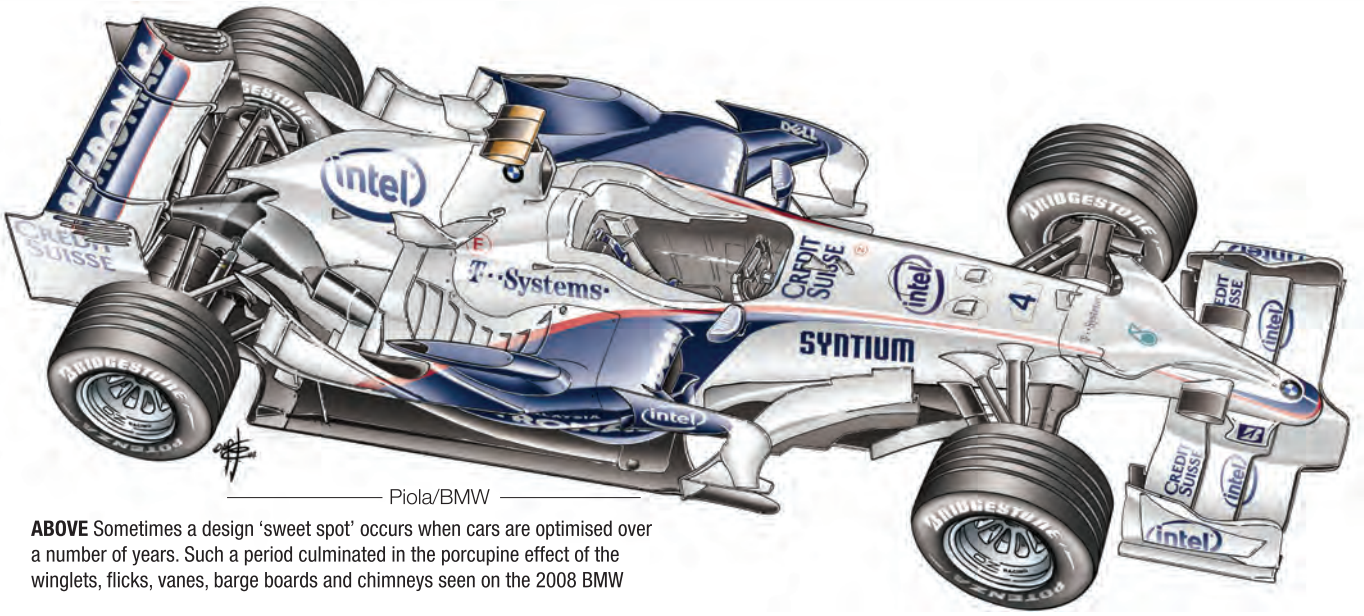

Piola/BMW

ABOVE Sometimes a design 'sweet spot' occurs when cars are optimised over a number of years. Such a period culminated in the porcupine effect of the winglets, flicks, vanes, barge boards and chimneys seen on the 2008 BMW

effectively capture or be sympathetic with the shape of this aerodynamic structure, then you can not only better control its trajectory but harness the benefit from its low pressure (see Figure 3). Unusually for F1, not only was this principle copied throughout the pit lane, but it can still be found on the cars 13 years and further rule changes later.

However, with constant development and additional inputs, this tip area has become increasingly loaded, requiring ever more complicated and multi-element geometry to maintain stability. Some teams even suffered aero structural flutter in 2011/12. This was caused by a high speed increasing of load and deflection, followed by a vortical tip burst and load loss instantly restarting the cycle.

What used to be a short-chord, two-element design has become a full-chord six-, seven- or eight-profile tip. It is important for performance because of trying to manage the two dominant structures in F1 today: the front tyre wake and the Y250 vortex.

THE FRONT TYRE

In the same way the front wing has a problem with having the large rotating cylinder sat directly behind it, the car has the even bigger problem of the wake that the tyre creates, which is poor, unsteady and time-dependent. In recent times teams have therefore tried to solve both issues.

With a combination of front wingtip load, tip height, endplate design and top additional fences, assemblies are creating increasing span-wise distribution or outwash. ▶

BMW

BELOW F1 gets ugly: most of the devices seen in the graphic above were swept away by new full width centre wing regulations in 2009. The forums lit up immediately!

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A general vector and a series of vortical structures that pull around the front tyre and drag its wake further outboard and away from the rest of the car, this is particularly important low-down, where this detrimental flow can be ingested into critical areas. Remember this system needs to operate most effectively in peak load or downforce cornering yaw, roll and steer conditions.

Y250 VORTEX

While managing front tyre wake has always been an issue, the Y250 or 'transition vortex' was one of the creations of the 2009 regulations. With the FIA neutral section stopping at 250 mm from the car centre line, teams are then immediately free to add load and asymmetry, which they do.

This then creates a step change in camber, load and pressure, coupled to a diagonal legality line in planform, exactly the circumstances for a huge vortex to be evolved. The challenge is that there are two – one each side (see Figure 1) – and they

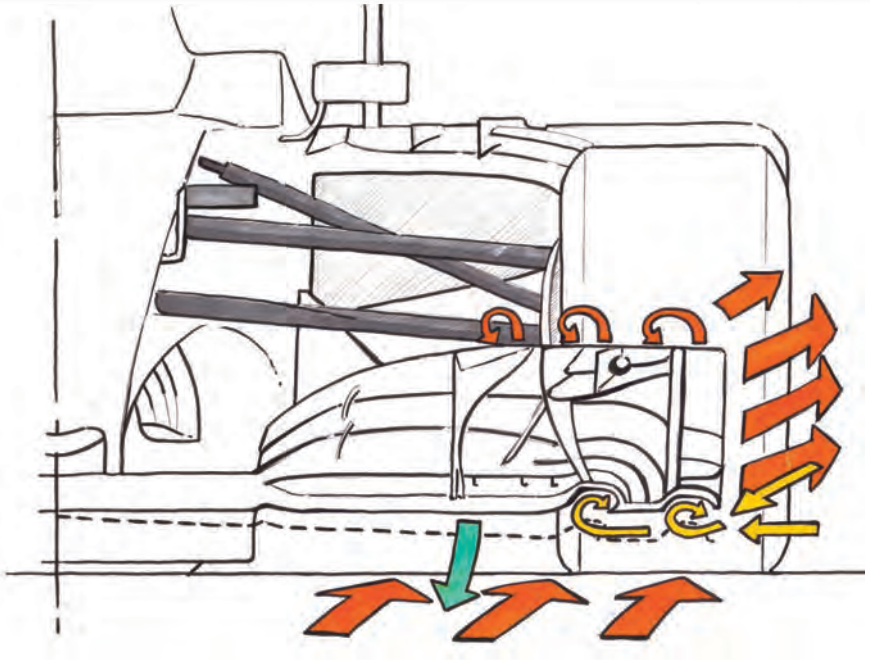
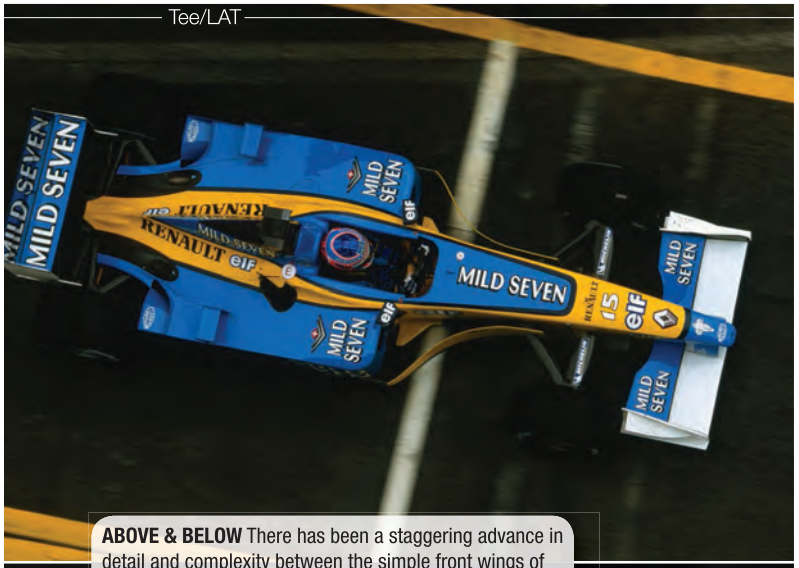


FIGURE 3: 2015 F1 FRONT WING MECHANISM With so much loading on this design at the tip, the structure bends (green & dashed line), improving its function and performance further. Top elements and turning vanes create vortices that improve the outwash and control tyre wake, while the two hollows under the tip capture and control these footplate vortices (yellow), a feature maintained since their introduction in 2002



ABOVE & BELOW There has been a staggering advance in detail and complexity between the simple front wings of the 2002-03 period (above) and those of the current cars

are close to the aerodynamically all-important middle of the car. Forward and rearward turning vanes, the front floor and bib, sidepod shape, undercuts and sidepod turning vanes all have to align, respond to and maximise the interaction of this complex rotational flow.

On the front wing the shape and feathering of the innermost flap elements and initial wing geometry is also all about managing this huge structure. If you look carefully in the wet or in high humidity damp conditions, water vapour will actually track this structure so that you can see it on TV with the naked eye. Teams use CFD and complex pressure arrays on track and PIV in the wind tunnel to confirm and try to control, understand and utilise this condition best.

An interesting by-product is that this, through volume size and direction of rotation, when used correctly helps move the aforementioned front tyre wake further outboard.

SUMMARY

The combination of roles, efficiency and opportunity created by the front wing over time has seen it develop from a simple device to hundreds of components, design and manufacturing hours. It has become ever more vulnerable to damage, tyre debris build-up and the wake structures from the car in front.

While the front wing is a fantastic technical challenge, the next step for the regulations and the racing would be to reassess technical freedom and aerodynamic stability, as was the case in 2009. Roll on 2017; let's hope they get the power of balance right. RT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From F1 freeze to the supermarket freezer

Felipe Massa, the Isle of Eigg and Sainsbury's supermarket have nothing in common, or so **William Kimberley** thought until he visited the offshoot of a well-known Formula 1 team

ABOVE Can motor racing technology really have an impact on your supermarket shop? It can now…

IT'S a warm summer's day so you're wearing a tee-shirt and shorts but need to pop into the supermarket to buy some frozen peas. As you walk down the aisle in the frozen food section, you are suddenly struck by a wave of cold air and wish you were wearing jeans and a sweater. That is what is called wasted energy. The coldness is flowing out of the freezers while the supermarket has to turn up the heaters to ensure the rest of the store doesn't get cold. However, this could soon be a thing of the past – and it may be down to Formula 1 technology.

Williams Advanced Engineering has been making quite a name for itself in the recent past. Even before it had a brand spanking new building that was opened by British Prime Minister David Cameron last year, its technologies were helping Audi win yet again at Le Mans, the energy-storing flywheels being an important and integral part of the hybrid system.

It had also been intrinsically involved with the high profile, but sadly discontinued, Jaguar C-X75 concept car – an all-wheel drive, plug-in parallel hybrid electric vehicle with the world's highest specific power engine; in addition, it was supplying the battery pack to every car on the Formula E grid. This is not to forget that its technology was also being used to store energy in a couple of Scottish islands as well as being involved in some highly confidential projects in the defence and aerospace worlds.

The list goes on – it could almost be called Williams Advanced Energy Engineering because of its work in energy solutions as energy seems to be the focus of everything it does. However, the one thing that has been overlooked because of all these high profile programmes, is that it continues as a motorsport resource company. Because there is a thick blanket of security surrounding motorsport projects, they are well under the radar and never reported on. However, they are an important contributor to the Williams F1 Group's bottom line.

MOTORSPORT KEEPS US SHARP

"Motorsport is a continuing feature of what we do and it keeps us sharp," explains managing director Craig Wilson. "We have a huge capability here and you don't need to be an Einstein to work out that following the regulation changes in Formula 1, work for our own team has necessarily scaled back. We've got both a full-scale closed loop wind tunnel and a 60% one as well, both with rolling roads. Also on site are a simulator, various test rigs, superb aerodynamic and CFD capabilities and a very large rapid manufacturing capability."

Wilson is keen to explain that the external motorsport programmes are not new, pointing out that over 15 years ago it was involved in BMW's Le Mans effort and it was also responsible for Renault's challengers in the British Touring Car Championship in the 1990s. In more recent times it supplied all the transmissions to the HRT Formula 1 team and a bespoke KERS system for Marussia F1, while Caterham F1 was using its 60% wind tunnel.

The talk in both the sportscar and F1 paddocks suggests Williams has also been deeply involved in Porsche's successful 2015 World Endurance Championship campaign. Not even the chance to claim a share of Le Mans 24 Hours glory will draw Wilson on the subject, though.

While Williams Advanced Engineering does initiate its own research projects, around 20% of the turnover according to Wilson, it is principally open for business to help other companies and teams. "What used to drive the company was the eternal quest for those nuggets, those performance enhancers that we could pass onto the Formula 1 team – that's the origin," says Wilson. "Williams' DNA ▶

is that it is an engineering company and Advanced Engineering is about commercialising the know-how.

"This is how the flywheel programme started. It was a technology that was felt to be a competitive advantage and although it was ultimately not used in F1, we saw other opportunities for it. It then started taking on its own life, leading to trials in buses that proved it worked. When it came to fully productionising it, though, the decision was made to sell that part of the business to GKN as we are not into mass manufacturing.

"Today we still look at technology being developed in Formula 1 but we also look at other technologies that have commercial benefits where we can use our combined engineering expertise to develop them. This is often customer-driven because there's no point developing something that no-one wants.

"Our key strength is taking a concept from the drawing board, making it and proving it out in a very short space of time and then producing the first batch for assessment. We have the ability to produce hundreds of a component, depending on what it is, or a product that's been developed by us that we know from the outset is going to be produced somewhere else. For example, we are currently working on three vehicle engineering programmes where we'll produce the production prototypes but the volume production will be done somewhere else.

