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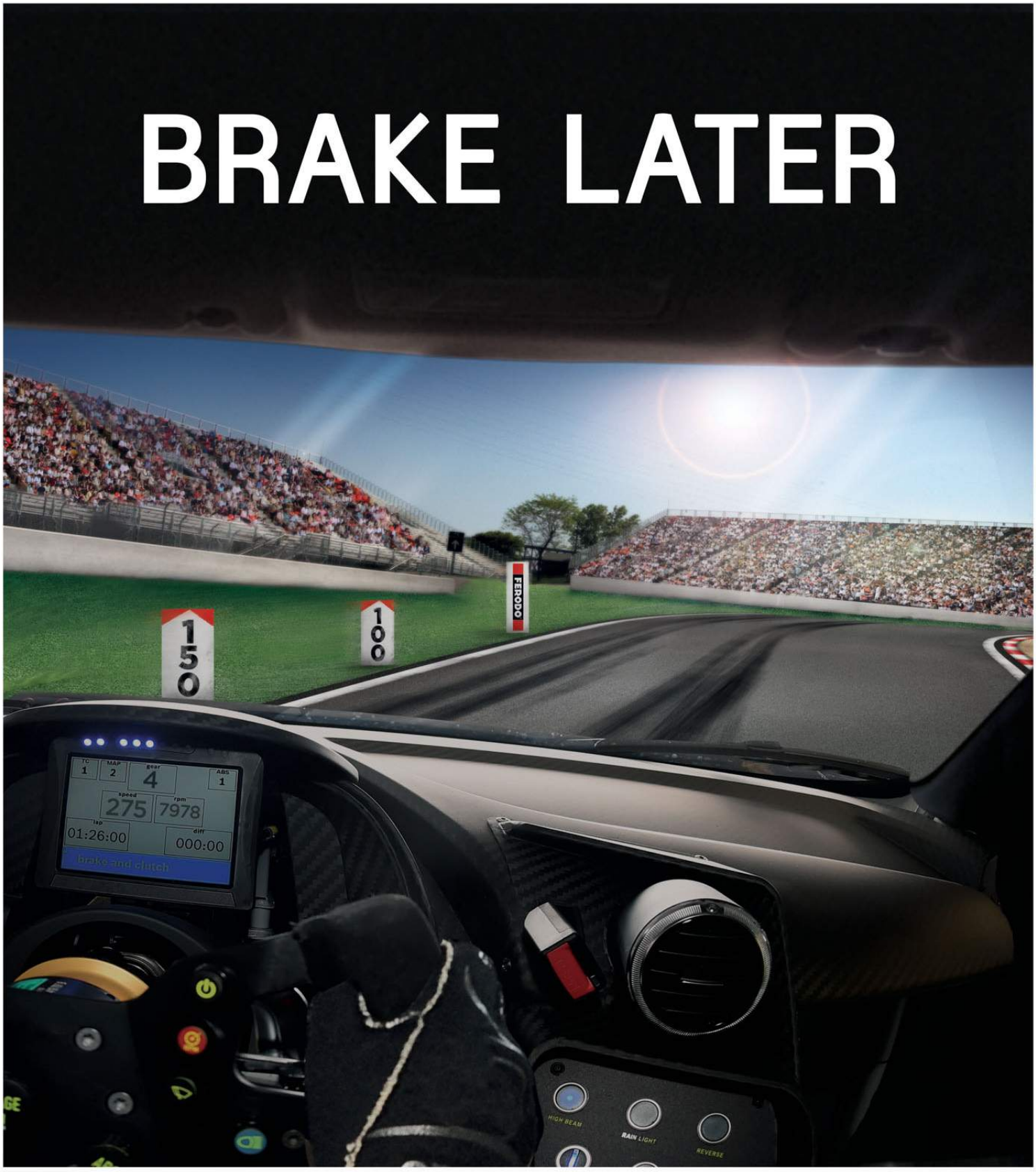

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The hydrogen fuel cell-powered racecars that offer a glimpse of the future

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TIME WILL TELL

IT'S something we keep coming back to time and again – is it a gamechanger or a passing fad? I am yet again talking about electric racing and electric vehicles. In September 2011 – is it that long ago? – our cover story was whether electric race cars were a gimmick or gamechanger, that word again.

Chris Pickering, who did the research and wrote the article, spoke to a number of experts and came away with differing conclusions but the overall feeling was that it was a coming technology and that motorsport as a development partner to the automotive industry should be playing a part.

We then ran as our cover story of the October 2012 issue the electric Toyota P002 EV that shattered the Pikes Peak EV class record by over 15 seconds, but more significantly was fourth fastest overall. However, it was the August-September 2013 issue that was perhaps the most iconic for us as we put a Formula Student on the front cover as it acknowledged the first time that an electric car had beaten an internal combustion-powered car in an accredited motorsport competition. Then in September 2014, just before Formula E kicked off, we ran a rather naughty cover line that shouted Freak Show or the Future? with a picture of a Formula E car doing a burn-out in front of the Houses of Parliament. Fast forward two years and while the jury is still out, every indication is that the electric car racing has been accepted and is here to stay. Although only anecdotal, in a Twitter survey conducted by our own Sebastian Scott that asked the question as to whether Formula E is going places or whether it is flawed, the result was 60% positive and 40% who thought it didn't have a future. I don't have the breakdown of the figures, but interesting all the same.

I did go the Formula E race at Battersea Park in London where I enjoyed the atmosphere. For qualifying I joined my son-in-law Jamie and my five-year old grandson who was attending his first motor race. Now Jamie is a real petrolhead, the proud owner of a supercharged Jaguar XKR-S, a Porsche Cayenne and an Abarth, his pride and joy, but just recently he has worryingly had his head turned by Tesla...

So I joined them to watch qualifying just past one of the chicanes and after watching a few cars whoosh by, Jamie turned to me and asked when were they going to start going fast as he felt his Abarth could negotiate the chicane more quickly. The trouble was that it was qualifying we were watching. I didn't watch the race with them but his reaction was that the most exciting part was when the cars were lined up behind the safety car. As for my grandson, in the three hour lull between qualifying and the race, he had his first taste of karting –powered by pop pop engines and not electric!

For all this, there is no doubt in my mind that Formula E is a vital race series and what it is doing is beneficial in many areas, including advancing the technologies employed, and it is also engaging the young, which is great. Personally I think the entertainment factor needs to be turned up and while watching qualifying none of us had a clue as to what was happening even though we had all been given small earpiece radios on entering the circuit. In my view, though, Formula E has become established and is here to stay.

Now for the next technology – the hydrogen fuel cell. Many of you will know that I have written about this technology before when it was the coming technology in the Nineties. As the editor of *Automotive Engineer* I would ask many senior car company executives about their view, and to a man – and woman – they said the fuel cell car would be in mass production by about now as it so happens. As we know, it hasn't happened, but it could, which is why we are featuring such a car on our front cover. I think it is the start of a very long journey for this technology when it comes to motor racing but I applaud Green GT and its backers like Michelin for having the courage to give it a go. Perhaps in a few years time I will look back at this front cover and point to it being the precursor of something that has become quite common. Time will tell.

Before I finish, though, I do have to make a final point about Formula Student, which is a great competition for engineering students. I was proud to give the inaugural *Race Tech* award for the Spirit of Formula Student to the University of Edinburgh, a truly under-financed team that was attending it for the first time in Class 1 but who to a man and woman were prepared to help every other team in the paddock. At the other end of the spectrum was the team from TU Munchen who actually stood in front of us while we took a picture of its car and refused to move as it was "secret" – and we weren't the only ones they blocked. Shame on them! There is no room for Formula 1 style secrecy in Formula Student. RT

William Kimberley
EDITOR

Force India F1's Otmar Szafnauer endorses supply chain

William Kimberley

SILVERSTONE, UK: Otmar Szafnauer, Force India F1's chief operating officer, has endorsed the motorsport supply chain as innovators and delivering engineering solutions. Speaking as the keynote speaker in the Motorsport Industry Association's Driving Future Motorsport Business Growth through International Trade and Innovation Exchange Conference held at Sahara Force India F1 just before the British Grand Prix, he told the packed audience of around 250 delegates that having been in the motorsport industry for more than 20 years, he still marvels at the speed and efficiency of the supplier network.

"This is a highly competitive environment which has made the motorsport industry extremely efficient," he said. "When there's a problem, it needs to be fixed quickly in time for the next race and I can't think of any other industry that operates to such high and sensitive margins, especially in terms of the design production cycle. The key skill of the motorsport industry is the ability to design and develop and produce engineering solutions and technology in the shortest time possible. It is this core strength that gives it the competitive advantage in competing for business with companies in adjacent sectors. It's important that this strength, which is central to the culture of motorsport, is articulated and used as a competitive advantage when pitching for business growth."

He then said that it is almost a daily occurrence for a Formula 1 team to make a decision as whether to manufacture something itself or to outsource it, in other words, to make or buy. "What is it that drives us to use you or companies like yourselves instead of investing internally to make some of these components ourselves, and it's that answer I believe is important for your business.

"We often look at bringing technology in-house mainly for performance reasons, not cost ones although that's important as well. If costs are out of control and we have to pay too much for an item, product of service, it does have an impact on our performance because we have a limited budget so we have to make that performance cost trade-off. It's those reasons that drive Formula 1 teams to use external suppliers, and it's usually the factor that using suppliers such as yourselves will give us better track performance. That's when we go out because our total focus is on beating our competitors. So a Formula 1 team will use you and the service and products you supply because you're the best at what you do and better than what we can do. If you do more of that I can assure you adjacent businesses will make the same decisions and you will have opportunity to grow."

BELOW "I can't think of any other industry that operates to such high and sensitive margins."