> *"We believe energy storage will take on a whole new meaning in the next 10 to 15 years"*

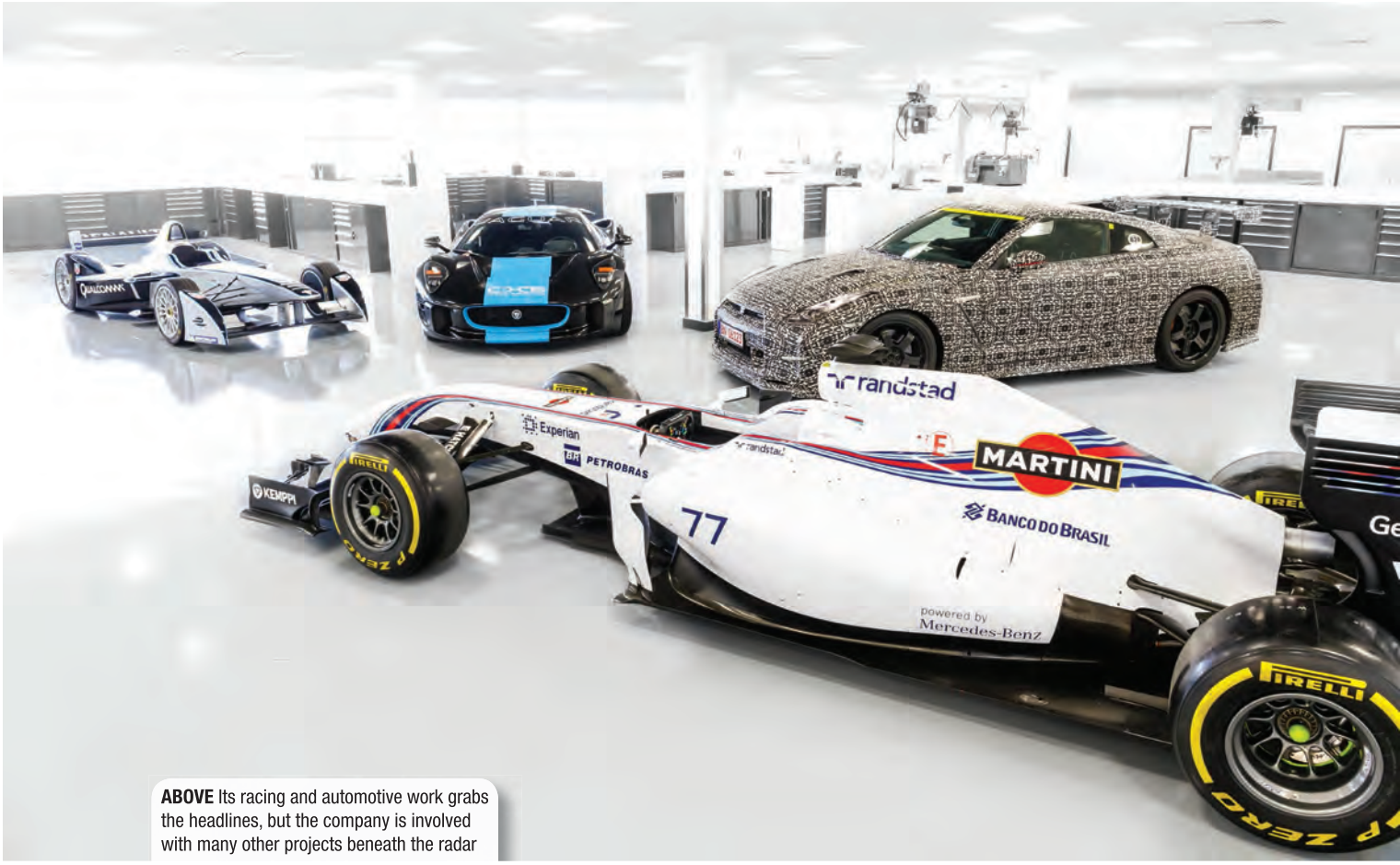
"We don't have the strategic objective of becoming a volume manufacturer – there's plenty of manufacturing capacity all over the world and overcapacity in some cases, so it's a case of applying our engineering skills and then finding the most cost-effective way for producing it in volume."

EXCITING FORMULA

Williams Advanced Engineering is perhaps best known as the supplier of the battery pack for the Formula E teams. "I think it's a really exciting formula to be involved in," says Wilson. "Through the F1 KERS programme we had a great deal of experience in batteries and energy storage, as well as with the Jaguar C-X75 project, and although we don't develop cells, these batteries are pushing performance levels and supplying all 40 cars on the grid has been a great learning curve for us.

"Our next battery generation will have quite a number of improvements that we've largely learnt from the first season but also from other battery programmes in which we've been involved, and it will definitely push the boundaries. The challenge is to maintain maximum power and maximum energy for the range and not have a dramatic drop off when the performance is pushed. The objective by season five is to have the grid consisting of 20 cars that can race hard for the entire race by also utilising clever regeneration strategies.

"We are also involved in new cell ▶



ABOVE Its racing and automotive work grabs the headlines, but the company is involved with many other projects beneath the radar

chemistry and working with a company that makes a sodium-based battery, making it into a pack to improve its performance. It's got a long way to go but it does have a pretty good energy density and cost potential and it has good safety characteristics as well."

One of the reasons it is easy to forget that the company is primarily a motorsport one is because all its high profile projects revolve around energy and energy storage. Partly this is customer-driven but it fits in well with Wilson's own beliefs that this is the direction the world is heading anyway.

"We believe energy storage will take on a whole new meaning in the next 10 to 15 years," he says. "It's all to do with the national grids that don't exist, are overloaded or are unreliable. Even today there are circumstances where you can't sell your excess energy back to the grid because it's overloaded; there's no capacity to take it back in. To get any benefit means that the energy needs to be stored for when it's required or when there are gaps in the grid – and the situation's only getting worse.

ENERGY STORE

"The two forms of renewable energy that are most viable are solar and wind because they're free commodities, but you can't fully benefit from them unless you have some way of storing the energy. It's always been about the cost-effectiveness of the storage. Combined with the added pressures of the grid often being overloaded, it means that if we can take a lot of those supply and demands away, then you are beginning to free up capacity on the grid and the equation starts to be more balanced."

All this is a long way from preventing customers at their local supermarket from feeling the cold. Energy consumption makes up a significant percentage of a supermarket's operational costs, with energy-hungry refrigerators that keep the produce cool the largest consumer of power. Open-fronted multi-deck refrigerators that line the aisles of supermarkets consume excessive energy, with some of the cold air spilling out into the aisles, resulting in increased energy consumption and 'cold aisle syndrome' which can be unpleasant for shoppers.

"It's all about developing a new retrofittable aerofoil system that attaches onto each refrigerator shelf to keep more of the cool air inside the refrigerator cabinet," Wilson explains. "We were asked by a company called Aerofoil Energy whether we could look at it from an aerodynamic point of view as it had a concept but it wasn't able to perfect it.

"We looked at a lot of the market data first because we are involved in the energy field and were able to do our own models in terms of energy saved, the cost of parts, payback for the customer – all that side of it in the consideration of whether we should be taking it forward or not. There wasn't much money involved so we went into a partnership where we developed this device."

A number of supermarkets are currently evaluating it with promising results. Sainsbury's, the UK's second largest supermarket chain with 1,100 stores that together use 1% of the UK's energy in total, has been testing the product.

"Much of our work focuses on improving energy efficiency and the collaboration with Aerofoil Energy is a perfect example of how Formula 1 innovations can have a tangible benefit to ordinary people and the environment," says Wilson. RT

ABOVE & BELOW Williams technology underpins the battery pack on every car in the Formula E field

> *"Formula 1 innovations can have a tangible benefit to ordinary people"*

Arms race hots up as Porsche reclaims crown

Craig Scarborough swaps the Formula 1 paddock for the Le Mans pitlane and is surprised by the technology he discovers

WITH four manufacturers in the top LMP1 hybrid class, Le Mans was a classic this year. Porsche broke Audi's stranglehold on the 24-hour race and with it ushered in a new generation of the LMP1 car.

Huge technical diversity was on show between the contenders. While the cars may be familiar to those following the wider WEC series, many innovations were exposed in the pitlane at La Sarthe. This was my first visit to a WEC race for two years and it's clear that the technological development has accelerated in this series – to the extent that the technology is at the same level, if not greater, as that seen in F1.

HEAD-TO-HEAD

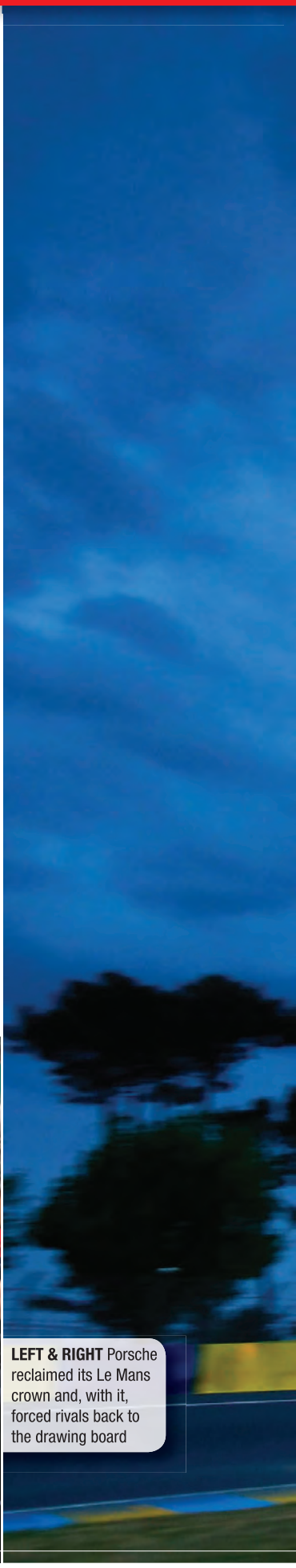
It was a close-fought race, although the results might suggest Porsche had it all its own way. Qualifying was less of a fight: only two of the three Audis set out on a qualifying programme and neither Toyota took up the bait.

As the race unfolded it was clear that pace was roughly equal between Audi and Porsche. So the German marques battled it out, with the Porsche running 13-lap stints, well below its potential to stretch to 14 laps. This lower risk approach saved time at fuel stops. Porsche, like Audi, was also able to run four stints on a set of tyres.

Audi pushed Porsche and led at various stages, but penalties and incidents delayed its cars. Finally the number 19 Porsche was able to stretch a lead overnight as the temperatures cooled, leaving both its sister cars and the Audis behind.

Toyota never had the pace to challenge. When its rivals had relatively reliable runs through the race, its trump card of reliability couldn't be played. Nissan, meanwhile, was not at La Sarthe to hunt for a win or podiums. Two cars made it to the flag, albeit only one as a classified finisher, which was some reward.

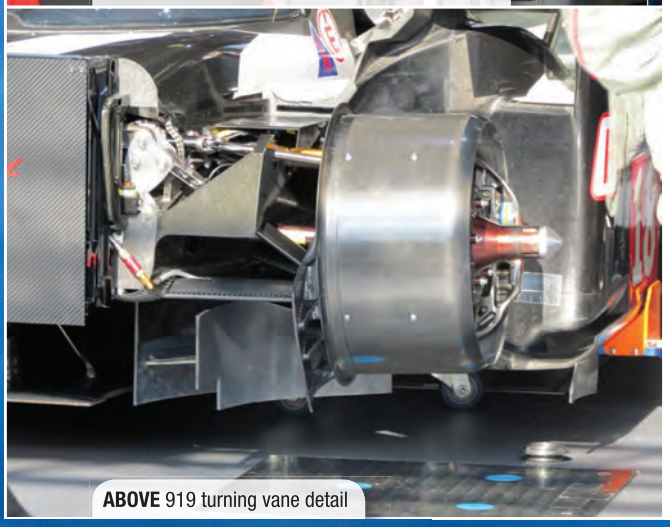
Porsche AG



LEFT & RIGHT Porsche reclaimed its Le Mans crown and, with it, forced rivals back to the drawing board

ABOVE Porsche's front suspension caught the eye

All photos: Craig Scarborough



ABOVE 919 turning vane detail

Porsche

Despite the marque's 16 previous wins at the 24-hour race, it must be remembered that this incarnation of Porsche is only in its second year of competition. Its 919 is also a new generation of the LMP1 Hybrid, produced with a clean sheet for 2014 and the new hybrid rules.

Not having to carryover a large power unit meant that Porsche uniquely was able to design a downsized PU specific to this new category. A mere two-litre petrol turbo V4 sits far forward in the chassis to the benefit of weight distribution and aero, aimed at making the most of the relatively wide front tyres. Where Nissan trumpeted its efforts to exploit the technical freedom the rules permit at the front of the car, it seems Porsche's quiet work in this direction had already paid dividends.

This layout forces a long gearbox and wanting weight equally forwards meant a light carbon fibre case was required. However, as technical director Alex Hitzinger explained, the carbon case is only an external structural element; the gear cluster sits within a separate aluminium inner case. This 'cartridge' setup is similar to the Mercedes AMG F1 gearbox, albeit the F1 car sports a titanium inner case.

At the other end of the car, the front suspension mechanism for heave and roll is unique. A pair of pushrods operate rockers, which in turn operate linkages with spring dampers that decouple the heave and roll motions. Hitzinger added that the car doesn't run side dampers, so these two central elements provide all of the front axle's damping and springing, albeit aided by torsion bars splined to the rockers.

With the car's downsized powertrain and efficient aero, it's clear to see the future direction of conventional LMP1 Hybrid cars has been set out. Porsche can now focus on refining the package for pace and reliability, leaving its rivals with a redesign on their hands. ▶

Porsche AG

Audi

More than any other team, Audi focuses its design on victory at Le Mans. The low-drag setup for this year's 24 hours was developed in the Sauber F1 wind tunnel. The resulting bodywork, opened up to allow airflow to expand around the front end, is matched to the solid turbo diesel rear end and an ERS strategy to place the R18 in just the 4 MJ class. Porsche's equal on reliability and close on pace, the Audi is punching above its own powertrain's weight: with the current formula, the large, heavy diesel should not be competitive.

Audi's Le Mans package concentrates on two areas: the front wing and the exhausts. Rather than a splitter and diffuser setup between the front wheel arches, Audi runs a two-element wing. Thus it has opened up the front bodywork to allow the wing's wake to expand. To meet the WEC LMP1 rules on hiding the suspension arms, the R18 features fairings strategically placed between wheel arch and chassis to obscure the wishbones in frontal and plan views. These fairings are 'U'-shaped to also avoid forming illegal aerofoil sections.

As in open-wheel formulae, the spinning front wheels create a turbulent wake as they hit the oncoming airflow. Some of this wake spills laterally from under the tyre to upset the diffuser and along the flanks of the car. Audi has dedicated inlets in the front of the tall, bluff front wheel arch: a duct is formed which directs a jet of air at the tyre/track intersection, reducing the lateral airflow's effect.

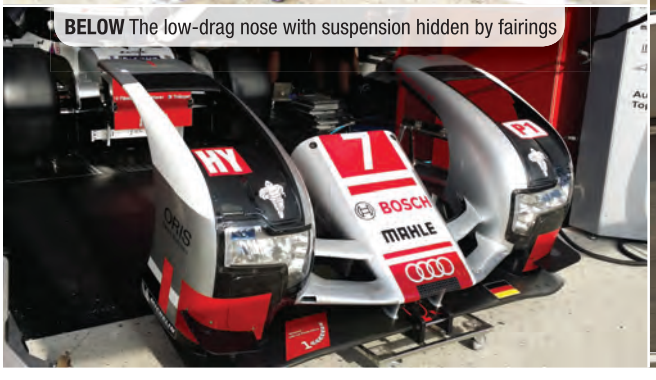
At the rear Audi continues to try to exploit the exhaust gasses. With overt blown effects banned, it appears to still have found a beneficial solution. Audi splits the single turbo exhaust into two and each separate pipe meets the diffuser's top surface tangentially. Rather than blowing directly at the diffuser's trailing edge, small ducts pick up the exhaust plume and direct it out over the top of the rear edge of the engine cover. This appears to avoid blowing the diffuser, but airflow passing inside the engine cover may well be entrained by the exhaust flow and pass over the diffuser's edge for a small but beneficial blown effect.

Audi retains pace and reliability, but the optimised turbo diesel design is now becoming outdated by the downsized PU approach. That is not to say Audi has exhausted the development of the concept, but moves towards a lighter PU making more use of recovered energy may have to be considered if the fight is to be taken to Porsche in the future. ▶

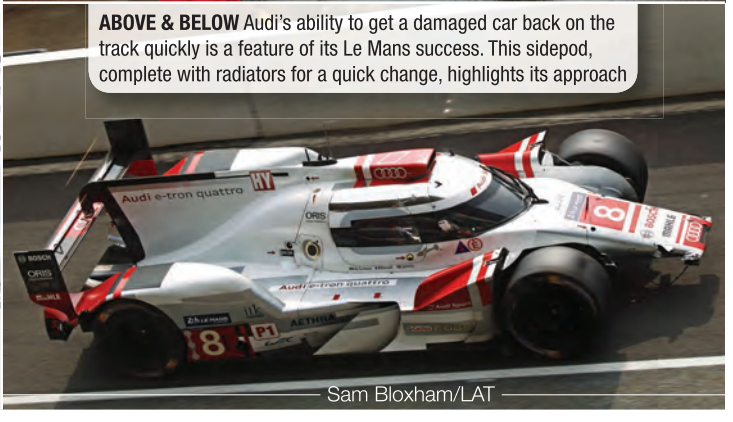
ABOVE Audi's front fender with integrated mirror and turning vane

ABOVE The inner wheel arch with a vane formed from the lower portion

BELOW Overtly blowing the diffuser isn't permitted but Audi continues to try to exploit the exhaust gasses



BELOW The low-drag nose with suspension hidden by fairings



ABOVE & BELOW Audi's ability to get a damaged car back on the track quickly is a feature of its Le Mans success. This sidepod, complete with radiators for a quick change, highlights its approach

Sam Bloxham/LAT

Toyota

It only runs two cars for Le Mans and the marque is now embarking on a full WRC programme, which is potentially a huge draw on resources. It's clear the team now needs to reconsider its design, especially its powertrain, in order to continue to be competitive.

As it decamped from Le Mans after a chastening experience, it confirmed that it will abandon the current engine configuration. Furthermore, it will switch from a super-capacitor to batteries in order to join Porsche in the 8 MJ class.

LEFT Toyota endured a painful race, underlining that the current engine has run its course

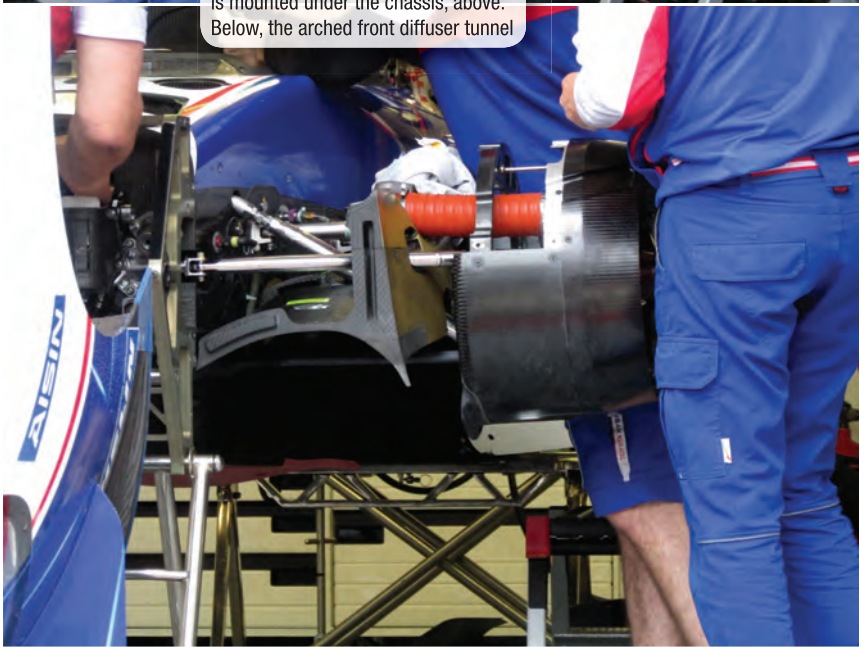
Toyota

As current WEC World Champions, 2015 should have been another competitive year for Toyota but the development battle between Audi and Porsche has moved up a gear. Toyota has made progress over the winter, but simply not to the same degree as its rivals. Fundamental to Toyota's LMP1 programme is its F1-inspired powertrain, the 3.7-litre V8 normally aspirated petrol engine and dual KERS. While lighter and more powerful (in the 6 MJ class) than Audi's powertrain, the setup is becoming inefficient from a chassis installation point of view as Porsche has proven.

Toyota runs a front splitter and diffuser setup. The wide slot across the nose separates the two surfaces, with the upper edge of the slot sweeping up to form the roof of the under-nose diffuser. When the nose section is removed, the profile of the arched diffuser roof can be seen around the footwell area. The distinct arched 'M' shape is required to both help direct the flow out between the chassis and wheel arch, but also because the Toyota has a unique low-mounted front MGU.

The ERS Motor Generator Unit is heavy so rather than mount the unit in the footwell, Toyota has mounted it under the raised footwell area. Then a spur gear system transfers drive up to the short driveshafts and out to the front hubs. This design has several benefits: the weight is mounted low down and also the driver position can be pushed forwards.

Toyota is financially restricted in the WEC compared to Audi and Porsche.



ABOVE & BELOW The TS040's MGU is mounted under the chassis, above. Below, the arched front diffuser tunnel

Nissan

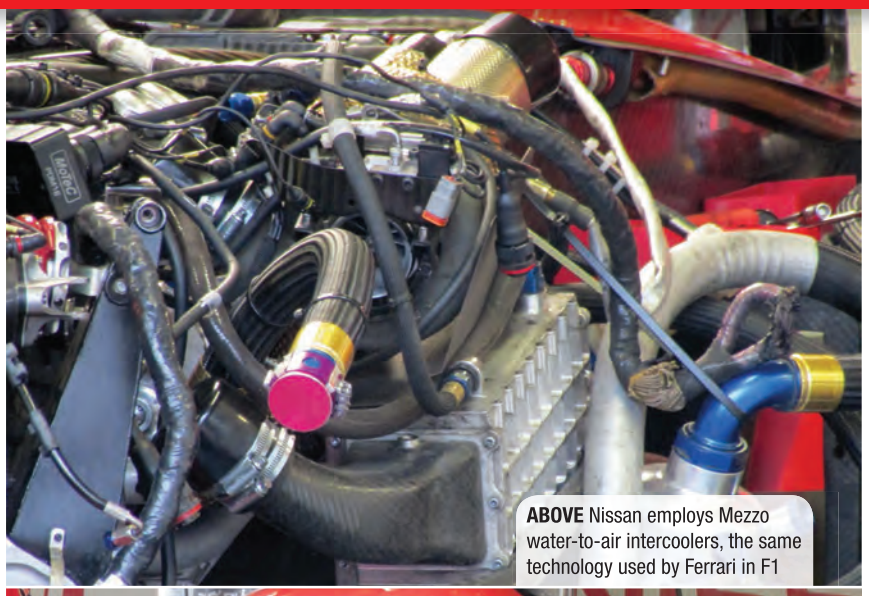
As fully detailed in Race Tech 176, the GT-R LM NISMO Hybrid is a totally different take on what could be competitive at Le Mans. With its intended ERS delayed, the car went to Le Mans with a downsized 2 MJ ERS mated to the front axle. This change forced a late redesign of the front corners, with larger brakes inside large diameter wheels to overcome the reduction in braking from the less powerful ERS.

These alterations, along with the compressed programme to get to the car's first Le Mans, meant compromises – lack of development time with the front tyres among them – which hurt reliability and performance. Ultimately, the team ran without its hybrid system engaged. Come the race, one car hit debris and sustained damage that finally proved irreparable; front brake issues delayed the sister cars.

With the Nissan's front engine setup, the gearbox sits ahead of the motor. The Xtrac unit is in itself unusual: the two gear shafts sit ahead and below the final drive, with the longitudinal shafts being side by side rather than stacked one above the other; the selector forks and barrel are above and to the left of the cluster.

Designer Ben Bowlby was also open about turbos being intercooled by Mezzo water-to-air intercoolers, the same technology used by Ferrari in F1. These are in fact mounted below the turbos, with an aluminium pipe exiting the turbo to feed the intercooler, then carbon ducts take the cooler charge air up to the low-line inlet plenums. These intercoolers appear to be cooled by the same coolant as the engine via the front-mounted radiators.

Nissan will continue to make progress with the GT-R. For 2015 the car was under-developed, but with its correct ERS and another year of testing, I am sure we will see the car be far more competitive. While it may not be in a league with Porsche and Audi, it should be ahead of the non hybrid LMP1 cars.

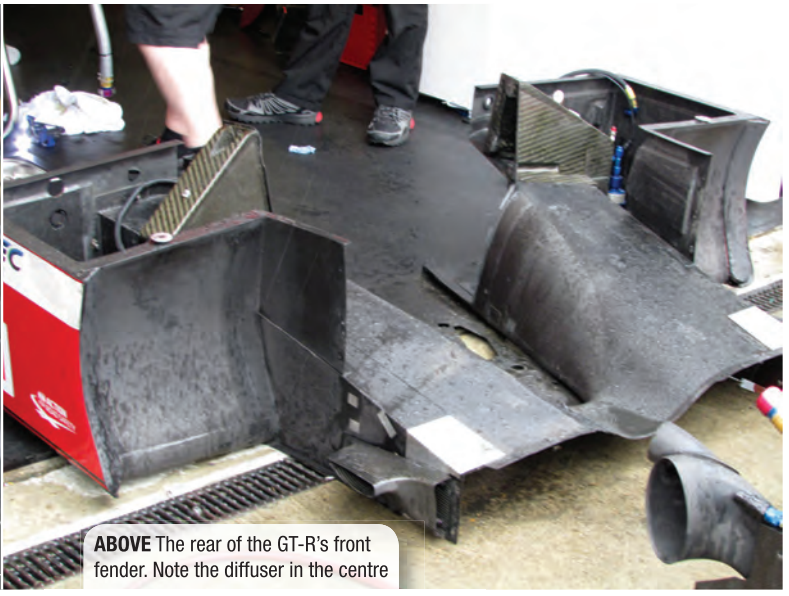


ABOVE Nissan employs Mezzo water-to-air intercoolers, the same technology used by Ferrari in F1

ABOVE Nissan's GT-R LM unclothed, revealing the through-duct which dictates the car's aero philosophy

BELOW Mission accomplished? Nissan saw the flag but performance was lacking

Nissan



ABOVE The rear of the GT-R's front fender. Note the diffuser in the centre

Behind the scenes

William Kimberley takes a snapshot of just some of the suppliers who were hard at work at Le Mans ensuring their customers were never in need

WHILE the drivers and teams understandably reap all the glory for competing at Le Mans, behind the scenes the supply industry is hard at work to ensure that the show can go on.

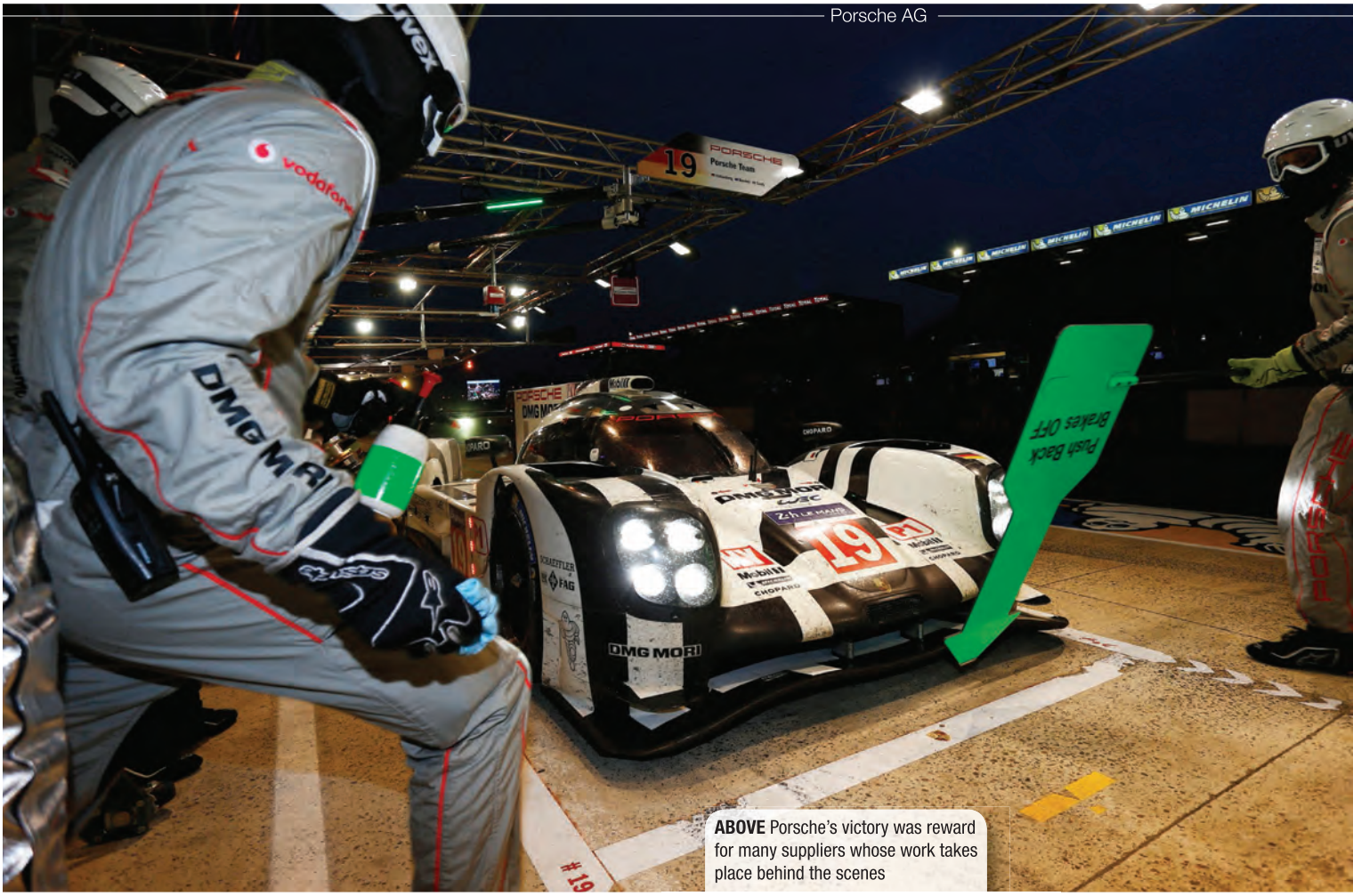
Often their participation is shrouded in secrecy as they are gagged by non-disclosure agreements, but in many cases they are free to talk about their involvement. As a major player in the sport, Bosch Motorsport is one of them.

Some companies are involved with just one or two cars but others, like this offshoot of a major automotive tier one supplier, are on nearly half of the grid. For example, every Porsche 911 RSR and Porsche 911 GT3 RSR was equipped with Bosch engine control units, data loggers, starters, and a variety of sensors for variables such as pressure and temperature; the Ferrari 458 Italias in both LM GTE Pro and GTE Am, meanwhile, featured Bosch gasoline direct injection technology that has been optimised for motor racing, consisting of an engine control unit, power stage unit, high-pressure injectors and a high-pressure pump.