Post Brexit Positives

William Kimberley

LONDON, UK: Talking to *Race Tech* after the British Grand Prix, Chris Aylett, CEO of the Motorsport Industry Association, underlined the positivity that was apparent at the motorsport business growth conference, noting "The overseas visitors we had at our conference were stunned by the positive atmosphere of the UK and in particular motorsport after Brexit.

"If you were in the road business with lots of regulations and you represented importers, then yes, there's a lot to do, but we aren't, companies in the motorsport are natural exporters that charge a price for success which reflects whatever the purchase costs are – the pricing of motorsport is about winning. It has never been a sales line in motorsport to say that you could do it cheaper in another country, so unless there are some major trade barriers that we somehow fall foul of, I don't see it having a hugely detrimental effect. In fact, anecdotally I am hearing from MIA members that they've never had it so good and that meetings at the British Grand Prix were all very positive. I will say that we will be welcomed in many markets as long as we go to them and see this as a very valuable opportunity."

Aylett then highlighted the opportunities that are opening up with the new regulations in Formula 1 and other top level championships. "We are entering an interesting period where I'm sure changes in Formula 1 and some other series will lead to an increasing demand to meet the technical regulations. Right now the tap is being turned on in Formula 1 because of the new regulations and that's high value business."

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Jerry Markland/Getty Images for NASCAR

BELOW Loosening up: Kentucky victor Brad Keselowski credited the aero package with making his late-race winning pass possible

Third race possible as NASCAR seeks aero answers

Andrew Charman

SPARTA, KY: NASCAR's continuing search for better racing in its lead Sprint Cup Series could see a third outing this season for the latest 'low low' downforce aero package – despite more mixed reviews from its second trial in the race at Kentucky on 9 July.

Comments following the Kentucky event suggested that the package, which as detailed in *Race Tech* last month further reduces aerodynamic component sizes particularly on the front splitter and rear spoiler, had produced less action than the equivalent event in 2015. However, winner Brad Keselowski suggested that the lack of passing could be partly due to resurfacing of the track before the 2016 event, resulting in a narrower 'groove' but added that the new rules package makes the cars harder to drive and requires a lot more precision as a driver.

"We're still facing and fighting the same dilemmas in our sport of the lead car having a significant advantage over other cars in the field, but that advantage seemed to go from maybe on a 1 to 10 scale, from an 8 to a 6 or a 7 here, which I think is good, but until the track widens out and gets multiple grooves, I honestly think this is the best race you're going to see on a repave," said Keselowski. He added, though, that the aero package had won him the race, enabling him to take the lead from Kevin Harvick following the final restart. "If I could stay within a half a car length of him I could create an aero wake behind his car and loosen him up a little bit without touching him, and sure enough, we went down in the corner and it looked like he got really loose and I was able to make the move and get by him.

"There were certainly moves you could make today that you couldn't make before with respect to getting behind somebody and being able to alter the way their car drove."

NASCAR competition head Scott Miller suggested that the package had produced a safer race on the resurfaced track. "I think the corner speeds would have been extremely high, and with the higher downforce stepping out of the groove might have even had more consequences than we had."

Series officials are reported to be considering running the package – which is likely to form the basis of the aerodynamic configuration for 2017 – at Michigan on 28 August. As reported last month the track hosted the first 'in-race' test on 12 June. However, the organising body has repeatedly insisted that there are no plans to make any changes to aerodynamic regulations during the remainder of the 2016 season and particularly in the season-ending 10-race 'Chase for the Cup.'

Meanwhile NASCAR tyre supplier Goodyear has insisted that it will be ready for whichever aerodynamic specification the sport decides to use at Michigan, having used data from the 12 June race and testing to produce suitable tyres for both setups.

Teams in NASCAR's second-division Xfinity Series have been testing at Daytona with a view to cutting the tandem or 'bump' drafting that occurs at restrictor plate tracks such as the Speedway.

The practice sees one car push another for much of a lap, the two benefiting from more efficient aerodynamics, but can be dangerous, the second driver's vision completely obscured.

It was eliminated in the lead Sprint Cup Series in 2014, primarily by reducing the efficiency of car cooling systems, ensuring they cannot run with the grille blocked for very long. Running for an extended period 'hooked' to a car in front is officially outlawed by NASCAR but some tandem drafting still takes place in Xfinity races. It is thought that the series is looking to follow the lead of the Sprint Cup by switching to a lower downforce format in 2017. RT

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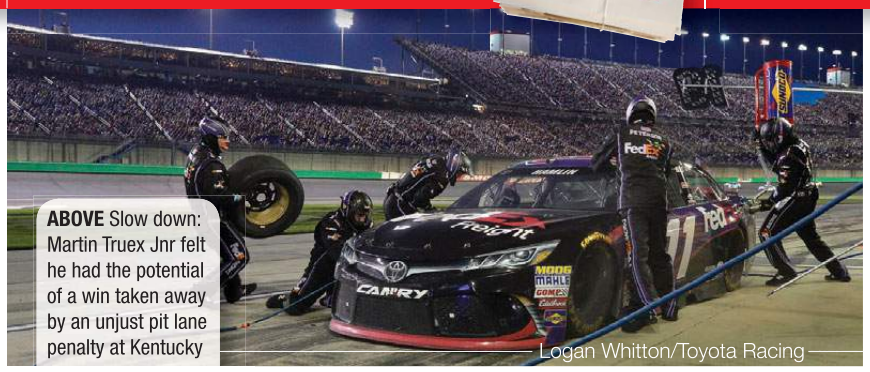

ABOVE Slow down: Martin Truex Jnr felt he had the potential of a win taken away by an unjust pit lane penalty at Kentucky

NASCAR bids to cut pit lane speeds

Andrew Charman

INDIANAPOLIS, IN: NASCAR's efforts to curb potentially dangerous speeds in the pitlane took another turn at the Indianapolis race weekend on 23-24 July when the number of pitlane speed timing zones in the track's very long pit lane were increased from six to 12.

Having been tested during the New Hampshire race meeting a week earlier, the extra timing lines were trialled successfully in the Xfinity Series race at Indianapolis on 23 July and rolled out to the Sprint Cup Series event the following day.

They were designed to prevent drivers trying to cut the length of a pit stop by accelerating towards their pit box after crossing a timing line, and potentially passing other cars in the pit lane. NASCAR monitors its pitlane speeds by measuring time over distance, and by reducing the length available in which to accelerate, the governing body hoped to make accelerating a less effective move. Earlier in July at Kentucky, NASCAR had penalised driver Martin Truex Jnr, after he accelerated towards his pit box and in the process overtook the car of Kevin Harvick on the inside.

The penalty caused controversy, with Truex claiming the practice was common throughout the season and that he had been unfairly singled out for punishment. The resultant penalty dropped him to 22 place and while he recovered to finish 10, he felt he had been denied a chance of victory.

"I feel like I did the same thing guys do every week," Truex told local media. "You get to your timing line, you step on the gas, and you head straight toward your pit. Obviously I turned left and came up next to the 4 car (Harvick) and passed him as I was driving to my pit, which is what guys do every week. I've been passed on pit road 15 times this year that same exact way - and I didn't see guys get penalised."

In response NASCAR officials stated that Truex's move had been "blatant" and in clear contravention of the series rule book.

Steve O'Donnell, NASCAR's chief racing development officer, confirmed that other methods of monitoring pit lane speed are also being studied, but were more likely to involve more consistent use of data gained through GPS, rather than speed limiters on the car dashboard. "We like the fact that it's in the driver's hands and team's hands instead of flipping the switch," he said. Six-time Sprint Cup champion Jimmie Johnson was among those hit with a speeding penalty during the Indianapolis race. RT

No IndyCar aero changes for 2017?

Andrew Charman

LEXINGTON, OH: The Verizon IndyCar Series is believed to be considering a freeze on aerodynamic package development in 2017, with a single standard kit then being introduced for the 2018 season.

Reports in the US suggest that the current 2016 kits developed by Honda and Chevrolet will be retained unchanged for 2017, providing an immediate cost saving for the two manufacturers in terms of development, and for independent teams who will not need to purchase new kits for their cars.

IndyCar's governing body will in the process be provided with more time to develop a kit for use across the series in 2018. Several manufacturers are believed to have come forward with suggestions.

On 21 July the IndyCar Series began what are expected to be multiple tests in search of the format for the future aero kit. The Chevrolets of Tony Kanaan and JR Hildebrand stayed on an extra day following a championship test at Mid Ohio, completing several laps trying a number of specifications that included running without the distinctive rear wheel guards and with more underfloor downforce.

• IndyCar's intentions to adopt cockpit-mounted driver head protection, as reported last month, is understood to be looking increasingly likely to involve an aeroscreen, in preference to the halo device that the Formula One World Championship intends to use from next season. Such screens are unlikely to be introduced to the IndyCar series before the 2018 season. RT

ABOVE Winging it: JR Hildebrand and Tony Kanaan stayed on after the Mid-Ohio championship test to help the series with its aero studies

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ABOVE Front row, from left to right: Dr Hermann Pengg, head of renewable fuels, Audi; Pascal Vasselon, technical director, Toyota Motorsport GmbH; engineering consultant Gilles Simon; Soheila Kimberley, Race Tech's publishing director; Dialma Zinelli, chief aerodynamicist, Dallara Automobili; Willem Toet, aerodynamicist; engineering consultant Luca Marmorini. Rear row, from left to right: Sergio Rinland, managing director, Astauto; Ulrich Baretzky, director, Audi Sport engine development; Thomas Krämer, manager, engine design, LMP1, Porsche; Steve Eriksen, chief operating office, Honda Performance Development; Peter Wright, FIA technical adviser; Vincent Beaumesnil, sports director, ACO; Christopher Tate, managing director, Donington Park Racing; Bruce Crawley, ExxonMobil's motorsport technology manager; Russ O'Blenes, senior manager performance and racing engines, GM Powertrain; John Iley, managing director, Iley Design; William Kimberley, editor, Race Tech.