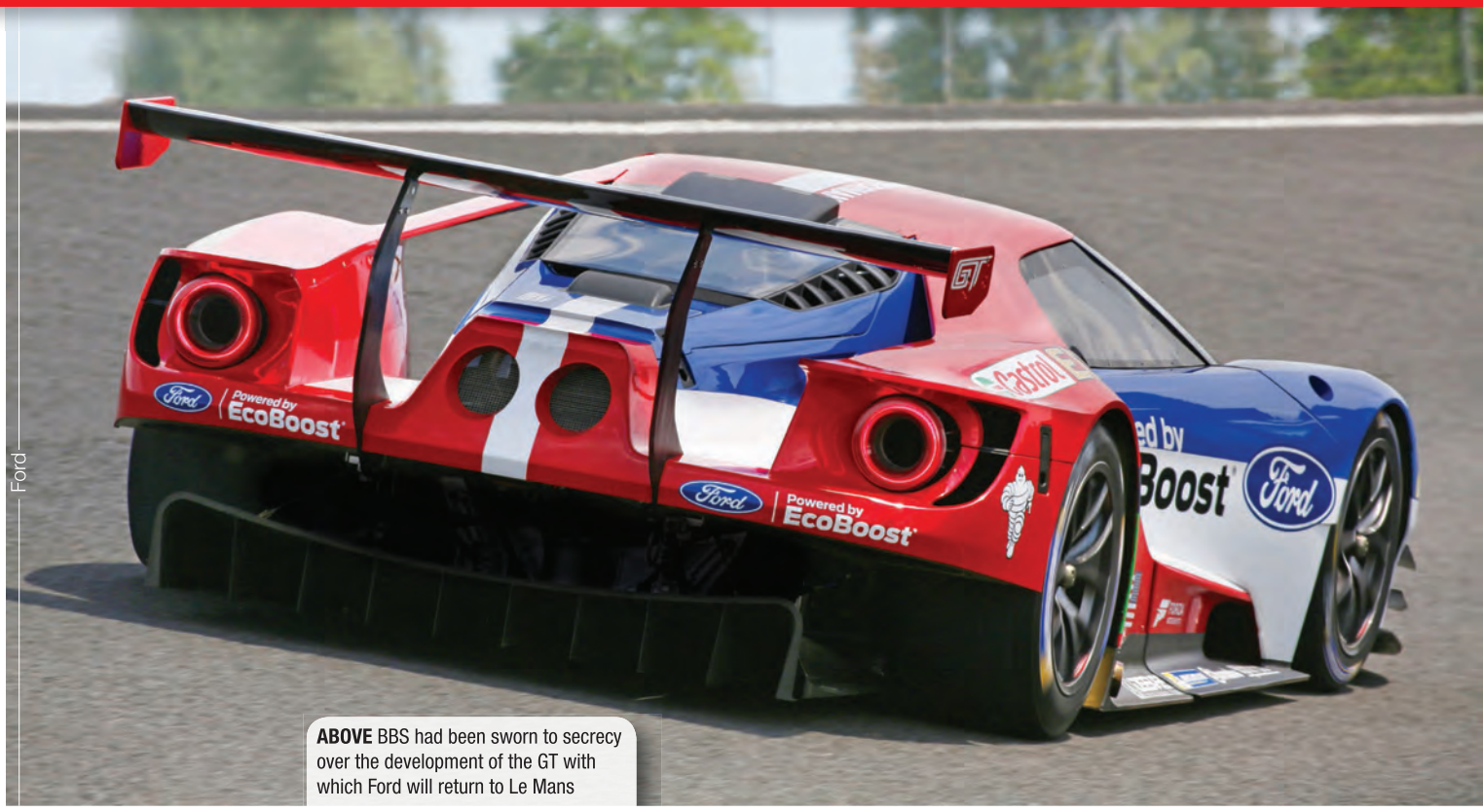
Bosch Motorsport also has a proud record of having been on the victory podium since 2000, a claim it can still continue to shout about as its MS5.6 ECU was on the winning Porsche 919 Hybrid. It has helped that it is also one of Audi Sport's development partners. The demands from the manufacturer are exacting and challenging, but as Klaus Boettcher, managing director of Bosch Motorsport says, he would not want it any other way as it brings out the very best from them.

As in previous years, Bosch Motorsport supplied both the injection technology and core components of the electric powertrain on the R18 e-tron quattro. It also supplied the common-rail injection system, comprising a high-pressure pump, injectors, and high-pressure rail, the ECU unit and the vehicle data acquisition ▶

Porsche AG



ABOVE Porsche's victory was reward for many suppliers whose work takes place behind the scenes



ABOVE BBS had been sworn to secrecy over the development of the GT with which Ford will return to Le Mans

system, starter, and generator. It was also involved in the development of the motor-generator unit (MGU) and the power-assisted rack and pinion steering.

The works Corvettes also use multiple systems and components from Bosch Motorsport, including the ECU, telemetry system and the freely programmable, high-resolution driver display. Furthermore, Bosch also supplied the collision warning system that was co-developed with Pratt & Miller, the product that won the prestigious Most Innovative New Motorsport Product of the Year award in 2014.

It is based on a third-generation long-range radar sensor fitted to the rear of the vehicle that monitors the space up to 250 metres behind. It can simultaneously detect up to 32 objects, along with their distance from and speed relative to the vehicle. The data is combined with a video camera, feeding drivers real-time images on a cockpit display. As a result, they have all kinds of useful information directly in their field of vision, such as how many cars are behind them, their approach speed, and on what side the faster prototype vehicles are trying to overtake.

ABOVE Bosch's collision avoidance system

Another winner this year courtesy of Porsche was BBS Motorsport, which has been a longstanding supplier of the German sportscar manufacturer. Motorsport director Erich Gissler, though, was particularly delighted that Ford had opted for his company's wheels with the new GT that will be competing in the race next year.

The company has a long history with the Dearborn manufacturer, supplying both its road and race cars over the years, but it was sworn to absolute secrecy during the development of the new car that was unveiled at the Detroit Show at the start of the year. Further work was entailed for the race version, Gissler saying that as with every manufacturer BBS Motorsport supplies, it works with the team on the development of bespoke items. He pointed out, however, that the regulations nowadays are so rigid that it is a challenge to produce anything too radical.

BBS Motorsport also worked with Nissan on the GT-R LM NISMO. This is a car that required special wheel sizes that at the beginning of the programme were 16-inch all round. However, this was later changed to 18-inch at the front and 16s on the rear with tall sidewall tyres measuring just nine inches wide, five inches narrower than those on the front wheels. ▶

Warner/LAT

LEFT Rebellion's speed impressed after a race against time for AER, supplier of its P60 V6 DI twin turbo engine

BBS also supplies wheels to customer teams, Gissler saying that some use them for three consecutive seasons. "Something we've done for years is to offer our customers a wheel refurbishment service whereby they send them back to us and we completely evaluate and test them to make sure they are still in a good and safe condition. It's also useful to us as we see how the wheel is standing up to real-life use and how they compare to our FEA calculations and test results."

"It always helps when the components are winning," was the reply that Pankl Engine Systems' Werner Bruck answered to the question as to whether lessons learnt at races like Le Mans are useful for the company's other businesses in the automotive sector. "However, the DNA of Pankl is not to publicise any success because at a race like Le Mans, the entire community here are our customers. They all know what we are doing and are a part of any success and when they read that Porsche or Audi is winning then they know that we are part of that."

ZF Race Engineering was present at Le Mans in force, its dampers and clutches being found on cars in every class. Product manager Rainer Kirchner, along with development engineer Michael Istschenko and Mehmet Ozerman, who looks after ZF Race Engineering's activities in the US, plus many others from Schweinfurt in Germany were all at the race to look after their many customers. Some buy products that are more or less off the shelf, but others like the factory teams work closely with the company to develop bespoke items.

"Depending on the customer and the class they run in, they have different demands on the service and support they want to have," says Kirchner. "For sure we have a wide range of products but there's more of a demand on the drivetrain side, especially as our damping systems are on nearly all the LMP1 cars, including Rebellion Racing."

"Le Mans is an important race for us," says Istschenko, "and it's important that we are here in force to support our many customers. It's also a very good way to see how our products stand up to the rigours of a tough 24-hour race on the huge variety of cars we are on. We are always learning things even after so many years."

A major challenge for the company is providing the wide variety of clutches up and down the pit lane. "Obviously a 24-hour race brings its own demands," says Kirchner, "but it's the variety of engines and power units that our clutches have to service that is the challenge. This is because every one has its own vibration signature which has a heavy influence on the clutch itself, so we can't just provide a one-clutch fits all solution. Even changing the mapping of an engine changes the drivetrain vibration, so it's a very complex challenge."

REBELLION GROWS

This year's race was like no other previous Le Mans experience for Rebellion Racing, the reigning privateer LMP1 winners at La Sarthe. After a decision deep into the off-season to change its engine supplier, preparation for the event turned into an intense race against the clock after it received its first modified chassis tub from ORECA on 30 April and the first race-ready V6 gasoline direct injection, twin turbo engine, designated the P60, from Advanced Engine Research (AER) on 18 May.

Three days later the shakedown of the first car was completed (R-One #13) with that of the second car (R-One #12) the day after. Just three weeks later and both cars were taking their place on the grid for the 24-hour race.

There were many questions surrounding their performance, such as whether they would be on the pace, as well as their reliability. Qualifying offered some sort of reassurance as both cars secured top 10 grid positions ahead of the three factory Nissan GT-R LMs in the LMP1-H class.

The race transpired to be far less fraught than the timescales involved had suggested, the Swiss team having to deal with crash damage, driveshaft failure, wheel bearing failure, fuel injector failure and spark plug failure. Despite all this, both cars finished, earning a 1-2 in the privateer LMP1 class ahead of all three works Nissans. Their best lap times were three seconds quicker than last year. In fact, one of the cars set the second fastest straight line speed during the week, within just a couple of kilometres per hour of the leading factory car, a feat accomplished without the benefit of hybrid power.

For Mike Lancaster, AER boss, it had been a real test of everyone's character back home at the premises in Basildon, Essex in the UK. "It showed real commitment from Rebellion Racing to come to AER for its engines this year," he says. "If it had been the wrong choice it could have been ▶

disastrous for them."

The fact that both cars finished the race was therefore a source of satisfaction for Lancaster, but it was qualified. "While it was satisfying that both Rebellion Racing cars finished the event, it was frustrating that they were partially delayed by the failure of some ancillary parts, specifically the gasoline direct injection pumps. What was doubly frustrating was that they had worked all last year on the ByKolles car without any failures at all. That one issue with the pump had a knock-on effect leading to spark plugs and fuel injection issues. Having said that, we do regard the result as a real success as the engine itself and the integrity of the mechanical parts were excellent and we have come away with valuable data.

"It goes to show, though, that unless you can do a full Le Mans race simulation regularly as the manufacturers tend to do, you can come unstuck. For example, we wasted a chunk of time on things that we thought would be reliable."

The culprit GDI pumps were AER's own but as Lancaster explains, it is all to do with the LMP1-L cars being given gradual incremental increases in fuel flow, one even coming just before the race. "We now know that we reached the limit of the pump's capabilities and had pushed it just a little bit too hard. Whereas it would probably have survived for a lesser race, the engine duty cycle being lower, at Le Mans there's a tremendous engine duty cycle with full throttle on the long straights.

"At the same time the pump was being asked not only to produce a very high level of pressure but also the flow had gone up by a couple of per cent. This was just enough to make it run in an unstable area. As a result of this it caused increased pressure fluctuations and that led to premature pump wear. In the race we literally used every GDI pump spare we had.

"I think it was a very borderline problem but unfortunately we didn't have enough of those problems before the actual race to let us see it coming. If there's any consolation, it's an easy fix and a relatively trivial problem to put straight." RT

IBD enjoys "good vintage"

SINCE its inaugural running in 2008, the International Business Days event in the lead-up to the Le Mans 24 Hours has grown in significance and importance. It generally attracts the same number of participants each year although there is a continual churn of those companies and organisations that attend.

"Again it was a good vintage," says event organiser François Lassalle. "We had 41 companies participating over the two days and a much greater involvement from the local authorities which now recognise the event as a way of promoting their region and encouraging inward investment. We were also pleased to have buyers from Citroën Racing, Toyota Motorsport, ProSpeed and ORECA.

"We are now actively preparing the ninth event next year in connection with local authorities and a few other partners with a 'Save the Date' being released by September or October."

ABOVE KA Sensors was present, investigating markets for products such as its air temperature sensor featuring a PEEK tip

One of the new participants this year was UK company KA Sensors, which is totally dedicated to motorsport, designing and manufacturing high-performance sensors. "While we offer a large range of our products off the shelf, we also offer a full ground-up custom design service," says KA Sensors application engineer Gary Rands.

The product range is extensive and includes pressure sensors, temperature sensors, force and torque sensors, position sensors, speed sensors and accelerometers and gyros. "Depending on the series, just what sensors a team can use varies," says Rands, "so while a car may not be permitted to run with a full set during a race, when it comes to testing, teams often want to record as much data as possible. In some cases, such as touring cars, it might even mean a second wiring loom being fitted that's then removed for a race."

KA Sensors is currently working with a number of World Endurance Championship and Formula 1 teams on their hybrid systems, but it's a project with a car manufacturer that is developing a full electric vehicle that it exercising the best minds, says Rands, with some of the data that's required really pushing boundaries. With its motorsport background, though, this is something that the company is quite used to.

ABOVE The IBD event continues to grow in significance

As the Patron of the event, Italian engineering service Danisi Engineering, which has a 20-year history in motorsport having developed components, sub-systems and complete rolling chassis for various teams and manufacturers over the years, was flagging up that it had just reached a technical partnership with simulator manufacturer VI-grade. The aim is to provide integrated engineering services to the global automotive market through what it termed as a system-level approach.

"We are currently combining the VI-DriveSim static simulator with a physical EPS-assisted steering rack," says Giacomo Danisi, owner and CEO of Danisi Engineering. "The ultimate goal is of more accurately reproducing steering feedback to the driver by including physical hardware in lieu of complicated and difficult-to-obtain software models. Thanks to this combined technology, we can perform a set of manoeuvres encompassing different driving conditions, matching the results of dynamics simulations with measured data and therefore building a reliable specification network." RT

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Did you *really* brake? Let's see...

British Touring Car Championship clerks of the course and stewards have a new ally in their eternal battle to improve driving standards. **Scotty Whitelaw** reports

THE British Touring Car Championship has forged its popularity with spectacular wheel-to-wheel racing. For the fans, it's fantastic, keeping us on the edge of our seats. For the championship organisers, though, that uncompromising battle on the racetrack can cause headaches in the stewards' room afterwards as they seek to determine whether contact was intentional or not.

"We never really used the data provided by the teams before, because of how unreliable it could have been," says Jeff Allam, the BTCC Driving Standards Advisor. "We're not saying the teams were altering their data, but they have the resources to do so if they wanted to. Sometimes there would be an indication of the data being wrong, but we had no method to prove it." With this in mind, the BTCC needed a way to police what each team was doing during the race.

This has been a recurring problem for the series organisers. The first solution attempted in 2005 utilised Fuji cameras, installed inside every car's driver cabin and footwell, to monitor the driver input. Initially this worked really well. As technology made the cameras more foolproof, though, the auto focus meant the area in focus depended on the light levels and hence they were unable to stay in focus for the entirety of a track session.

Subsequently the BTCC replaced the Fuji cameras with GoPros. They were able to stay in focus but suffered their own issues, such as poor battery life, meaning the system had to be constantly monitored and batteries replaced when required. This increased operating logistics and time. Another problem revolved around the GoPros' sensitivity to light. Because of the camera setups and their positioning within the cabin, images were sometimes unclear due to the glare of the sunlight.

In the meantime, well away from racing, Cosworth had been developing its 'aliveDRIVE' system for a major road car manufacturer, specifically for high performance sports cars. Designed to enable post-driving analysis, it had proved a big success. Perhaps this was the answer the BTCC had been looking for?

BTCC Technical Director Peter Riches was soon alerted to it and set in motion a process to look at the system to see whether it was applicable for racing. It seemed to tick the boxes: the cameras remained in focus; there were no lighting issues; and no battery.

The setup is very similar to that of the cameras tested before, but now addresses all of the issues previously encountered. They are connected up to the vehicle's own battery, along with the rest of the Cosworth data system. With the Cosworth aliveDRIVE, stewards have reliable video footage to view. ▶

ABOVE & BELOW The use of aliveDRIVE means the BTCC's spy in the cockpit is better than ever before. Here the stewards can see Gordon Shedden at full throttle (above) and on the brakes (below)

Nowhere to hide with aliveDRIVE

ABOVE The next generation of Cosworth's aliveDRIVE: bringing video data logging to a wider market

THE success of Cosworth's aliveDRIVE in the BTCC demonstrates how video data systems that were once the preserve of elite motorsport championships could soon become commonplace amongst every series.

"aliveDRIVE pushed the boundaries when we first conceived it as an affordable video data system that could be tailored for mainstream automotive or motorsport applications," says Pio Szyjanowicz, head of communications and partnerships at Cosworth. "We're delighted that it's proving a success with the teams, drivers and stewards in the BTCC.

"We're seeing interest from championships around the world and working on an extensive programme to develop new features that will bring high-res video data logging to a much wider market." As well as the BTCC, the system already features in Porsche Carrera Cup GB and its brother series Down Under.

Cosworth's electronics division has been involved in video data systems for almost 20 years, dating back to projects for teams racing in Formula 1 and NASCAR. To achieve the level of accuracy required, the hardware has always been expensive. However in the last two years Cosworth has focused on creating a data acquisition platform for the high-performance OEM market which was drastically lower in cost to the end customer.

General Motors installed it in Corvettes so that post-driving analysis could be conducted, be it for track days or improved customer safety. The system included HD video cameras, car analysis data (similar to that found in Pi Toolbox), GPS data and accelerometer sensors. Such was its success that GM added it to a selection of its other models, including the Cadillac.

The electronics team at Cosworth has also been heavily involved with the BTCC for many years, delivering a range of different chassis and engine control systems. It was therefore a natural partner to turn to when the BTCC encountered issues implementing successive cockpit camera systems in its bid to aid stewards.

Cosworth's motorsport version of its aliveDRIVE solution is based on the same technology that underpins the GM system, but with significant alterations to adapt it for the needs of a motorsport championship.

One of the major adjustments to the system has been to ensure that the BTCC teams cannot access any of the data sent to the stewards – but are still able to access the data that they log to understand and improve vehicle and driver performance.

Video footage and track data are synced and displayed side by side to allow the stewards to easily visualise what occurred. One of the main features that make this setup stand out is the inclusion of custom wide angle lenses in the HD cameras used in the motorsport system. With the driver's view through the wing mirrors and rear view mirror both displayed in the same image, miscreants now have nowhere to hide.

ABOVE & BELOW Video footage and track data can now be synced and displayed side by side

HOW DO THEY WORK?

This ingenious process records the onboard camera footage on a Fuji memory stick that the stewards can review after every practice session and race, allowing them to visually analyse the drivers' control of the vehicle. The system also creates a video map of the incident, presenting all of the camera angles in question at the same time, from all of the cars. To rule on incidents, the stewards now have direct access to the vehicles' performance data, recorded via PI Toolbox – with a live streaming arrangement being fitted from the previous two systems. This ensured that teams could no longer cover up their actions and play excuses such as 'a higher rev count accrued because of an engine misfire' or 'there was an incorrect gear change'. Instead the drivers must now face the consequences of their actions.

Using Pi Toolbox the stewards can also run synced footage from two cars on the screen at the same time. This enables them to get both drivers' views of the incident and their reactions during it.

RELIABLE AND ACCURATE

"This new system is simpler and more consistent," enthuses Allam. "It gives us reliable and accurate information." He also notes that having the car data directly streamed to the stewards gives them reassurance, knowing that there are no discrepancies with the data acquired. This new setup also produces a much faster response time, as data can be accessed almost instantaneously.

As a former champion himself, Allam is effectively a poacher turned gamekeeper. He reveals that when investigating contact incidents in the past, the stewards encountered a familiar problem: if the driver claimed they had braked going into a corner, the unreliability of the previous systems made it difficult to prove to the contrary. With the Cosworth aliveDRIVE in place, the game has changed.

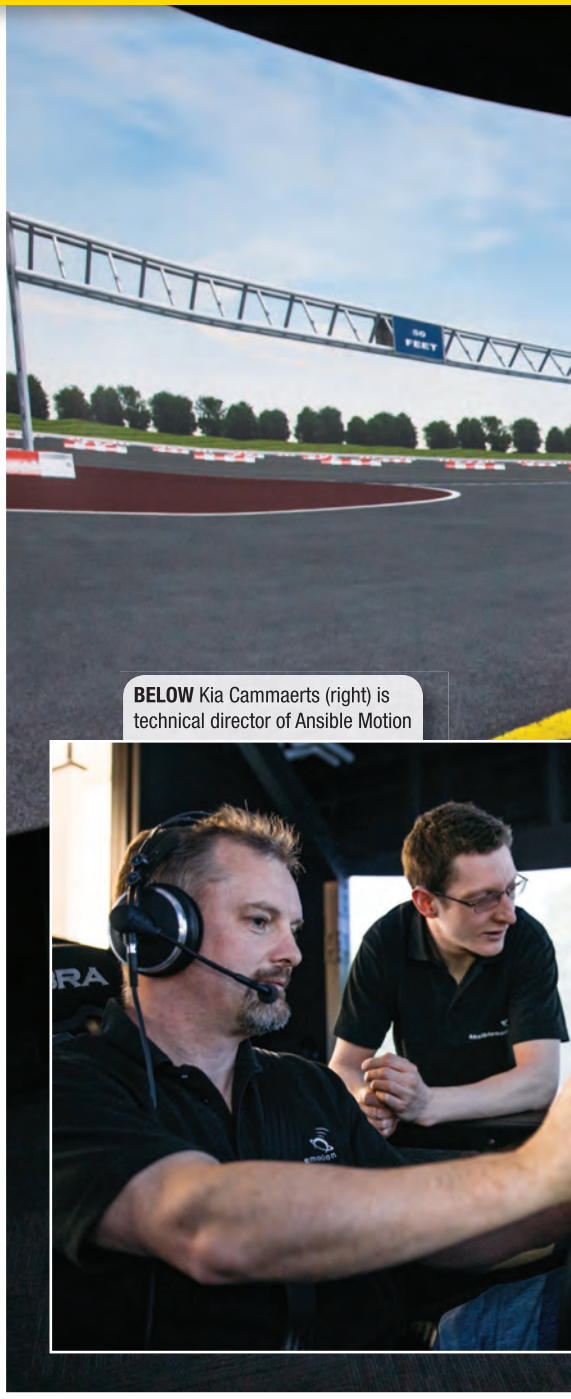
Now the stewards are free to analyse the actions of every driver. If one of the protagonists claims he was braking but the data shows otherwise, it's possible to retort: "No, you didn't! You clearly kept your foot planted in the corner."

"In previous seasons teams would argue cases like this," says Allam. "With the Cosworth aliveDRIVE now being used, these disagreements are a thing of the past. The stewards can now see clearly what the driver's actions were. I wish we had this setup years ago. Getting to the bottom of these skirmishes between the drivers now takes mere minutes, with data we know we can trust." RT

LEFT & RIGHT The cameras installed in the BTCC cockpit

INVENTING THE FUTURE

Hearing about a simulator with human feelings, **William Kimberley** just had to go and find out whether the robots are finally taking over



BELOW Kia Cammaerts (right) is technical director of Ansible Motion

VEHICLE simulators have been undergoing a revolution in the last few years with huge advances in graphics and responsiveness and more accurate road modelling. Along with this, driver-in-the-loop (DIL) simulation has been promoted as one of the most effective tools for vehicle and component development. However, it still has its detractors, those who distrust the data generated, while at the same time the motion sickness label refuses to go away.

Located in deepest Norfolk in the UK's East Anglia and just a stone's throw away from Lotus Cars, Ansible Motion designs, manufactures and supports 'engineering-class' driving simulators for all types of ground vehicles with particular relevance to the professional motorsport and road car sectors. Nothing new there then, but enter technical director and company founder Kia Cammaerts.

"When Ansible Motion opened its doors at the Hethel Engineering Centre as a research unit looking into how laboratory motion systems could help in the development of a racing car, the first question my co-founder Bob Stevens and myself asked ourselves was whether a motion platform would add anything to a driver-in-the-loop simulator. Such things were around but the first question that needed to be addressed was what was the most direct way to do the job properly?

"So we approached simulation and driver-in-the-loop with a clean sheet of paper and looked at how we could create an immersive experience for drivers of virtual vehicles. This caused us to think about entirely new motion machinery and motion cueing strategies, and ultimately an entire suite of simulation products we define as engineering-class simulators.

"We quickly came to the understanding that the machinery is secondary to the motions that were going to be imparted and that we first needed to get a good understanding of what they should be. We then created our first motion platform in a form-follows-function sense so that the motion space and the motion capabilities suited the requirements of our motion cue logic.

"We originally thought we'd just build clever motion platforms, thus our company name, but very quickly realised that there isn't a market just for them and that we needed a complete tool chain. You can have the best motion platform in the world but if the other parts aren't up to par, it leads to a poor driver experience, which is disastrous. So, pretty quickly, from late 2010 onwards, we essentially became a general simulator design and manufacturing company to include the entire simulation chain and turn-key simulator solutions. We assembled components from specialists, some of whom are many times our size, but we assembled them in such a way as to create a compelling whole. The motion platform completes the system."

BATTLING 'BIGGER IS BETTER'

The result seen in the £2m research centre is the Delta Series full motion simulator. It has been designed for use by highly skilled drivers and looks to provide accurate and subjective feedback when evaluating new handling, steering and dynamic performance on racetracks and virtual proving grounds. It has a six-degrees-of-freedom motion system, powered by 16 5GHz computers, with five projectors projecting a 240-degree wrap-around view onto an 8m screen. The R&D Centre also includes a full control room to allow engineers to monitor up to 300 channels of data.

One thing that stands out is the simulator's compact size. "We are very proud about just how compact our motion platforms are," says Cammaerts, "although it does require some explanation as to why it's better, since conceptually we must counter the subjective bigger-must-be-better mind-set with the objective assertion that performance is inversely related to mass for dynamic machinery.

"Many simulators can accommodate full car bodies on them and can take the payloads without apparently suffering problems, but the consequence of designing a motion system to accommodate such large payloads is necessarily a poorer quality of motion and a higher latency of motion. One of the essential components of our design philosophy – with a 20-year background in

ABOVE The company's ambition is to deliver an ansible – a fictitious machine capable of instantaneous or superluminal communication – in the form of a driving simulator

the design of lightweight structures – was to put material only where it was needed and remove it where it was not and include that philosophy in both the machine and the payload design. The result of that is a virtuous circle with lighter payloads needing lighter supporting structures, lighter actuating elements which in turn leads to lighter components and the end result is a lightweight, highly responsive, very accurate system that behaves correctly when coupled to dynamic [vehicle] simulations ”

Another significant feature of the simulator is that all the ground plane axes are independent of each other and so allow full motion authority on any of them irrespective of any of the other axes. According to Cammaerts, this is different to any other simulator which is completely dependent on the state of all of the other axes for any particular direction of motion. “We also have a three-degree-of-freedom parallel arrangement in the centre that we have buried inside the machine giving us an extremely low centre of gravity.”

Another building block in the process was the creation of virtual models of the platform, its control system and the motion cue filters. “We then adapted one of the newer control strategies for motion cue filtering and have since worked closely around that,” he says.

“The development of graphic adapters with very high rendering capabilities, resolution, quality and image generation processes, is coming on at a pace that is exceeding processor development.

“We don't create the graphics and road modelling ourselves but instead integrate high end solutions such as rFpro because they understand the importance of low latency image generation and synchronisation with complex tool chains. Supplemental motion cues in the car include audio and haptic feedback through the steering wheel, seat, the pedals and seatbelt tensioners, but we class all those as supplemental layers on top of the crucial inertial and visual stimulants that are informing the driver.”

Cammaerts then talks about how the latency between the command in motion – the driver input – to the physical motion – ▶

ABOVE & BELOW The motion and vision are highly synchronised to avoid disorientation

the simulator's response time – needs to be such that it is below the driver's perceptual threshold which, depending on the person, is around 30 ms, so he or she can't feel the lag. "The reaction time is much larger than that but the perception time is what matters here," he notes. "If there's a lag between expected and actual motion it causes all sorts of bad things. At the very least it makes the human driver feel he's driving a sluggish vehicle, although the more experienced and professional driver is more likely to start to feel motion sickness.

EMOTIONAL INVOLVEMENT

"Key was the understanding that the driver's emotional involvement is vital in creating a high quality simulation experience, so we built a model of the human vestibular system into the simulator so the drivers can accurately relate to the handling of the cars. The human body is great at controlling vehicles designed to suit our abilities but if we receive feedback that doesn't fit with what we expect, then we become disoriented and confused. This is a key element behind some drivers experiencing motion sickness in poorly configured DIL simulators.

"In initially measuring the reaction of humans to motion, we used publicly-sourced scientific papers that developed mathematical models of human perception of motion. We then embedded detailed mathematical models of the human anatomy, such as vestibular system models, right into the motion cueing and control algorithms of our motion control systems. The human vestibular system, which comprises the semi-circular canals and otoliths of the inner ear, are affected by inertial stimulation and are a key part of a person's spatial awareness and sense of balance. Factoring this directly into our motion control algorithms fundamentally increases the realism in ways you can experience.

"Along with this, the visual feedback must be correct to have a real sense of velocity and location in the worldscape and the motion and vision must also be highly synchronised in order to avoid sickness and disorientation.

"In fact, this human modelling aspect isn't unusual, but what's unique about our approach is the uncompromising way in which we implement it. We can achieve this because our motion control and hardware is up to the task with sufficient headroom to simulate even extreme dynamic situations."

In summing up, Cammaerts believes that this is the future, whether it's in motorsport or automotive. "We have come to the stage now where not having performed engineering quality, driver-in-the-loop simulation with motion prior to the next race will become unthinkable for the major constructors in racing. We think this will percolate through the rest of the constructor world in motorsport."

ABOVE The company offers turn-key simulator solutions

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DOUBLE WHAMMY

ABOVE A new motion platform is to be integrated into the single-seater simulator

Chris Pickering visits Base Performance Simulators, established by double Le Mans class-winning racer Darren Turner

ABOVE Turner is a two-time class winner at Le Mans

TUCKED away in a quaint corner of the UK's motorsport valley lies Base Performance Simulators. Owned by Aston Martin works racer and former F1 test driver Darren Turner, the company specialises in building simulators for customers and providing on-site hire facilities in its two purpose-built rigs.

In last month's Last Lap column we sampled the firm's GT simulator first hand. Modelled on an Aston Martin Vantage GT cockpit, it uses a six metre wraparound screen with three ultra-low-latency projectors to create a truly immersive experience. You even have to thread yourself through the roll cage to get in.

The simulator is powered by a pair of high specification PCs, built in-house and running bespoke software based on rFactor, including full data logging and analysis. Hardware includes a genuine racing steering wheel with a paddleshift system, full hydraulic systems for the clutch and brake, and a high torque steering motor, capable of producing GTE levels of feedback.