Citroën tests next year's WRC car on asphalt

William Kimberley

AUDE, France: Three months after its first outing, Citroën Racing's 2017 World Rally Car made its asphalt debut on the bumpy roads of Aude in southern France, with Kris Meeke and Stéphane Lefebvre learning how the car behaves on this type of surface.

By opting to hold the first development sessions on gravel, the Citroën Racing engineers had given priority to a surface used in the majority of World Rally Championship events. "By test-driving the car in the toughest conditions first, we were able to check the reliability of all the components," explained Citroën Racing technical director Laurent Fregosi. "What is more, there isn't just one type of gravel. Finland and Mexico offer completely different surfaces. So we wanted to explore that diversity by testing the car on asphalt, where the operating window is narrower."

In terms of the regulations, the differences between a WRC car's gravel and asphalt setups are minimal, but they are vital. "The biggest change is in the suspension," Fregosi continued. "We use lighter parts that allow us to reduce the ground clearance. The drivetrain kinematics are also adapted to the 18" wheels. Large wheels mean we can increase brake disc diameter and use water-cooled callipers.

"We should also mention the lighter body protection. On the aerodynamic front, we now have the ability to adapt the lower part of the front bumper specifically for asphalt. During this first session, we worked in particular on the programming of the centre differential. The aim is to distribute power between the front and rear axles according to the situation. Obviously, the settings will be different from one surface to another. The drivers were also able to assess the effects of mechanical parameters, such as spring stiffness, the anti-roll bar and the differential. Overall, the results were positive and we know where we are at. Once again, the car's reliability allowed us to get plenty of kilometres in." RT

Citroën Racing

ABOVE Citroën Racing is now extending its test programme for its new 2017 WRC rally car to asphalt

BTCC to adopt new car recovery system

Andrew Charman

LONDON, UK: The British Touring Car Championship will introduce a new vehicle recovery system in 2017 with the aim of cutting the delays that occur clearing stranded cars following incidents on track. Based on a system already used by the Porsche Carrera Cup, the format will require all BTCC cars to be fitted with lifting components developed by series chassis supplier RML, which had been contracted by the BTCC to produce a better solution to car recovery.

The new lift method will negate the recovery difficulties previously caused by the variety of cars that compete in the series, with both front and rear-wheel drive formats and as a result differing centres of gravity. The concept was trialled during the series' mid-season tyre test at Snetterton on 3 July, the Dextra Racing with Team Parker Ford Focus being specially modified for the test.

"We've seen the positive impact the system has had in the Porsche Carrera Cup and we're sure that with the full lifting system in place for all cars on the grid for next season, we'll be able to increase green-flag time and give the fans even more on-track action over the course of 2017 and beyond," said BTCC technical director Peter Riches.

The traditional two-day test enabled tyre supplier Dunlop to gather data as it works towards the introduction of a taller, wider tyre to the series in 2017. RT

BTCC Subarus obliged to run RWD

LONDON, UK: Team BMR's choice of the Subaru Levorg as its model in the 2016 British Touring Car Championship obliged the team to choose a rear-wheel drive format. Last month we stated that as the Levorg road car is sold as an all-wheel drive vehicle, the team was free to choose either front or rear-wheel drive for the race car. In fact the car was required to be rear-wheel drive because it is only available in road form as an all-wheel drive car. The BTCC regulations allow entries from large-scale production four-wheel drive vehicles only if a 2WD version of the car is not available. Then the requirements for the crankshaft position, engine longitudinal position and orientation effectively required the car to be built to the RWD configuration, a format long claimed by lead Subaru driver Jason Plato to be an advantage in the BTCC. RT

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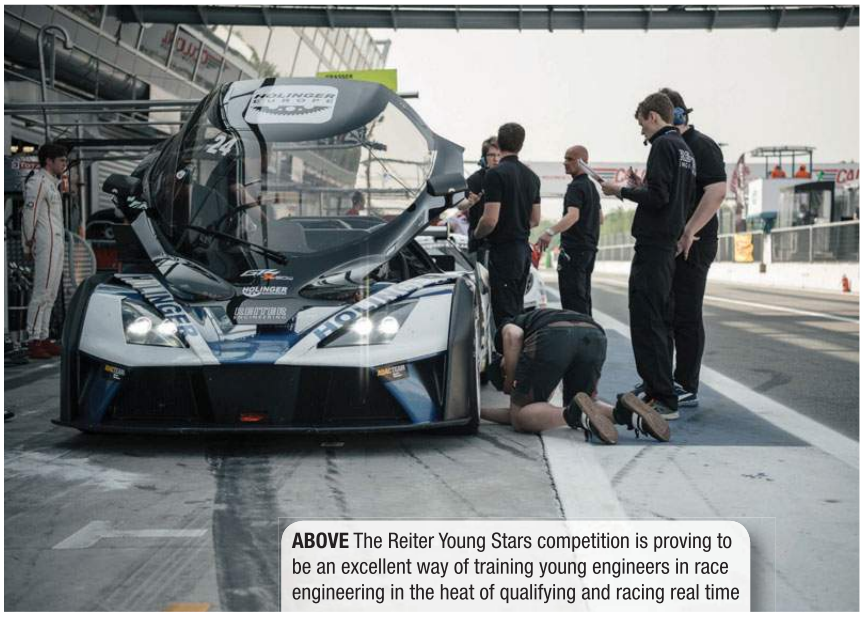
Reiter Young Stars programme to continue in 2017

Sebastian Scott

KIRCHANSCHOERING, GERMANY: Reiter Young Stars, the radical motorsport education programme introduced by Reiter Engineering this year in co-operation with KTM and the Stephane Ratel Organisation (SRO), will be extended to 2017. Every team is supported by two student engineers and a marketing and business student from one of eight European universities that are involved in the competition. Reiter Engineering assumes responsibility for the logistics of the KTM X-Box GT4 cars between events.

Sebastian Wedgwood, race engineer for RYS Team Holinger and motorsport engineering student at the University of Hertfordshire said, "Since joining the Reiter Young Stars championship this year we have learned far more than I imagined we would. There are no shadowing engineers, so when we arrived in Monza, for example, we sat down for an hour and had everything explained to us in detail, were given our run sheets and then left to set the car up."



ABOVE The Reiter Young Stars competition is proving to be an excellent way of training young engineers in race engineering in the heat of qualifying and racing real time

The engineering students score points on various aspects of race car engineering, fuel consumption calculations, setup preparation, communication with mechanics and even behaviour over the team radio. Team Holinger currently sit fourth in the engineering points but for Wedgwood the points are a bonus. "I cannot stress enough how important this series is to me and my teammates now. If anybody wants to have a career in motorsport or offer careers in motorsport, this is the way forward," he said.

"Reiter Engineering has trusted us, and the fact that the series is continuing into 2017 resonates that the fact that the trust placed on us has paid off. Holinger has also been incredibly supportive of us too and it is something we won't forget and I think it has set an example for other motorsport businesses to follow by supporting the next generation," he added.

The Reiter Young Stars Cup is taking applications for student engineers and partners now, for those interested applications should be sent to info@reiter-engineering.com RT

New-look aero conference returns to Coventry Transport Museum

William Kimberley

COVENTRY, UK: The Institution of Mechanical Engineers is organising the 11th edition of the biennial Vehicle Aerodynamics conference at the Coventry Transport Museum on 21-22 September. The theme is Aerodynamics by Design. Topics that will be covered include drag reduction through design, low control concepts and technologies, improvement in test techniques and instrumentation and handling and stability among many other topics.

With *Race Tech* as the media partner, the second of the two-day event will concentrate on motorsport aerodynamics. The idea behind this, said Geoff le Good who chairs the organising committee, is because he wants to find out more about the creativity of aerodynamics in motorsport. "The solution a motorsport aerodynamicist comes up with when under pressure and with next to little or no time, is often truly astounding and I want to explore this creativity. Some of it won't be relevant to road cars but the methodology will be."

The day will begin with a panel session comprising F1 consultant John Iley, Multimatic's Mark Hanford, McLaren F1's Mike Brown, Prodrive's technical director David Lapworth, and Peter Stevens, the designer of the McLaren F1 supercar. Still to be confirmed is the FIA's Peter Wright. The panel will be chaired by TotalSim's Rob Lewis and Michael Pfadenhauer, general manager aerodynamics and thermal management at Porsche.

A number of papers will be presented during the day, including Experimental and Numerical Investigation of Aerodynamic Drag in Turbulent Flow conditions and Wall-Resolved LES (Large Eddy Simulation) to Predict the Boundary Layer Separation Around a Side-Mirror of a Full Scale Vehicle at the Critical Reynolds Number from aerodynamicists at Honda R&D.

For more information about the event, please contact eventenquiries@imeche.org RT

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ABOVE The new 3000 sq ft metrology facility is a joint venture between Silverstone Park developer MEPC and Hexagon Manufacturing Intelligence

Global leading metrology centre opens at Silverstone Park

SILVERSTONE, UK: Britain's first dedicated sub-contract inspection metrology centre has been officially opened at Silverstone Park's Innovation Centre by Daventry MP Chris Heaton-Harris who has called it a "global-leading" facility. The 3000 sq ft state-of-the-art facility is a joint venture between Silverstone Park developer MEPC and Hexagon Manufacturing Intelligence – the world leader in the science of metrology.

The Silverstone Park metrology facility managed by Hexagon Manufacturing Intelligence will provide the UK's start-up businesses and SMEs operating in high-tech engineering with vital access to cutting-edge equipment, support, training, and networking opportunities. The ability to verify and validate predefined standards for accuracy, reliability and precision is a real coup for SMEs and start-ups which are often unable to achieve this due to financial restraints and restrictions.

"We are delighted to be working in partnership with the team at Hexagon Manufacturing Intelligence to launch this fantastic new facility, which will provide SMEs with unique access to a wealth of support and specialist expertise," said MEPC's Roz Bird, commercial director of Silverstone Park. "The launch of the metrology facility is a key element of our overall vision for Silverstone Park which is to create a global destination for engineering, innovation and business development.

"It is also a key facility for the Silverstone technology cluster which aims to support the exceptional engineering skills of the companies in the region and attract investment to enable companies to grow."

"We are absolutely thrilled to have launched this specialist facility within the iconic Silverstone Park and are hugely excited about the real, tangible difference this will make to not only SME and start-up businesses, but to industry as a whole," said John Drover, sales manager for Hexagon Manufacturing Intelligence. "Our team of engineers and application metrology specialists are able to deliver inspection, validation, and quality control of components through the use of Hexagon systems which are capable of measuring to the sub-micron level, enabling our customers to achieve high performance and accuracy each and every time.

"Through this new facility, we are opening up exclusive access to both the equipment and the support to enable tier two, three and four suppliers across the UK to achieve first-rate provable standards. By also offering dedicated training programmes, along with networking opportunities, this new facility will help to both facilitate growth and development across the SME sector and raise standards industry-wide."

Following the unveiling Chris Heaton-Harris, MP for Daventry, said: "The facility is extraordinary and it is obviously not just a nation-leading but a global-leading facility in the heart of Silverstone which is a hub that is on fire for engineering and precision engineering. The future seems exceptionally bright and exceptionally global for the businesses around here.

"When you get businesses like this in the heart of a thriving engineering community you become the centre of the global chatter around it. If you are a start-up or someone investing you will want to be near it or part of it. For Silverstone – for this region – this is exceptionally good news." RT

PERSONNEL

FERRARI Formula 1 technical director James Allison has left the team after three years at Maranello, the team has announced. His position will be taken up by Mattia Binotto who will become chief technical officer. RT

BRITISH Touring Car Championship head Alan Gow was presented with an award for the Outstanding Contribution to the Motorsport Industry during the House of Lords summer reception held by the Motorsport Industry Association on 28 June. Gow, also president of the FIA World Touring Car Commission and chairman of the Motor Sports Association, was described by MIA CEO Chris Aylett, who presented the award, as "a reliable and knowledgeable advocate of the British motorsport industry, (with) a well-deserved reputation as the backbone of touring car racing, both here in the UK and worldwide." RT

McLAREN Applied Technologies has announced the appointment of Rodi Basso as motorsports director, where he will spearhead and continue to develop the company's longstanding and highly regarded motorsport offering. He arrives at McLaren from Magneti Marelli, where he headed up sales and marketing, first for the motorsport, and latterly the innovation division. He started his career as a race engineer at Scuderia Ferrari before moving to Red Bull Racing, and then went on to form his own successful engineering consultancy. RT

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Haas F1 focusing on 2017 car

Sebastian Scott

KANNAPOLIS, NC. Haas F1 Team has ceased development of the 2016 car in order to shift attention to 2017. It joins Renault Sport F1 and Sahara Force India F1 that have already announced that they are solely focusing on 2017 car development.

"We are always trying to hit a moving target, but everybody's confident we are getting there," said Haas F1's team principal Guenther Steiner "Wind tunnel sessions are filled with parts to test, we are doing CFD, we are maxed out on everything as allowed by the FIA and everybody seems to be confident that we are on the right path."

One hurdle unique to Haas F1 is key components supplied by Scuderia Ferrari as the US-Italian partnership continues for 2017 which suggests that the Italian Formula 1 team is also well underway with its 2017 car development.

All teams on the grid face the same challenge regarding cockpit protection, which if implemented could prove pivotal in chassis design. "At the moment, we are assuming that there will be a halo," said Steiner, "but if there isn't one, it's pretty simple to take it out before we go to production as we won't be doing the moulds and tooling until sometime in September, so we've got still some time and, by then, it will be decided what to do." RT

CYRIL Despres and David Castera took their Peugeot 2008 DKR to victory in the Moscow-Beijing Silk Way Rally. It follows the success of Stéphane Peterhansel and Jean-Paul Cottret in January's Dakar and on last September's China Grand Rally. RT

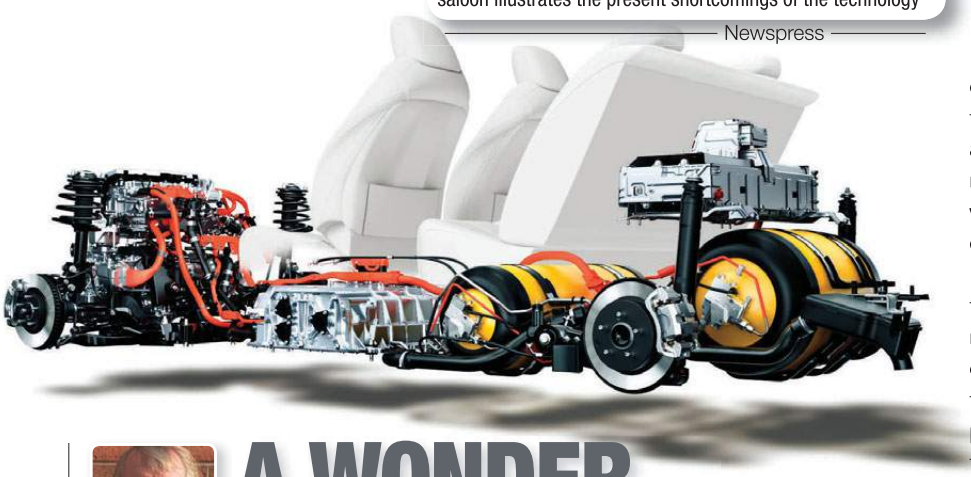
IN BRIEF

SAUBER Formula 1 and the holding company that owns it has been acquired by Longbow Finance. It secures the continuation of the Sauber name in Formula One and will open opportunities to further grow the engineering activities of the group. There will be no changes to either the company or the team name. Peter Sauber will retire from all functions, being succeeded by Pascal Picci as chairman of Sauber Holding. Monisha Kaltenborn will remain as a member of the Board of Directors and continue to lead the company in her functions as CEO and team principal. RT

HONG Kong will stage the FIA Formula E Hong Kong ePrix for the first time on 8 & 9 October at Central Harbour front. Formula Racing Development Limited (FRD) has been appointed an "Official Racing Partner" of the event and will host the world's first-ever e-Touring Car Challenge as a prelude and highlight of the event on Saturday 8 October. It will feature 15 of the new Volkswagen e-Golfs that have all been modified with specially selected suspension, brake, roll cage, racing seat, 6-point harness, wheels, rims and fire extinguisher to meet the racing safety standards. Five celebrity drivers who have previous racing experience will be invited to compete with 10 veteran drivers. RT

THE Verizon IndyCar Series staged a blind test of three carbon braking systems at Road America in July, with current supplier Brembo tested alongside PFC and Carlisle Brake & Friction. IndyCar has not yet announced the results of the test but sources suggest that the PFC package was declared the superior option by testing drivers. The brakes are consistently the most criticised aspect of the current Dallara DW12 IndyCar chassis. RT

AUDI Sport Customer Racing head Chris Reineke has ignited speculation of a return to Touring Car racing for the German manufacturer by confirming that the German brand is likely to build an A3 saloon to the TCR concept, with a final decision expected in July. "TCR has good cost control, worldwide reach, something which is very important to us," he said. RT



BELOW The range of Toyota's Mirai hydrogen fuel cell-powered saloon illustrates the present shortcomings of the technology

Newspress

A WONDER FUEL WORLD

The prospect of a hydrogen fuel cell-powered car racing at Le Mans urges **Chris Ellis** to ponder the future

THE Automobile Club de l'Ouest has set up a working group to examine the practicality of allowing cars powered by hydrogen fuel cells to race. It is hoped the date for their introduction can be announced by Le Mans next year.

Some form of surge power system will be *essential* if the energy source is a fuel cell, simply because of the fuel cell's poor transient response. The ideal solution is flywheel-based, to provide high specific input and output power with excellent efficiency, more durably than battery-based systems.

The Chinese are sometimes accused of merely copying the technology of others. However, in this case they are leading (in partnership with a small UK company), because the optimum electro-mechanical system for transferring kinetic energy between the flywheels and all four driving wheels and distributing the electrical energy supplied by the fuel cell will soon be in pilot production near Shanghai. So don't be surprised if two Chinese LMP1s powered by hydrogen fuel cells and flywheel-based surge power units arrive in Le Mans as soon as the ACO is ready. And perhaps two more cars with surge power and hydrogen-fuelled engines?

The ACO has demonstrated once again that it is 'collectively smart', unlike some organisations I won't bother to mention this month. It is pursuing a cautious but open-minded approach to future fuels, which is much more helpful than a semi-religious commitment to a single 'wonder fuel'. Right now, there is no front runner, but there have been some recent developments which suggest what the winning fuels may be, for France in particular.

Hydrogen is just one fuel option; all being well, Gerard Welter will enter a bio-methane powered car next year. Methane can be stored as a liquid at a higher temperature than hydrogen, so needs less energy for liquefaction, and less insulation. But any system that cannot sit parked in the sunshine for more than a few days unless it releases most of its fuel into the atmosphere is obviously a non-starter for the mass market. Consequently, I believe motorsport should concentrate on solutions which are practical in road cars. Bio-ethanol is practical and proven, although it is currently produced mainly from food stocks. Bio-methane as a gas is impractical in a family car, because of the size and weight of the storage tank(s). Methane can be stored as a chilled liquid in a racing car, but that is a controlled environment. The same argument applies to hydrogen, revealed by a close look at the two large gas cylinders of a Toyota Mirai, which has a practical range of only some 270 miles.