Just down the corridor lies the open wheel rig, using a similar wraparound screen and a replica single-seater cockpit. Both are available to hire and teams can either work with BPS to develop a bespoke vehicle model or bring their own model (a small amount of adaptation is required to get a conventional rFactor model to work, but the company can provide the necessary assistance). Non-disclosure agreements and data quarantining can be provided for customers wishing to work discretely.

> *"Sim-savvy professional drivers find their times in the virtual world match real life almost exactly"*

BPS also has a comprehensive library of car and over 140 circuit models for drivers who just want to get in and go. Typically it takes about 10 laps for a driver to get a feel for the simulator, we're told. Some – particularly those from the Playstation generation – take to it even quicker, while a minority struggle to find correlation. In general, though, sim-savvy professional drivers find their times in the virtual world match real life, almost exactly. Make no mistake, this is a serious piece of kit.

Perhaps surprisingly, the one thing the simulators at BPS don't currently possess is a motion platform. We've grown used to seeing the likes of Lewis Hamilton being bounced around in multi-million pound full motion simulators on the TV, and the top end systems are indeed freakishly good. But, generally speaking, the more affordable options tend to be a mixed blessing. In some cases they can end up doing more harm than good by feeding the driver misleading or badly-timed cues. In short, it needs to be done properly. And that costs a lot of money.

"We've been playing around for a number of years with low-cost motion ▶

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platforms, but in the past they never performed quite as we wanted or offered the tunability we were after," comments Base Performance Simulators' business manager, Ella Barrington.

Things are about to change at BPS, however. Last year the company was awarded EU funding through the Northamptonshire Enterprise Partnership, which it has combined with some of its own funds to commission a full motion system from Moog Controls in Amsterdam. (Those of you who know the company might have spotted something odd here; the postal address is given as Banbury, Oxfordshire, but the site is actually located half a mile inside the Northamptonshire border. More to the point, a significant portion of its customer base comes from this part of the world.)

"We are working very closely with the Moog engineers to integrate the new motion platform into our single-seater simulator and we hope to have it up and running by late August or September," Barrington reveals. "It's a large undertaking for a small business like ourselves, but we're very fortunate in the partners we have. A number of well known drivers with F1 simulator experience have volunteered to help us set it up."

SHOCKED

Because of the NEP funding, she explains, BPS should be able to install the new facility without passing the cost on to its customers.

Of course, there's more to the company than hiring out seat time. "A lot of people in the UK see us as primarily a hire facility and they are sometimes quite shocked when they come in and find we've got a fully-fledged workshop with guys soldering circuit boards and building chassis [for the simulators]. Overseas, on the other hand, we're best known for exporting chassis and a lot of those customers are surprised when they visit us and find there are teams going in and out on a daily basis."

When speaking to prospective customers, the discussions tend to start with a package similar to those found on-site, but they quickly evolve. Just about every aspect of the system is scalable and configurable. Want your GT simulator based around a Ferrari 458 cockpit? No problem. Likewise, screen sizes and the like can all be tailored to the requirements and the available space.

ABOVE & BELOW The setup provides an ideal environment for driver coaching

SIM IN THE BEDROOM

Generally the recipients are professional race teams, but that's not always the case. One customer in the US has a simulator in his bedroom, while another was recently installed in an apartment in Hong Kong, up five flights of stairs. "No two are the same," comments Barrington. "There are certainly individuals out there for whom the cost isn't a problem, who will install one in their house without any intention of becoming a professional driver."

The cost and complexity of installing a full motion platform make it a very big commitment indeed. Even the building housing the simulator may need to be modified, so BPS is anticipating that most of its custom builds will remain static.

"A lot of our customers are professional race teams and they're very busy, so they want a turn-key solution that's going to be easy to maintain," says Barrington. "Generally they're not looking for a full motion system that will require them to dig up the floor and raise the roof."

That said, the company will be able to work with prospective customers, should they require a motion platform. And as for the cost? Well, to replicate the company's current [static] GT simulator will set you back somewhere in the region of £100,000. Adding a motion platform could well double that, we're told. It's not cheap, but it should be worth every penny. RT

Performance enhancers

William Kimberley takes a look at recent developments in engine components

THE Aussies are coming! To most cricket-loving Englishmen this will mean the imminent arrival of the mighty Australian team and its likelihood to once again clobber the English and retain the Ashes – apologies to non-cricket loving readers of this magazine (although you don't know what you are missing) – but in this context it means **Turbosmart**.

Despite only being founded in 1997 by Nic Cooper in New South Wales, the company quickly established itself as an important manufacturer. Its range of products included blow-off valves, external wastegates, wastegate actuators, manual and electronic boost controllers, fuel pressure regulators and silicone hose.

However, while its home market was important, the export market was where the real growth was going to be made with the US in particular being a vital element of that. Despite a strong and well established industry there, Cooper grabbed the bull by its horns and set up Turbosmart USA eight years ago, a move that has paid dividends.

The icing on the cake is the recognition it has received both for the company's export efforts, with numerous industry and government accolades in the last few years, and for the quality of its products. It won a Global Media award for an innovative wastegate sensor cap, and was also runner-up in the Best New Racing Product for 2015 category at the SEMA Show. Cooper now has Europe and the Middle East in his sights.

The responsibility for developing this market has fallen to UK general manager Chris Milne, who is well placed to set up this new office, also continuing to serve as group export manager. Milne, who moved to the UK last year to set up offices and a warehouse, says: "We have yet to trade for a full year in the UK but it's already exceeded expectations. One of our philosophies is that we haven't come here to tell customers and potential customers what they should be having, but rather listen to them and meet their needs."

Milne says, "One of Turbosmart's USPs, which is especially important to our customers, is that the company designs, develops, manufactures and then tests every single product back home in Australia. Everything is made and manufactured under one roof at our Sydney facility."

Another aspect of the business that Milne is proud of is that every other year every product is analysed and assessed and updated where necessary. "We are continually learning," he says. "What might have been satisfactory four or even two years ago no longer is for a variety of reasons, so we look at it and decide where it can be improved."

While motorsport runs through the company's veins, Milne says that the volume comes from the road car performance side of the business. "Each product has motorsport DNA within it," he notes. "We align most of our products with motorsport in mind but it's the performance tuning and mods for the street that provide the volume."

Supplying the drag racing market is key to the business in the US. In Europe, Milne says that while there is a certain amount of drag racing interest, his customers tend to be much more into track and endurance racing, so the products need to be aligned accordingly. "In drag racing, the whole race is over in five or six seconds, meaning that the heat build up is instantaneous but short," he reports. "In Europe, the heat build up is slower but sustained, so it's all about

ABOVE Turbosmart's RX7 development mule pictured in the company's (then bare) new facility. The Sydney HQ features 10 times the space of the old building

heat management and thermal stability and the products need to reflect this."

Turbosmart provides more than just products, as it is also a technical partner with a number of companies and teams. "We have the capability, the knowledge and nearly 20 years' experience in this field," says Milne. "I think we have a lot to offer any potential partner."

ELECTRONIC THROTTLE ACTUATORS

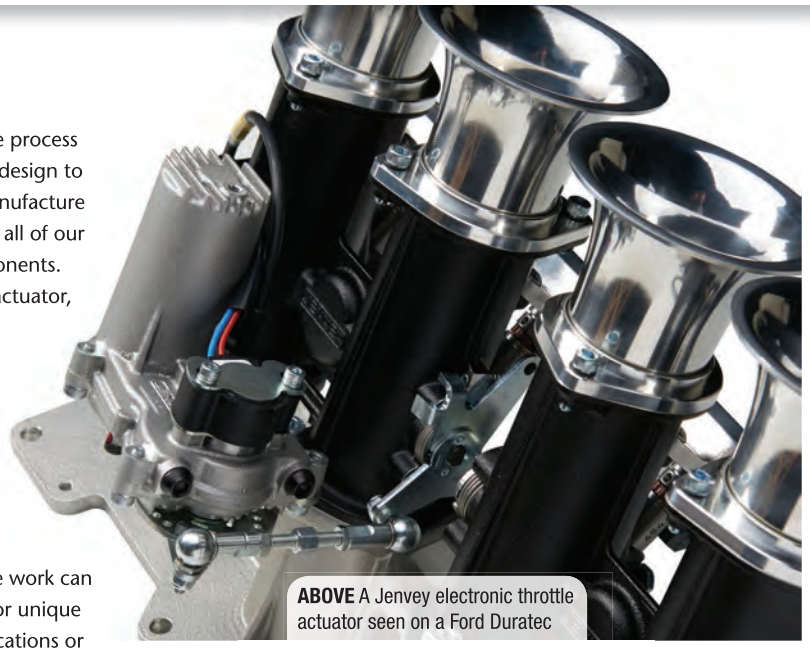
The induction system of any racecar is only as good as the sum of its parts, and while large amounts of time and money are invested in squeezing out every available horsepower and improving durability, physical throttle actuation is an often-overlooked area. This is the view of **Jenvey Dynamics**, a leading developer and producer of throttle bodies and induction components, which believes that its new electronic throttle actuator provides a definitive answer to the electronic versus mechanical actuation debate. It also makes a fly-by-wire derivative for individual throttle bodies a more attainable proposition, without compromising component quality or durability.

"Electronic actuation is a vital method for optimising race-bred induction systems," says Jenvey Dynamics managing director Mike Jenvey, who explains that the company's new ETA2 Motorsport electronic throttle actuator provides a high quality, proven solution for a comprehensive range of applications.

"Highly complex and often prohibitively costly fly-by-wire throttles are not always a viable option for smaller-scale teams or privateer racers, whereas a mechanical linkage can result in an engine running at less than optimum," he adds. "We identified a need for a component that is good enough to be used in international race series, which is highly configurable depending on use and application, and yet which can benefit one-car teams, or even track day enthusiasts due to unit cost."

The ETA2 Motorsport electronic throttle actuator unit is tested to function in the temperature range of -20° to 140°C, and weighs just 500 grams. It operates a voltage range of 10V to 16V depending on applications, provides a gear ratio of 20:1 and has a maximum torque capacity of 3600 Nm.

Any Jenvey individual throttle body (ITB) kit and most alternative induction systems are compatible for use with the ETA2. "We handle the entire process in-house – from design to prototyping, manufacture and testing – for all of our induction components. This means the actuator, for example, is not only entirely configurable for common applications and with a range of fuelling options, but that bespoke work can be undertaken for unique or unusual applications or specific requirements for demanding race series," continues Jenvey. "It also means that we have complete control over standards as everything is manufactured in-house, to OE-quality, and with a thorough understanding of the advantage that can be gained through the use of lightweight, durable components."



ABOVE A Jenvey electronic throttle actuator seen on a Ford Duratec

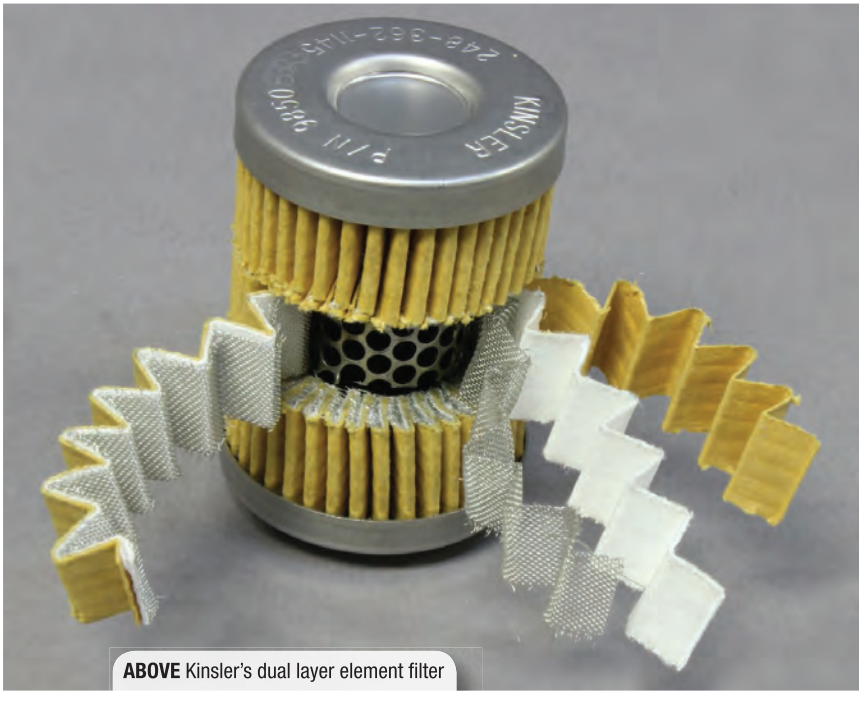
The ETA2's compact size provides packaging and weight-saving advantages over mechanical alternatives. The wider benefits of Jenvey Dynamics' electronic throttle actuation include autoblip for use with paddleshift transmission, compatibility with launch control, anti-lag, switchable pedal map, controllable push-to-pass strategy, pit lane speed control, traction control and variable bank-to-bank control.

"In a race situation, electronic throttle applications are safer than traditional mechanical actuation due to the ability to closely monitor pedal position versus throttle position, improve throttle control and ensure active closure or power down in the event of linkage breakage or another issue," says Jenvey.

FILTERS

Every injector manufacturer would like to have three micron filtration for their injectors, but they know that three micron filters plug up much too fast, so they all recommend 10 micron. As NASCAR ramped up to start running EFI in 2012 **Kinsler** worked on a new filter concept – a two-layer element: a 10 micron paper top layer that catches about 90% of the dirt to protect a three micron fibre glass lower layer.

This fibre glass uses premium fibres laid ▶



ABOVE Kinsler's dual layer element filter

down by a CNC machine. It has the most precise micron rating of any filter material and is used in the most expensive filtration systems for aircraft and premium hydraulic systems.

Kinsler was surprised to find only a very small increase in pressure drop with the dual layer element versus the 10 micron-only element. The flow data can be reviewed in Jim Kinsler's eight-page NASCAR fuel system article at Kinsler.com.

Most NASCAR cars are now running the dual layer element filter to protect their injectors and their pressure relief valves, both of which are very sensitive to dirt. It is also used by almost all EFI customers who have become aware of it.

DRY SUMP SYSTEMS

AT Power has responded to the demands of its client base and offers a range of fully integrated dry sump systems, with the pump drive and scavenge galleries contained within the internals of the sump package. This minimises potential failure points and reliability concerns.

This is showcased by the release of AT Power's new Honda K20/K24 integrated dry sump system. It offers excellent packaging, performance and value via the reduction of required accessory items such as scavenge lines and fittings.

Months of design development, collaboration and testing were put in with the EP Tuning time attack team and Exon Race Engines. This resulted in a high performance and cost-effective solution for the Honda K20/24, with excellent package consideration for the most demanding installations. Consistent oil delivery and oil pump drive reliability were the key considerations during the development period, with numerous performance increases being found at each design iteration.