So what's the future? As just one possibility, take a look at www.carbonengineering.com. If this proves as good as it sounds, carbon dioxide can be extracted directly from the atmosphere. Now search 'Stanford ethanol' and take a look at the '9-April-2014' press release. Again, if this process can achieve cost-effective volume production, then join the dots, and CO2 will be sucked out of the air using almost zero-cost (at the margin) nuclear energy, and will be combined with water to produce a novel form of bio-ethanol, with no impact on food production.

France is in the best possible position to achieve this, and it should be highly motivated, given the high cost of its almost complete dependence on imported oil. If the new CO2 extraction and bio-ethanol production systems are co-located with the nuclear plants, then they can exploit the cooling water and, most importantly, be managed as a combined system, with ethanol production peaking at weekends (when some plants are currently shut down), and falling to near zero when demand for electricity peaks. A secondary benefit will be the increased reliability and durability of all the generating equipment, particularly the turbines and generators (see www.world-nuclear.org for full details).

France also has a management advantage, unlike any other country except China. The government is the major shareholder in EDF, France's main energy supplier, which is the owner and operator of all the nuclear facilities. The French government has a unique, self-imposed problem, which this opportunity could help solve. It has accused itself of over-committing to nuclear power, and has legislated to reduce nuclear's share of electricity production from some 75%(!) to 50%, to open up a market for solar and wind. Because large French industrial customers pay roughly half as much as their competitors in the UK for their electricity, renewables are currently much harder to justify in France. By now, I am sure you have spotted the end game – France exporting large amounts of bio-ethanol to its grateful neighbours by fully utilising its massive investment in nuclear power (rather than mothballing some of it), potentially slashing its oil imports and making billions from a product that will cost close to nothing to produce.

So the ACO is doing absolutely the right thing, particularly with the promised promotion of bio-fuels by 2018. Now ask yourself – isn't this much more interesting technically than Formula 1? And relevant? And how much money will the French government give the ACO to ensure the marketing of the whole concept is a roaring success? Vive la France! Rest of the World – Attention, s'il vous plaît.

ENTER THE SAINT

Williams F1's Pat Symonds explains to **Soheila Kimberley** the impact the 'halo' is having on next year's cars

Bloxham/LAT

ABOVE The halo, tested here by Ferrari, will impact on the airflow to the car's airbox

IT is thanks to the painstaking work that's been put in over the years that Formula 1 is as safe as it is today, although accidents still occur that cause serious injuries or even death. No-one will ever forget what happened to Jules Bianchi in Japan in 2014 but at the same time, when you look at the total wreck following Fernando Alonso's accident in Melbourne this year, it's a miracle that he walked away unscathed.

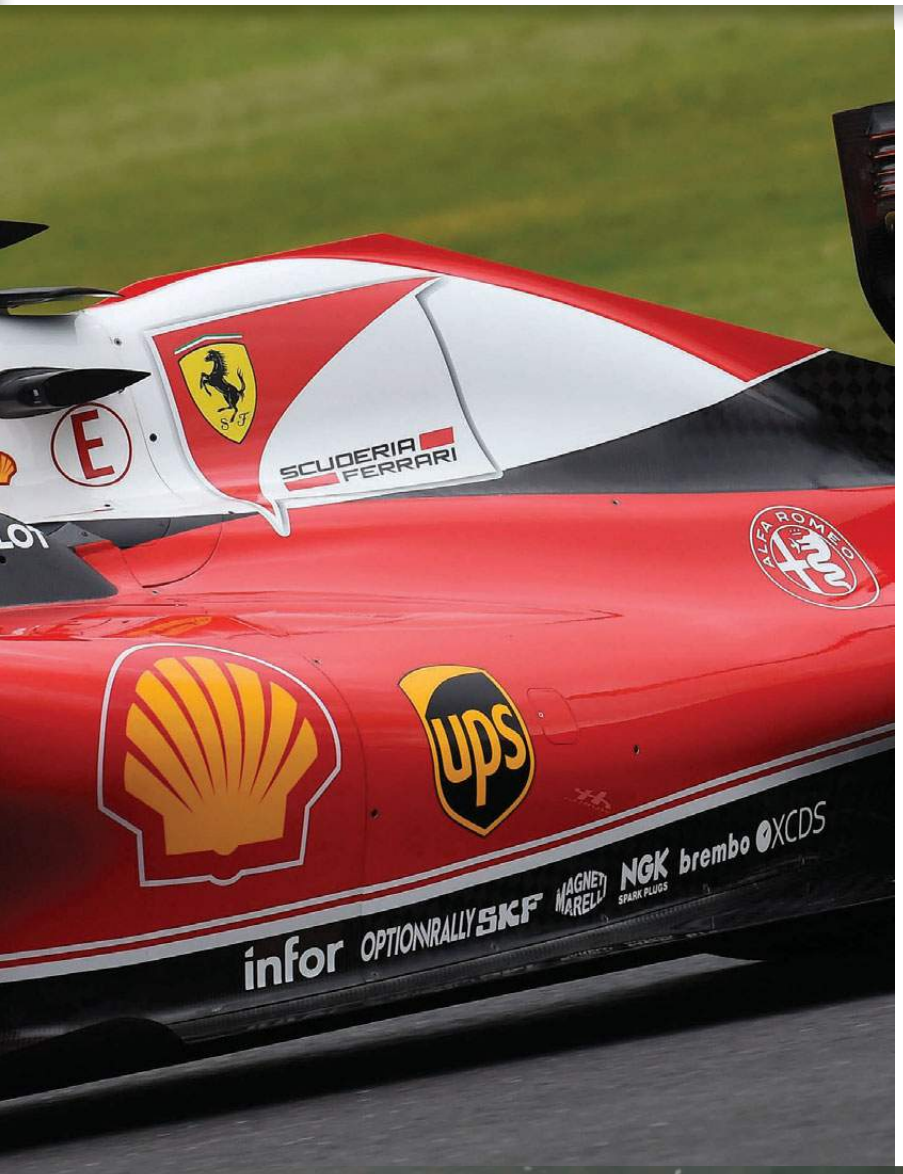
The quest for protecting drivers and making cars even safer is never ending, though. The latest development is the introduction of the so-called 'halo', a concept originally developed by Mercedes, that will now be seen on every Formula 1 car from next year.

As the chief technical officer at Williams F1, and also a lifelong advocate of making Formula 1 safer, Pat Symonds is pleased that it is being introduced, although he does have some reservations: "Everyone knows why this frontal protection issue has come up, but I'm a little bit sorry that the canopy isn't the adopted technology because I think that it's quite futuristic whereas the halo is quite an ugly device. It's a bit of a shame because in my mind the racing car is quite an aesthetically pleasing thing, although some might not agree.

"Actually I do believe it would be technically feasible to introduce a canopy for 2018 but I don't know whether that will happen or not. We'll probably have a look at what the public reaction will be to it, but I think that it's not going to be good as people don't like change.

"However, the halo will cover the really catastrophic case, the loose wheel that's flying around. It's good in that respect but the canopy offers additional protection in a Felipe (Massa) type accident. [The Brazilian driver was knocked unconscious when a spring, which had become detached from the rear suspension of Rubens Barrichello's Brawn that Massa was following, struck him on the head as he reached 175 mph on one of the fastest sections of the Hungaroring.]

"One of the things that worry me is the case when one car is launched over another, as happened in Australia in 2007 when



David Coulthard's car was launched over Alexander Wurz's head with the rear tyre just missing him. It's possible that the underside planks, which are now shorter, can get hooked by the halo, which is potentially a very dangerous thing. I'm not against the halo, it's the right thing to do, but I think it's a bit of an interim step and that we can do better."

> *"The canopy is futuristic, whereas the halo is quite an ugly device"*

Symonds admits that this structural device will affect the aero flow, forcing teams to attempt to reduce any negative effects: "The flow that's coming off the halo is impacting on the rear wing, but there's not a great deal we can do to recover it because it's a standard part and it's in a restricted area.

"In a way more importantly, it has affected the roll hoop area much more and what we need to do is make sure that we can still feed the engine with good air. There was very close to full dynamic head up there so it was a remarkably efficient way to cool which is why in the last few years everyone has used it, but it's now far more difficult to feed any cooling system from there."

According to Symonds, the canopy is even more of an aero problem than the halo. "We ran it in CFD although not yet on a model and found that it was actually slightly worse believe it or not as there was a bit more of a wake from it in a more destructive area. It needn't be, but it was."

Symonds then talks about the load impact the halo ▶

Bloxham/LAT

ABOVE That Fernando Alonso was able to walk away from this crash in Melbourne was testimony to the hard work put in on safety

will have on the car. "That's not too much of a problem as the front mounting is where the secondary roll hoop was anyway and it's a strong area of the chassis, but we now design it to a slightly different load case. However, it's not one that troubles us. The rear mountings are just another thing to do, but it's not really a problem as there's nothing difficult there, just a little bit of additional weight because we're also keeping the strength on the cockpit sides. It's just a question of doing the calculations and designing to those loads."

TIME TO SPIT THE DUMMY?

Although this year's car had trouble passing the mandatory FIA crash tests, taking 10 to 12 attempts to get there due to the very short nose, Symonds is still a huge enthusiast of them. "The crash tests are fantastic," he says. "They've been a major benefit in the way we design the cars, although there are aspects of them that could be improved. One of them is the dummy, as it isn't terribly representative of the driver and it's questionable whether data from it is still relevant. We're looking at things like that and we're looking at the loads and the whole process as part of the continual review that goes on."

Next year will see faster, more dynamic cars thanks to the regulations changes coming into effect. The suspension track has increased from 1800 mm to 2000 mm, the front wing span from 1650 mm to 1800 mm and the rear wing from 750 mm wide/950 mm high to 950 mm wide/800 mm high. The tyre widths have also changed from 245 mm wide on the front to 305 mm and 325 mm on the rear to 405 mm wide. The maximum weight has increased from 702 kg to 722 kg.

"The cars are a bit heavier, cornering speeds are a bit higher, and it has a wider front wing but speeds on the straight will be similar because although it's inherently a higher drag car, we'll probably be running with less wing and we won't be running with maximum downforce or maximum drag everywhere," says Symonds.

"While the cars are a bit faster we're not necessarily addressing that but next year the wheels and tyres will be a fair bit heavier which means that the tethers need to be upgraded for that. You can't just leave everything as it is; there are certain bits that we need to improve."

> *"We ran the canopy in CFD and found there was a wake from it in a more destructive area"*

Asked whether this has implication for the crash test, Symonds replies: "I don't think there are any implications as in a crash we try and get rid of the front wing so that we've then got a nice pure crash structure to work with. So no implications from that point of view, but there are certainly plenty of structural implications in trying to meet deflection limits. It's very, very difficult and will require a great deal of research and work." RT

BELOW Red Bull championed the case for the canopy with its 'Aeroscreen' but problems persist with this solution

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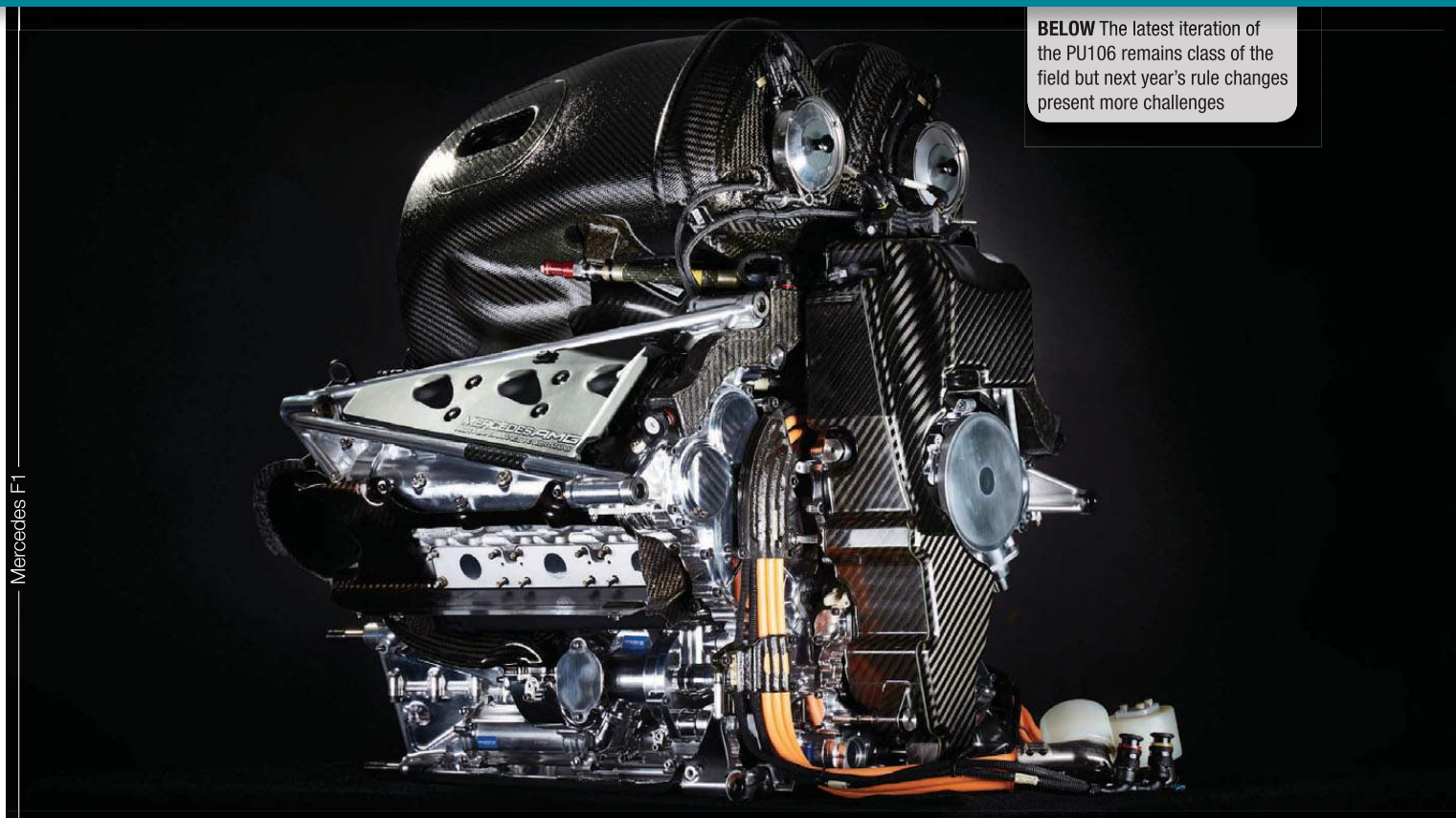


BELOW The latest iteration of the PU106 remains class of the field but next year's rule changes present more challenges

Mercedes F1

Kings of F1's castle

Thermal efficiency, the new regs and working with customers – **William Kimberley** gets an update on such things from Andy Cowell, managing director of Mercedes AMG High Performance Powertrains, at the British Grand Prix

WK *We talked last year about the increasing thermal efficiency of your engines, how proud you are about the targets you're achieving and how you're exceeding that of a production diesel engine. Is this still the case and is it still one of your targets?*

AC "Yes, I think that's the heart of the current Formula 1 regulations and the fact that you've only got 100 kilos of fuel means that the prime objective that all the power unit engineers are working on is how much of that chemical energy they can turn into useful work. That's the first thing to chase so that you've got good strong crankshaft power.

"We're in the high 40s percentage-wise in terms of efficiency now. Some truck diesels are around the mid-40s but we're a couple of per cent over that. We have the advantage of dedicated fuel and lubricant suppliers, fuels specifically to help us, and we're operating in a lower life market which isn't quite so cost-sensitive. Nevertheless it's Formula 1 motorsport which is an area to help develop new technologies, to take things from the R&D labs and turn them into something that will do reasonable mileage."

WK *That's what we've spoken about before. It's not just the technology, it's the processes that you are developing and learning that you can pass on to your colleagues on the production car side, AMG, and the parent company so that ultimately they will be producing more efficient engines.*

AC "Exactly that! We've got a dedicated group of people at Brixworth now, our automotive technology centre, who are purely focused on taking processes as well as technology that has been developed and how well we can apply that to future A45 AMGs or C63s or GTs, whatever. Also the main road car group, we're doing work there, not just the high performing AMGs, it's the main group as well."

WK *Turning to this season in Formula 1, it seems that while you are still dominant, there are signs that the competition is beginning to close the gap and that you might have to start looking over your shoulder before too long.*

AC "We try and stay looking forward; if you look over your shoulder, you fall over. I was at my son's sports day event in the last couple of weeks and he was a good two metres ahead of everybody else. Then he spotted my partner Sarah and myself and he looked sideways and all of a sudden he realised that he wasn't two paces ahead, he was neck and neck with second place. Thankfully he looked forward and managed to accelerate away again. I think you need to be careful you

don't consume too much of your resource looking at where your opponents are. There are only characters like Usain Bolt that can get away with it."

WK *With the MGU-Ks and Hs there's still only so much energy you can harness and use with the regulations. Would you as an engineer, especially with your road car colleagues in mind, like to be able to use more of that? Presumably there is the capability of harnessing more energy and deploying more energy in an efficient way.*

AC "I think on the MGU-H we have freedom with regards to setting the power limit, so we have the challenge of balancing how much energy we are going to recover in the exhaust stream via the turbine wheel and the MGU-H. That's always a very interesting challenge internally and not at all affected by the regulations.

"It would be interesting to have a larger capacity MGU-K, but equally it would be very interesting to have an MGU-K on the front axle. Maybe we'd call it something different, but an electric machine on the front axle would be very interesting."

WK *That seems to be the way of the world, whether it be production cars or the World Endurance Championship cars being able to harvest more energy, so would seem a sensible route to follow.*

AC "I'm sure at some point when the dust settles and everyone's within a few tenths of each other on the power unit, I think people will start looking at what next with the powertrain regulations and I think putting energy recovery on the front axle is one of those obvious next steps. We're constrained by 13-inch wheels, which makes it hard because of the brake diameter, so why not put it into a storage device instead of wasting all of that energy and putting it into the atmosphere?

"Of course, in the road car world, we need safe reliable braking systems to arrest the car but why does it need to be a disc? Why can't it be a safe reliable electric machine that slows the car but stores the energy somewhere where you can return it?"