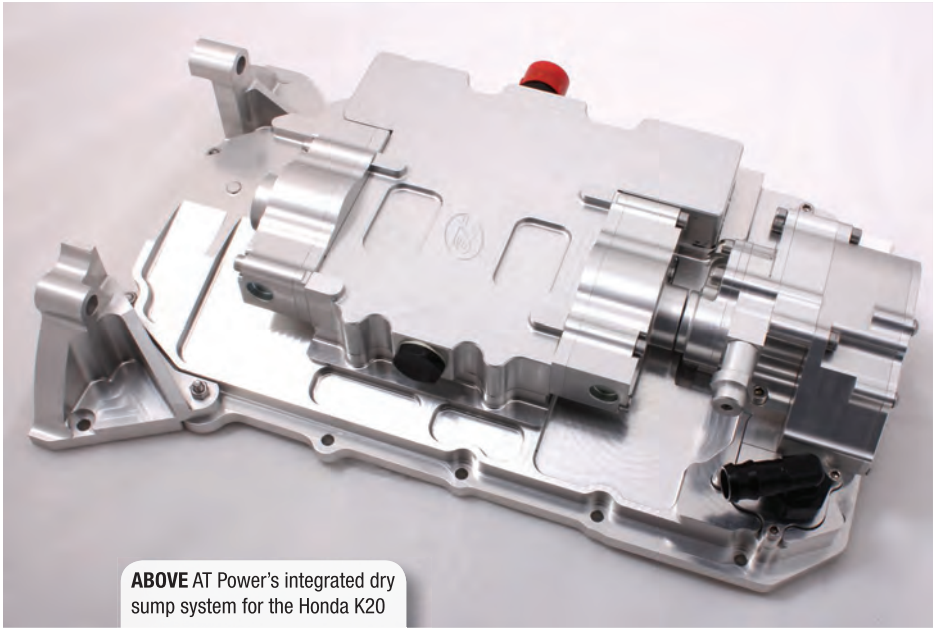
Designed for the optimal installation, this high-performance product features a gear-pump pressure stage and two gerotor scavenge stages, all driven from the standard OEM chain drive. With a total overall depth of just 96 mm, it offers a considerable reduction from the 155 mm of the OE dry sump pan.

The kit features fully integrated scavenge galleries from sump to pump, to minimise the quantity of vulnerable external oil pipes and reduce numerous potential oil leak paths and additional costs of fittings and lines. Oil return is configurable for inlet or exhaust side applications to minimise pipe lengths and neaten the installation, with the oil-in feeding directly into the bottom of the block as per the OE oil pump, removing the requirement for additional fittings.

With an incorporated adjustable PRV, excellent ground clearance and outstanding packaging, this kit is suitable for all types of Honda K20/K24-powered vehicles. This includes both naturally aspirated and turbo applications.

A modular scavenge and pressure pump allows the unit to be separated from the pan for any future servicing requirements. It also allows the pump unit to be developed for installation onto numerous other engine applications over the coming months.

Extensive dyno work was performed to ensure that this new product provided excellent oil delivery throughout the rev range. The adjustable pressure relief valve allows the oil delivery to be tailored for differing installations, or different users' requirements. Dyno data during testing also showed the potential for significant increases in engine power due to the negative pressure generated in the sump pan via an effective dry sump solution.



ABOVE AT Power's integrated dry sump system for the Honda K20

BELOW Race-Tec vibration isolation mounts

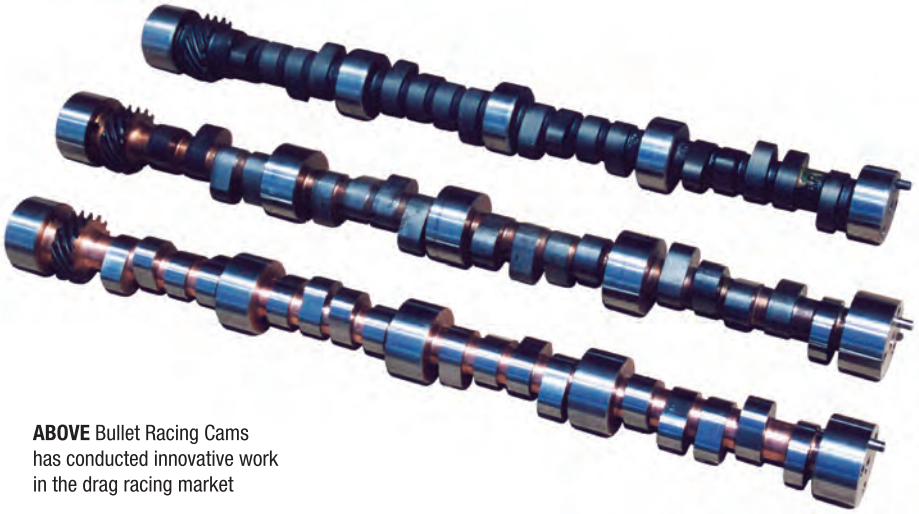
Many oil system failures on racing cars stem from losing vulnerable external oil lines or oil pump drive belts. It is therefore apparent that removing these external items can result in the reduction of potential failure points and increase the reliability of the oil system and the overall engine package.

ENGINE SEALS

Race-Tec Sealing specialises in the bespoke design and manufacture of a wide range of high-performance engine-related sealing components. However, more recently, besides its regular engine-related business of manufacturing high-performance low friction engine seals, it has seen a rapid increase in the requirement for specialist sealing products in energy recovery systems [ERS].

For example, the battery pack in an ERS system has a requirement for specialist moulded products with its FEA-designed vibration isolation mounts that can be used to support instrumentation, sensors, the ERS system and the battery packs themselves. It also protects them from both engine and track vibration, ensuring damaging amplification is kept to a minimum, and from extreme vertical g events caused by kerb strikes or off-track excursions. The ERS battery pack also has a requirement for its lid to be effectively sealed, which Race-Tec has achieved with its specially designed moulded gaskets.

The company has also now successfully ▶



ABOVE Bullet Racing Cams has conducted innovative work in the drag racing market

applied its PTFE-lined [PL] seal technology to compact low friction water/cooling pump seals. Due to their size and performance, the traditional mechanical face seals used in water pumps do not really lend themselves to motorsport applications. However, the Race-Tec compact water pump seal, which is capable of operating to the demanding Formula 1 requirements for high speed and pressure, clearly offers advantages to the motorsport engine designer and builder.

A further area of development has been with high speed turbo and ERS motor/generator seals. Here the requirement to seal high-speed shafts of relatively small diameters, subject to high frequency vibration, has created issues with both oil leakage and shaft wear. Following significant testing and adaptations to seal designs and materials, Race-Tec has now overcome the difficulties associated with sealing these demanding applications.

Bladder accumulators are used for applications where there is a requirement to maintain a reservoir of pressurised fluid. They are used in hydraulic actuation to facilitate the transfer of fluid, or to compensate for expansion in hydraulic, fuel or cooling systems. Using its in-house non-linear finite element analysis, Race-Tec has the capability to design the complete accumulator unit, comprising both the outer housing and internal rubber bladder.

CAMSHAFTS

Mississippi company **Bullet Racing Cams** produces camshafts for both pushrod and overhead cam engines, but the latter have become more predominant over the last few years. As the overhead type has its own set of unique requirements, with many involving variable rocker arm ratios, it has spent long hours working on designs for these engines as the need for them has increased 100-fold in recent years

"We maintain a large presence in the Top Fuel and Nitro Funny Car market due to our involvement with almost all the teams," says John Partridge, owner and managing partner at Bullet Racing Cams. "Consequently we have developed many new profiles/designs to take advantage of newer cylinder heads and blowers which has led to astounding elapse time numbers and mile per hour numbers by all of the quality teams with which we are involved.

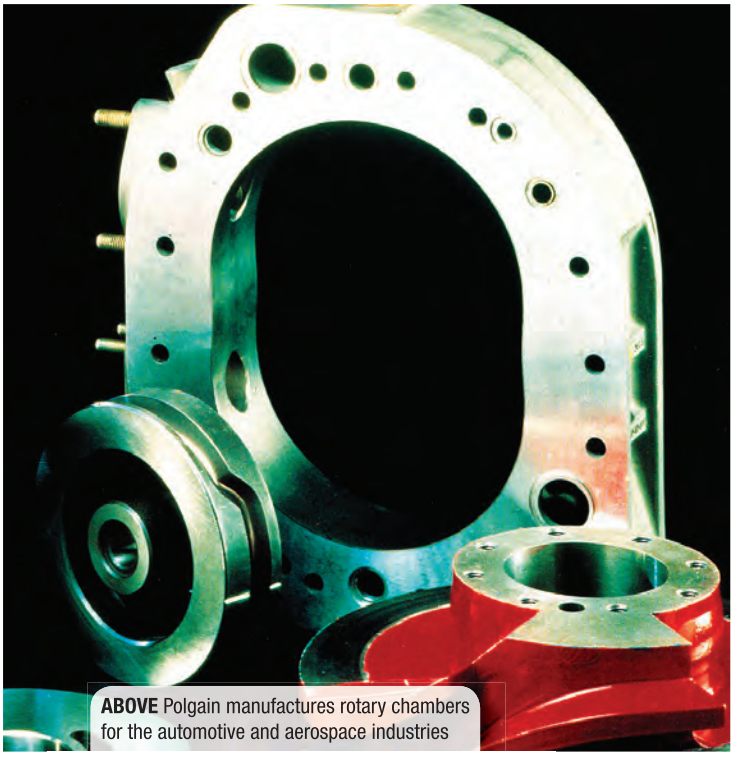
"Additionally, we continue to develop new profiles for non-supercharged applications as well. We work with several Pro Stock teams as well as the nitrous-assisted Pro Mod teams in camshaft development, both of which have unique needs and requirements."

In the past a 50 mm camshaft journal size might have been considered large but now 60 mm, 70 mm and larger are almost standard for most of these applications, says Partridge. "With these increased journal sizes, along with increased roller wheel sizes, new designs with increased rpm capability and valvetrain stability at higher rpm, we rely on a very sophisticated computer program for testing profiles. It enables us to modify any input – valvetrain weights, spring pressure or rate, rocker ratio, cylinder pressure and many more functions – which has allowed us to develop many innovative profiles for many-many applications."

With the recent investment of half a million pounds, **Polgain** has put itself at the forefront of manufacturing camshafts and other engine components for the automotive and aviation industries.

Despite only being founded in 2002, Polgain has a vast amount of experience, as company owner Adrian Bond has been in the engineering business since 1976.

"I'm proud of the company's ISO 9001 accreditation, and it consistently provides ▶



ABOVE Polgain manufactures rotary chambers for the automotive and aerospace industries

BELOW Piper's new camshafts for Ford's 2-litre Ecoboost engine

products and services that match industry standard," says Bond. "The high standards are achieved by using a Landis CNC grinder, Adcole cam contour measuring machine and a 3-axis coordinate measuring machine, as well as other high tech equipment." He also notes that, due to the high precision of the parts produced, it's able to supply OEM parts to high performance manufacturers Bentley, Jaguar, Lotus and Aston Martin.

One of Polgain's advantages is its ability to offer bespoke parts. However, if no technical drawing of the part is available, it is able to reverse-engineer from the original. Polgain can make design recommendations for all parts, such as cam profile and material choices. All projects are developed with complete confidentiality.

Polgain also manufactures rotary chambers for the automotive and aerospace industries, using a process called mechanical generation. It holds several templates for rotary chambers that have been put into production in the past. To ensure high-quality chambers are produced, Polgain uses an Eonic plate cam grinder.

One of Europe's leading specialty engine component manufacturers has released a new series of camshafts for high performance engines and sports cars. **Piper Cams** has developed camshafts for the new Ford EcoBoost 2.0-litre and 1.6-litre engines, as well as for the Subaru FA20, Toyota GT86 and the new Ford Focus RS out next year.

The new camshafts are designed to get the optimum amount of valve lift from the engine, running different profiles, lift points and shorter durations compared to the OEM parts. Piper has developed a spring kit to accommodate the extra valve lift.

"The camshafts have been tested and validated at a high performance level, running on a British Touring Car engine to extract maximum performance out of the design," says Piper Cams technical director John Crabb. Although he would not disclose which team ran the camshafts, he did confirm that it is considering running them next season.

To help keep the maintenance and production costs down, Piper used chilled cast iron for its material choice. This was preferred to steel billet due to the latter's cost implications and manufacture time.

TUBULAR FABRICATIONS

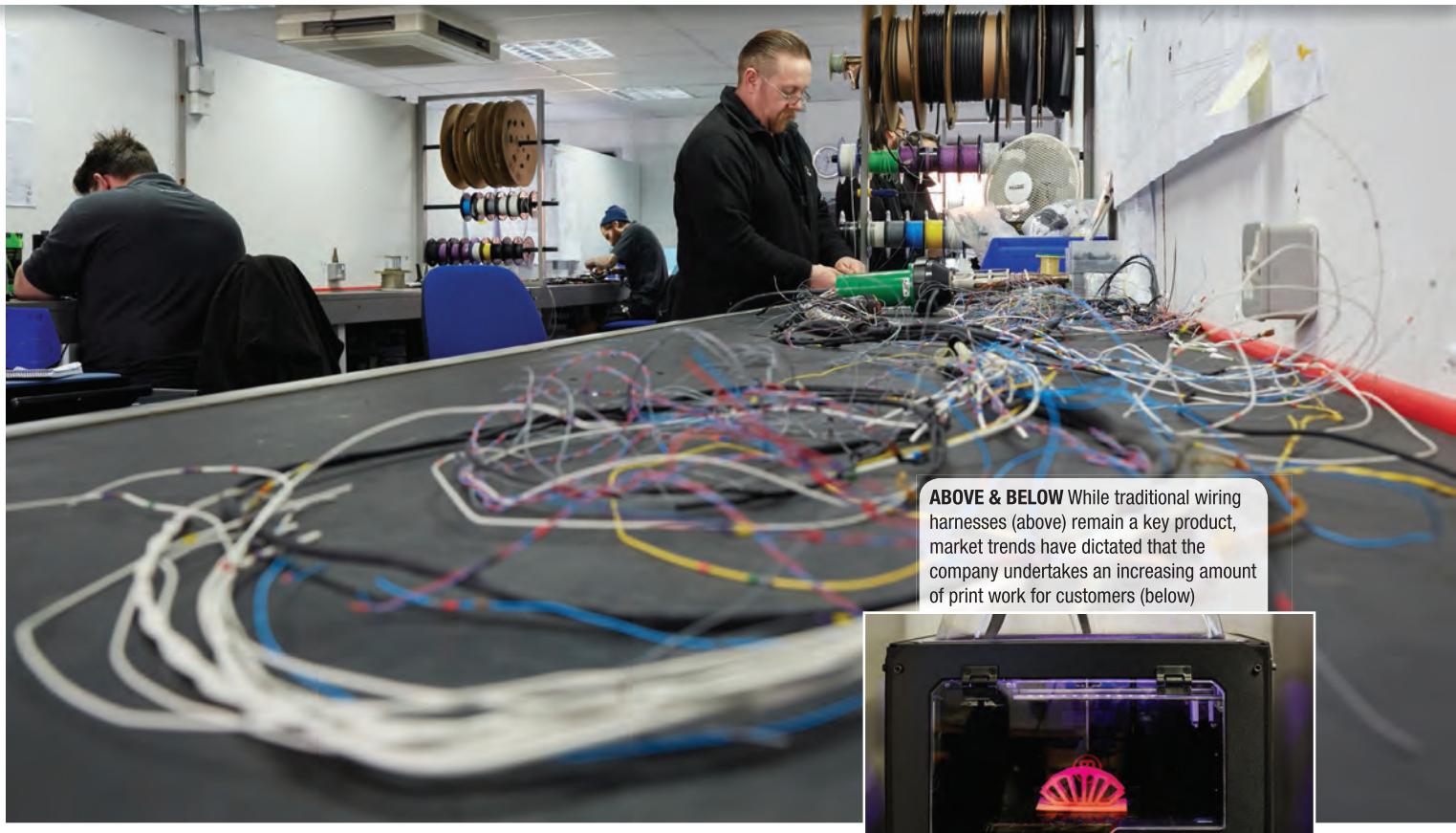
SS Tube Technology is part of one of the UK's most dynamic and successful businesses. Together with its sister companies, Lentus Composites and Horizon Engineering, it forms the Polar Technology Management Group, which recently attracted plaudits from British Prime Minister David Cameron.