WK *Next year's cars will have the halo that looks like it will have a massive effect in terms of both aero and thermal issues, so are you working closely with your aero colleagues?*

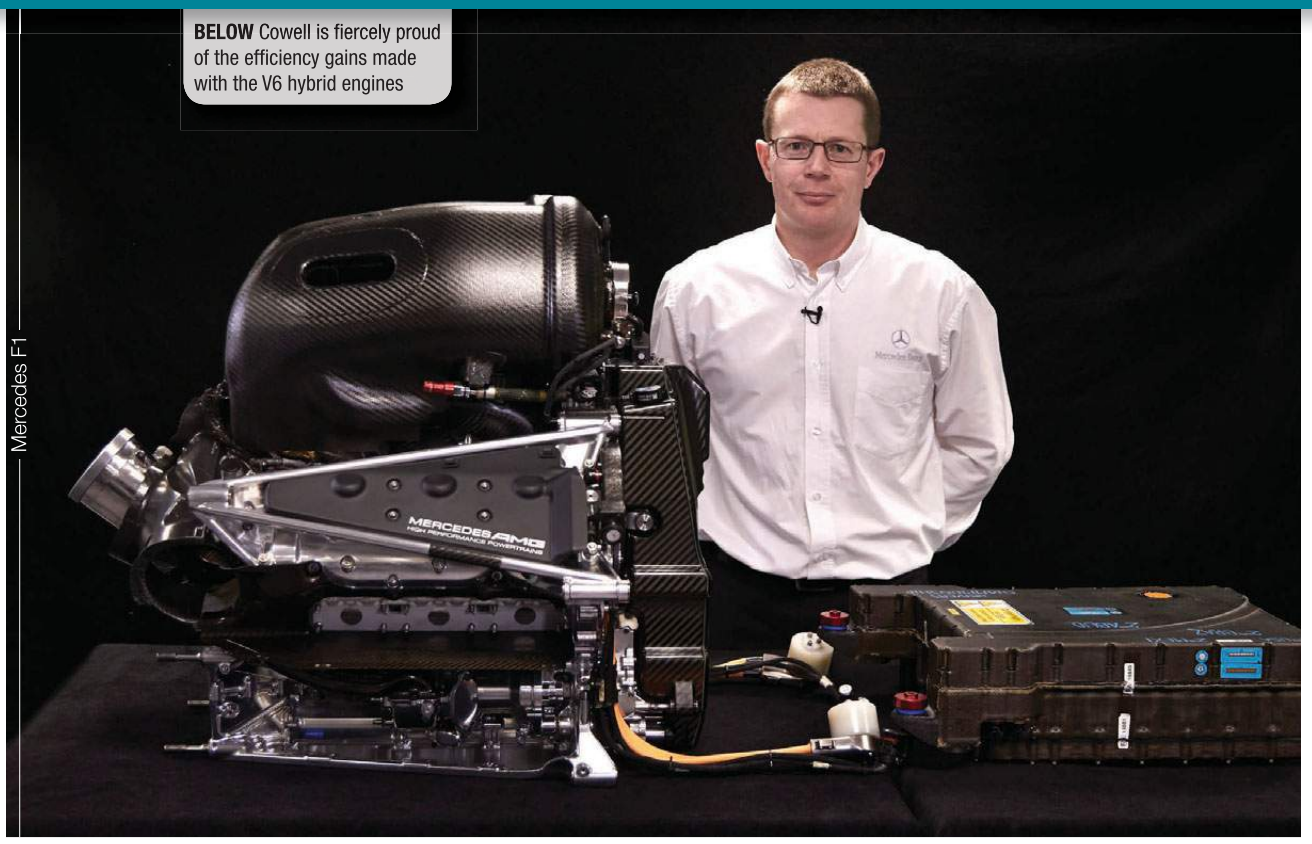
AC "We try not to stray into the aerodynamics side of the car. We try and make sure that we have very clear requirements in terms of what the compressor intake needs and what the cooling requirements are of all the circuits. Then we leave it down to the chassis experts in Brackley for them to work through that. What we do work closely on is identifying the sensitivities. So if we ask for too much cooling on a circuit, we ask for lower temperatures on water or oil or the ERS system, what's the lap time penalty on the car? Regardless of the system, regardless of whether it is car aerodynamics or an oil system on an engine, we all talk in milliseconds, we all talk in lap times so that we can equate everything to a common unit and work out what makes the net quickest car and then work on that."

WK *Will not having the engine token system next year make much difference to the way you develop engines?*

AC "Not a great deal to be honest, which was the main argument for getting rid of it and the risk was it ending up skewing the natural development rate. We had the token system for 2015 and it was initially intended to be an over-the-winter period token system so that over the season there wasn't any development except during the winter. However, nobody liked it. I think the thing that was particularly upsetting to the industry and to the fans alike was the thought of not being able to improve during a racing season and the championship. That's basically like saying however quick you are at the first race, that's how quick you're going to be at the end. No sport wants that. ▶

BELOW Like some of his rivals, Cowell believes recovering energy from the front axle is an obvious next step

Bloxham/LAT



Mercedes F1

BELOW Cowell is fiercely proud of the efficiency gains made with the V6 hybrid engines

"If you want the power unit to be a differentiator, if you want sporting improvement opportunities throughout the season, why have a confusing bureaucratic system? We're all saying we want development, just remove that system. It was put in place to contain costs, more specifically the development costs to the manufacturers, but I'm not sure it really managed that and it's just added confusion, so let's get rid of it."

WK *Next year the talk is that we're going to see much quicker cars. Presumably from a power unit point of view they're going to run longer at full throttle, so do you have to take into account that there might be more stresses on the power unit?*

AC "The direction is wider tyres, greater downforce and many seconds a lap quicker so that the cars are more spectacular. The result is higher cornering speeds that put mechanical loads on the whole car from tyres, rims, uprights, wishbones, transmission, engine and monocoque, so we have to consider that carefully. You also end up with a scenario where some existing corners become part of the straight and so the percentage that the driver can be at full throttle increases. This means that power unit performance is more of a significant player and it is harder for the engine to survive. Next year, assuming that there are going to be 21 races, the regulations are that you can only have four power units. However, the full throttle time takes a step up so the number of cycles that the components need to survive at full throttle considerably increases.

"It's more rewarding to have high power in terms of lap time, but it's more challenging to have lots of laps at high power. It's going to be an interesting journey, so notionally no technical changes for the power unit, but quite a challenging set of conditions. It's a lot harder for the power unit to survive and more rewarding to be a more powerful power unit."

WK *How important is it to develop as much of the power unit as possible in-house?*

AC "Paul Morgan, who co-founded Ilmor with Mario Illien, had a passion for enabling Mario's ideas to be conceived inside the factory, which is real luxury for the engineers to be able to see the parts being made on the same site. To be able to work in conjunction, to be able to buy machines from around the world specifically for new parts and develop and apply them to the manufacturing steps you want to do, provides great opportunity to do things that you wouldn't normally do and also doing standard things quicker than you can do.

"There are no goods in and goods out and white van journeys between suppliers which slows development down. It is literally taking it from one machine to the next, so from raw material coming in, to the parts being in build, having been inspected thoroughly, it's considerably quicker. While we look forward to the race on Sundays, actually the engineering race happens in the factories. That's the real sort of technology innovation race location."

WK *How is the relationship with the customer teams working out?*

AC "Very strong. They feed into us the aerodynamic impact of any of our overheads of the car. They're great guys to work with as well. Again their geographical proximity means that if we need to discuss something, yes we can do it on the phone, but we can get in the car and just have a face-to-face conversation. There are no airports and aeroplanes involved so the integration guys that are dedicated to those teams can just easily go and communicate face to face and quickly resolve issues.

"We've increased the capacity that we've got in the factory in order to be able to support them with up to date specifications, which is something that everybody was keen to have rather than being a race or two out of phase. It's again back to the sporting aspect. Everybody wants people to have the same opportunity; it isn't a one-make power unit supply. If you can supply all of the customers as well the works at the same time, it's so much better. Last year we didn't have the capacity, as we saw with the final Monza update; this year we're doing pretty well at keeping on top of that." RT

Main graphic... the year is 1957 and in Australia America's Cup-winning designer Ben Lexcen is already adding winglets to his rudder foils...

We've come a long way (baby)

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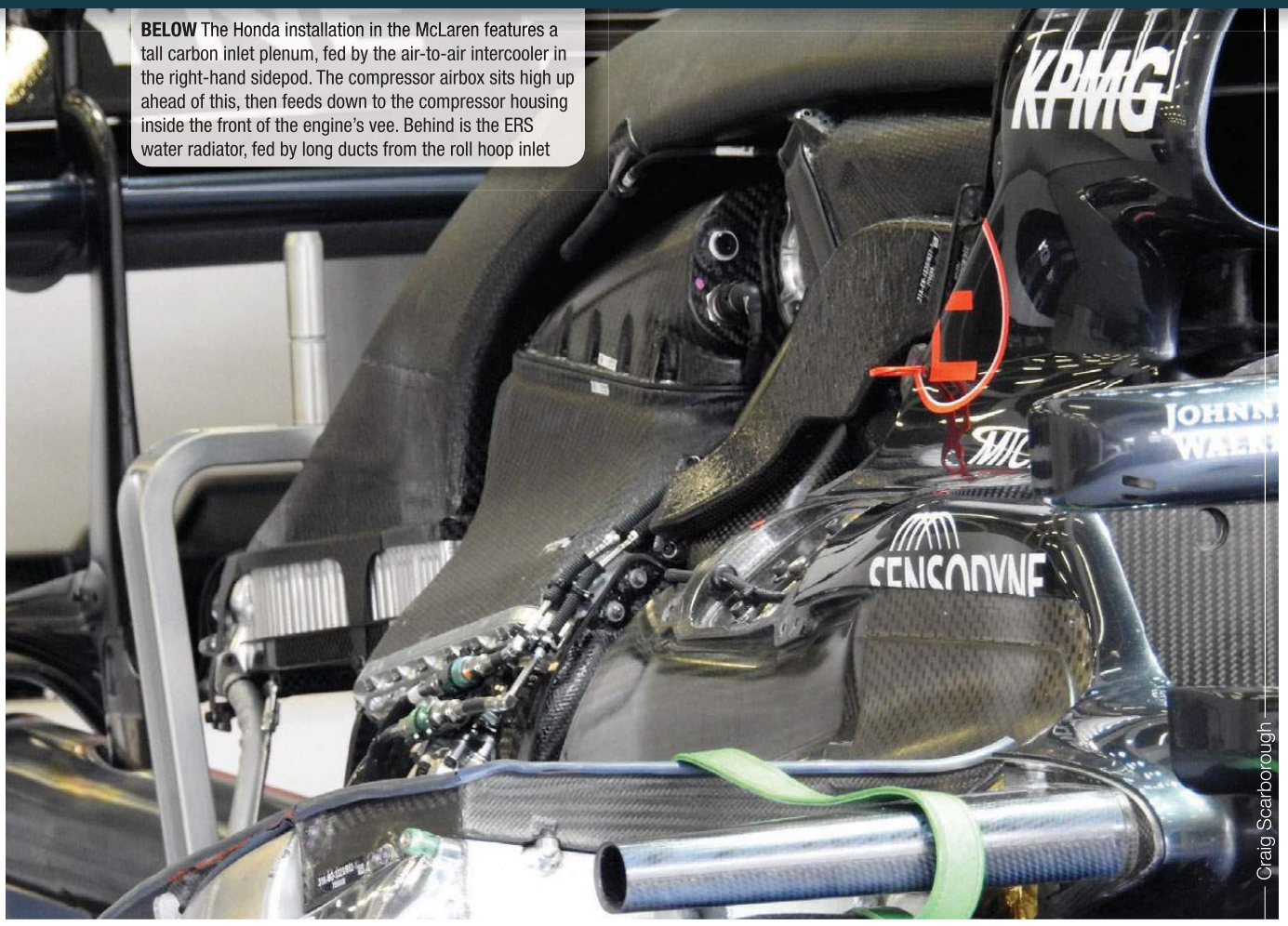