Cameron had the opportunity to see all three companies in action. He was impressed with the vision of the group, which is to become a world leader in the design, development and manufacture of advanced engineering products for the motorsport, automotive, aerospace, energy and oil and gas sectors.

SS Tube Technology specialises in the design and manufacture of advanced tubular fabrications and thermal management parts for high-tech motorsport applications. Most of its designs are bespoke, with products previously manufactured including pipework assemblies, exhaust systems and heat shields.

Founded in 2000, the company utilises cutting edge technology. This includes 3D modelling, 3D laser scanning, stress analysis, CNC tube bending, six-axis laser cutting, hydroforming, precision TIG welding, tube rolling and non-destructive testing. RT

ABOVE British PM David Cameron has praised the Polar Technology Management Group for its bold and innovative approach



ABOVE & BELOW While traditional wiring harnesses (above) remain a key product, market trends have dictated that the company undertakes an increasing amount of print work for customers (below)

PACE-SETTER

William Kimberley visits a company located in a town that has set out to slow down the pace of life. It's a policy that obviously isn't working

EAST Anglian town Diss might have been referenced in the Domesday Book in 1086 but its most recent claim to fame is that it became the third town in the UK to join Cittaslow, a movement founded in Italy with the intention of slowing down the pace of life. If the good town councillors had taken the views of one particular business that resides in their parish into account, then they would perhaps have thought a little more before ploughing ahead with such a commitment.

They obviously don't know that most of the cars on the F1 grid, over half the cars at Le Mans, almost every GT3 car manufacturer, a good chunk of NASCAR and every IndyCar team, let alone a huge number of cars in other series, would not otherwise be racing were it not for the products they were using from a company located in the town.

Bf1systems started life in 1994 as a manufacturer of wiring harnesses, employing less than 10 people. Over the 21 years that figure has grown tenfold with a current head count of just over 100. Its primary markets are motorsport, automotive and aerospace. Key products include electronics, force management and composites, everything being done on site at Diss, its premises from the start.

Its break into Formula 1 came through Jordan Grand Prix, since which time bf1systems has become a regular supplier to a good many teams on the F1 grid. Customers from other areas of the sport include Honda Performance Development, Aston Martin Racing, McLaren Automotive, Bugatti, Ducati and Lamborghini and Airbus and Rolls-Royce in the aerospace world.

While wiring harnesses were the company's core business in the early years, in 1999 it diversified into force measurement. A couple of years later, though, the business underwent a fundamental change when it was acquired by German OE supplier BERU, a leading manufacturer of diesel cold start systems that was looking to expand its portfolio. It was then itself acquired by US conglomerate BorgWarner in November 2004. Thus the situation remained until March 2011 when a management buyout led by managing director John Bailey, who personally became the majority shareholder, led to the business becoming independent once again.

Speaking of the buy-out at the time, Bailey said: "This will see us invest further in our products to deliver the state-of-the art measuring systems that give our customers a competitive edge in their fields."

One of those products was Wire-in-Composite (WiC) that was developed with motorsport in mind although it has proved to be highly applicable to road cars. It completely encloses the wiring looms in a bespoke composite sleeve, protecting them from damage and permitting designers to improve the packaging by laying wires securely side-by-side as opposed to in a traditional bundle. The carbon fibre used improves electro-magnetic compatibility, resulting in lower electrical noise, while the enclosed design increases the CAN network security for units outside the body-in-white.

As the first ever vehicle to use the technology in 2007, the Jaguar C-XF loom replaced the standard main engine wiring loom. Instead of being concealed, it became ▶

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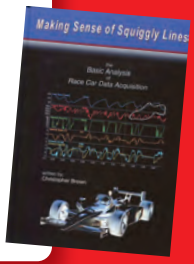
Race Tech is offering a number of books that it considers an essential requirement in the motorsport engineer's library:

FAST CAR PHYSICS

by Chuck Edmondson
Softback 229 pages
£20.00

This is a very erudite book that explains in quite some details the physics of performance driving. It will not be everyone's cup of tea but for those who want to know how it all works from the point of view of physics, this is a must-read book.

MAKING SENSE OF SQUIGGLY LINES



The Basic Analysis of Race Car Data Acquistion
By Christopher Brown
144 pages
Hardback: £40.00 Softback: £30.00

As the author writes, this book has not been written to explain vehicle dynamics or give instructions on how to adjust a racecar, nor was it written to coach drivers. The goal is to help the reader make sense of the data that has already been collected on the racecar – and in that is fully succeeds.

RACE CAR AERODYNAMICS

2nd editionn By Joe Katz
252 pages
Softback: £25.00

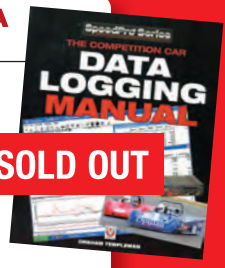
This book combines clear explanations, illustrations and photos to help the enthuisiast understand a complex subject, with invaluable reference material – including equations – for the professional race car engineer.

COMPETITION CAR AERODYNAMICS

2nd edition
By Simon McBeath
288 pages
Hardback: £25.00

This is a very fine book and along with the two books reviewed on this page should form the basic building block for any budding motorsport engineer's library.

THE COMPETITION CAR DATA LOGGING MANUAL



SOLD OUT

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Softback 128 pages
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An eminently readable introduction to club-level data logging from Race Tech's own Graham Templeman. This book takes a practical approach to the subject, explaining how and where data logging can be used to good affect and imparting many excellent tricks of the trade.

ENGINEER TO WIN

By Carroll Smith
Softback 280 pages
£19.99
Engineer to Win's tagline 'understanding race car dynamics' is perhaps a tad misleading as only part of the book focuses on vehicle handling and aerodynamics. In reality there's far more to it than that; it touches upon everything from metallurgy to budgeting. Highly recommended.

HOW TO BUILD MOTORCYCLE-ENGINED RACING CARS

By Tony Pashley
Softback 128 pages
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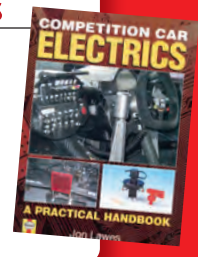
This book provides a superb guide to designing and building your own racecar. As the title suggests, there are plenty of tips aimed specifically at motorcycle-engined cars – things like chain drives – but it also covers general principles, from kinematic suspension design to fabricating aluminium honeycomb chassis.

COMPETITION CAR ELECTRICS



By Jon Lawes
Hardback 160 pages
Hardback: £25.00
Competition car electrical systems increasingly differ from their road-going counterparts and this book is aimed squarely at the motorsport market. It provides a general overview with some great photographs and a refreshing lack of jargon.

To order these fine books and many others, please go to **www.racetechmag.com/store** or phone +44 (0) 20 8446 2100 where our friendly staff will take your order.

an intrinsic part of the underbonnet design, opening further new areas for designers to explore. In this case, the designers wanted the engine loom to look as though it was strapping down the engine to the chassis.

However, the traditional wiring harness remains a key product for bf1 systems. Production manager Anthony Moss does note, though, that there has been a shift in requirements over the last six to seven years as teams get more into doing their own design and 2D and 3D CAD modelling, leading to more build to print work, "but we can offer as little or as much as the customer requires."

Another important product for the company is its tyre pressure monitoring systems that it supplies to a range of teams in Formula 1, the World Rally Championship and even motorbikes. "Race car OE has become one of our largest markets in the last five to six years," says Moss. "We are on 90% of the F1 grid and on the majority of cars in last year's Le Mans race. We've also just won the contract to supply the Australian V8 Supercar series, as highlighted in your News section last month."

Over the years the company has expanded so that it now comprises a building for electronics production, R&D and design, composites production, mechanical and composite design, and wiring harness design and production in which various experts ply their business. One area is devoted to the production of the increasingly highly complex Formula 1 steering wheel, the company first doing one for Marussia/Manor in 2013 and 2014. It is currently working with a number of high profile steering wheel manufacturers.

ABOVE Wire-in-Composite (WiC) completely encloses the wiring looms in a bespoke composite sleeve

Bf1 systems is adept at showcasing its products on slightly off-the-wall projects. A few years ago it produced the Factor001 high-tech bicycle that was then exhibited at the Science Museum in London in 2009. The £20,000 bike was equipped with a fully integrated, multi-channel ergonometric data recording system that could chart left and right leg power down to one-degree increments. It also featured full hydraulic disc brakes, integrated LEDs and a lithium polymer battery system supplying power to the on-board computer, sensors and Shimano Di2 shifting system simultaneously.

"The feedback we had from cyclist journalists was second to none but we never thought that the bike would be a massive seller," says Moss. "However, what did come out of it was the technology we developed for it such as the crank and instrumentation that were used by Team GB in the 2012 London Olympics to win its seven gold medals.

This bike then evolved into the Vis Vires, costing half the price of the Factor001 but featuring many of its advanced ideas such as the dual-bladed fork design. This essentially relocates the crown of the fork from where it traditionally is – where the fork passes through the head tube – and places it at the stem, removing axial loads from the steering of the bike.

The second is the dual down tube, its stiffness being a major benefit of this design, but it's mostly aero thinking that's behind it, so that turbulent wash from the front wheel can pass through the down tube rather than having to go around. This bike went on to win a prestigious gold iF Award for outstanding achievement in design and innovation at the 2013 Eurobike show.

The other eye-catching project highlighting bf1 systems' technologies was a go-kart it featured on its stand at the Autosport show in 2012. Originally conceived as a vehicle to showcase its technical capabilities, it rapidly turned into a dedicated project, with the sole aim of introducing a new, higher level of data logging and analysis into karting.

"In addition to logging standard inputs which are widely used in karting, such as pedal positions, steering angle, engine and exhaust temperatures, the system also uses our technology from other motorsport arenas," explains Moss. "This includes the tyre pressure and temperature monitoring system to provide real-time data for the driver on the tyres, and a torque measurement system on the rear axle, which can be used to calculate wheel horsepower. The system can also be used to measure and record the driver's heart rate."

Whether it's a car, bike or kart, performance is the name of the game for bf1 systems – so much for slowing down the pace of life in this part of the world. RT

ABOVE One area is devoted to the production of the increasingly complex F1 steering wheels

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JOKER TIME?

The rebirth of rallycross, combined with Lewis Hamilton's radio distress signals, give **Mark Skewis** an idea. It's not his own, but hey…

CAN a sport that legend suggests was born from Foot and Mouth disease *really* teach anything to one that seems afflicted with a Foot-in-Mouth problem? Having watched the Lydden Hill rallycross and Monaco Grand Prix in the same day, I wonder.

It's actually urban myth that the 1967 epidemic, which forced the cancellation of the RAC Rally, was the catalyst for the birth of rallycross. What's beyond doubt is that it combines the best of rallying and circuit racing. It was a made-for-TV sport long before many households even possessed one. Maybe that's why it remained motorsport's best-kept secret until IMG, its new promoter, thrust it into the limelight with elevation to FIA World Championship status this season.

While the new kid on the block flourishes, attracting big crowds and rave reviews, F1 is struggling; the situation isn't helped by the conflicting messages on its future direction coming from the top. Yet it was the radio distress signals emanating from the cockpit in successive races that concern me most: when even Lewis Hamilton is telling his engineers that it's impossible to overtake, we know we have a problem.

Granted, one of those races was Monaco. The other was Barcelona, a circuit perfect for developing an F1 car but a nightmare for overtaking in one. The world champion's remonstrations with his engineer highlighted two age-old problems: the first is that it's hard to overtake; the second, if we decide to fix that problem artificially, is whether F1 should be a business, pure sport or entertainment?

Rallycross, like many other race series, has opted for the entertainment route. One of the devices it employs to prevent a dull race is a joker lap. This dictates that all drivers must complete one lap on an alternative circuit configuration. It need not be that much longer, just sufficient to feed the car back into the action in a different position. In rallycross, it offers the chance to escape dust or mud being flung into a driver's windscreen; in F1, it could get a car out of dirty air.

I confess I snorted with derision when I first heard of the joker lap. I mean, that's not really rallycross, is it? Yet having seen it in action at Lydden Hill, I'm a convert. Shameless, eh?

If you think I'm crackers to suggest it for F1, don't take my word for it: a few years ago Patrick Head suggested the creation of an 'overtaking lane', to be used perhaps five times a race. Not so far removed from a joker lap. I don't think it was that spark which earned him the knighthood, but it was a refreshing take on an old problem.

A joker lap wouldn't be possible at Monaco, I know. But it could easily be incorporated into the new circuits, the identikit 'Tilkedromes' that increasingly litter the calendar.

Before purists bleat that this is artificial, tell me that the Drag Reduction System isn't. Or tyres that 'fall off the cliff' and disintegrate after two laps? Or refuelling? Don't even get me started on double points…

When a fan picks up that TV remote control, or drives through the gates of the race circuit, there is only one thing on the agenda: entertainment. Why else is he doing it?

The largest practical problem would be of releasing cars into their joker lap safely, and feeding them back in again. It's not insurmountable, though, as we see on pit lane exits. Montreal, for instance. And think of the drama.

Alternatively, of course, we could always design cars that can overtake…

Whatever the arguments, it works for F1's poor relation: World RX is enjoying unprecedented exposure under IMG. Cinders *has* ventured out to the odd ball before. It enjoyed a prime-time TV slot on World of Sport in the late '60s and early '70s after its creation by ITV producer Robert Reed. It was devised as a weather-proof sport that could provide short chunks of easily-understood action when rain stopped play elsewhere.

A decade later, the British Rallycross Grand Prix thrilled BBC Grandstand viewers. Wherever you watched the cars, it was impossible not to be impressed after an influx of spectacular machines from Group B rallying in the late '80s.

It's had larger than life characters too. Six-time FIA European Champion Martin Schanche, 'Mr Rallycross', was the ultimate showman. He's now enjoying a low-key retirement in Norway, where he officially adopted a wolf (to avoid it being hunted) and slapped a politician live on TV. I like him more than ever.

In his absence at Lydden, fans had to content themselves with a battle for victory between a former World Rally Champion and multiple DTM title winner. British fans, meanwhile, were cheering for former BTCC and rally heroes.

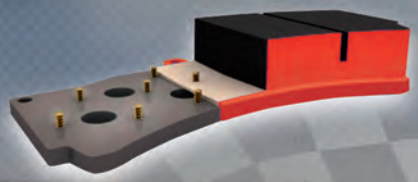
When even Peugeot is resisting attempts to lure it back to world championship rallying, insisting it can extract all the exposure it needs from rallycross instead, then you know that the revolution is gathering pace. RT

EKS RX

BELOW Mattias Ekström's quattro emerges back into the fray from its joker lap

PAGID RACING

Brake control from green light to chequered flag.



PAGID RST

Double DTM Champion Mattias Ekström has clinched his first-ever FIA World Rallycross Championship victory after a flawless drive in the Audi S1 EKS RX in Holjes, Sweden. In his RX campaign, Mattias relies on the supreme stopping power of PAGID RST racing brake pads – high initial bite, constantly high friction over temperature with excellent modulation over the whole temperature range. With the highest degree of braking performance, PAGID RST racing brake pads deliver the competitive edge that successful drivers demand.

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