BELOW The Honda installation in the McLaren features a tall carbon inlet plenum, fed by the air-to-air intercooler in the right-hand sidepod. The compressor airbox sits high up ahead of this, then feeds down to the compressor housing inside the front of the engine's vee. Behind is the ERS water radiator, fed by long ducts from the roll hoop inlet

Craig Scarborough

SIMON SAYS...

Gilles Simon is a Formula 1 engine man with a considerable amount of experience which he is now using to good effect on the Honda Racing F1 programme, as **William Kimberley** finds out

WHEN it came to managing expectations, both McLaren and Honda failed abysmally last year. On the announcement that the UK Formula 1 team was going back to a former engine partner, one that had delivered so many triumphs in the past, it was assumed that the cars would be quick from the off. As we know, they weren't.

Behind the scenes there were accusations flying left, right and centre but the one that stuck was that the Japanese manufacturer was not prepared to turn to specialist motorsport engineers to help it out of the rut. Twelve months later, though, and the tide seems to be turning, with former Ferrari F1 engine head Gilles Simon very much part of the new team striving to get it right.

"We now have a much tougher team and the guys are working together," he says. "We have a fuller understanding of the right processes and so everything has been put in place. I still think that we're not yet fast enough in our development and it's a huge job to match Mercedes, but I don't think anyone else has reached that point yet anyway. Catching the other competitors and then Mercedes could be a long fight, but I think we are on the right track, going in the right direction and have a clear strategy. However, we should be doing it more quickly.

"The power unit side have made good progress. The fact that we are more reliable has also allowed the car to run more, to be better known because it's quite a complex animal. I believe from what I see that our colleagues from the chassis and aero side have made huge steps."

Simon says that it was the energy recovery systems that primarily stymied their progress early in the programme, but the learning curve has now flattened out: "I think we actually had issues almost everywhere, but we now understand all of the energy recovery systems a little better which was very important in terms of management of this system, and we are also making reasonable steps on the performance of the combustion engine."

He is reticent to talk about the thermal efficiency of the engine, saying that there is still room for improvement although he is pretty upbeat that they will reach the same sort of figures as that claimed for the Mercedes engine. "We may be near, but in some aspects we are not yet there," he cautions. "My personal view is that there remains a big margin of efficiency improvement, even for the best of our competitors, but that's the beauty of these regulations.

"I think that the usual engine development until a few years ago was just about putting in more air and it would burn one way or another. Now it's much more about combustion and with the fuel flow limit

formula that we now have, it's far more difficult to look for efficiency without fully understanding combustion and the mixture. If you were able to have a proper mixture in the production chamber, our combustion issues would be much easier to handle. This you can see from simulation but also from some testing that we have all done."

ExxonMobil is the fluids and fuels partner, Simon saying that the programme has been enhanced by the joint development work. "We are working with them on the friction side, but I believe for now the best results we have are on the fuels side," he says. "This is because the performance improvement and the efficiency improvement we are looking for are really much bigger than just friction. The match between the combustion chamber, the fuel spray and the fuel is quite a complex topic and we are not yet there to fully understand what is happening. However, we are progressing together well with them and their research centre."

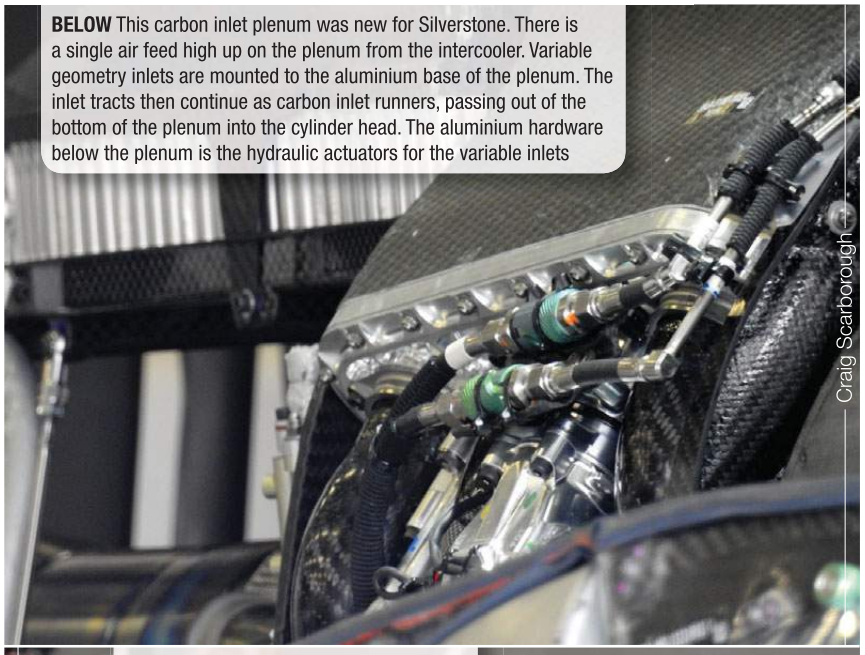
> *"Harvesting energy from the front axle is the future for both production and race cars"*

Simon then talks about the value of high injection pressure: "I think that if you look at what our colleagues are doing on diesels, there is a huge potential improvement for higher pressures. Maybe the next generation of regulations should take this into account but we are learning from our production car colleagues who are giving us some help and in doing so are learning in the process."

Turning his attention to the hybrid systems, Simon believes that the battery has become an ancillary. "What is important is the exchange of energy between the MGU-H and MGU-K. Because you are completely free to take exhaust energy and bring it to the shaft or take shaft energy and bring it to the exhaust," he says. "To digress a little, with the production car hybrids of today, the hybrid system is pointless on the motorway as it is redundant, so it's just added weight. With the system we use in Formula 1, even when at full load we are recovering energy from the exhaust and giving it back to the shaft. This is enhancing the efficiency, not of the combustion process but of the fuel efficiency. I think it's a trend that we will see on road cars at some point in time. I'm really convinced that from the technology point of view there should be other avenues explored that include harvesting energy from the front axle, which I think is the future for both production and race cars."

Talking about next year's cars being quicker, Simon believes that the current generation cars are underpowered anyway. "From what I've seen it seems that the cars will be much faster anyway and they will be more spectacular compared to what we used to see when I was younger," he observes. "I don't know what is good for the show, but if faster cars are better, then fine. The technical reality is that the cars we have today are underpowered. We are now more than 70% full load on an average circuit because there just isn't enough power. The driver is desperately trying never to lift when possible.

"However, I think next year's cars will see an even greater percentage at full load. They will be quicker which I think will impact on the reliability request for the engine, which is fair – it's the same for everybody. It's just my personal view but I suspect that having a little more horsepower could give some more spectacular results although possibly most of my colleagues would not agree with that." RT



Craig Scarborough

BELOW This carbon inlet plenum was new for Silverstone. There is a single air feed high up on the plenum from the intercooler. Variable geometry inlets are mounted to the aluminium base of the plenum. The inlet tracts then continue as carbon inlet runners, passing out of the bottom of the plenum into the cylinder head. The aluminium hardware below the plenum is the hydraulic actuators for the variable inlets

McLaren

BELOW A better understanding of the energy recovery systems, allied to progress with the combustion engine, has propelled the McLarens into the mix on occasions

RACE ON SUNDAY, *CELL* ON MONDAY?

Almost unnoticed, a hydrogen fuel cell-powered racing car completed a full lap of Le Mans before the 24-hour race. **Chris Pickering** examines the return of the GreenGT H2

A FEW weeks ago at Le Mans, the ACO made an announcement that could turn out to be a pivotal moment in the history of motorsport. Almost ignored at the time – overshadowed by the forthcoming rule changes and the unfolding performance balancing saga in GTE – the organisers revealed that they were working on a way of accommodating hydrogen fuel cells in LMP1.

To some that might sound like wishful thinking, but just a few days later a fuel cell-powered racing car *did* complete a high speed lap of Le Mans, albeit in a solo demonstration. That car was the GreenGT H2 – a development of the prototype that came tantalisingly close to racing in the Garage 56 slot in 2013.

It's probably worth taking a second to consider why this is such a big deal. Fuel cell vehicles are essentially electric, but instead of using a battery to store the energy, they generate it on-board, using a chemical reaction. In the case of most fuel cells – GreenGT included – this uses two of the most abundant chemicals in the universe: hydrogen and oxygen.

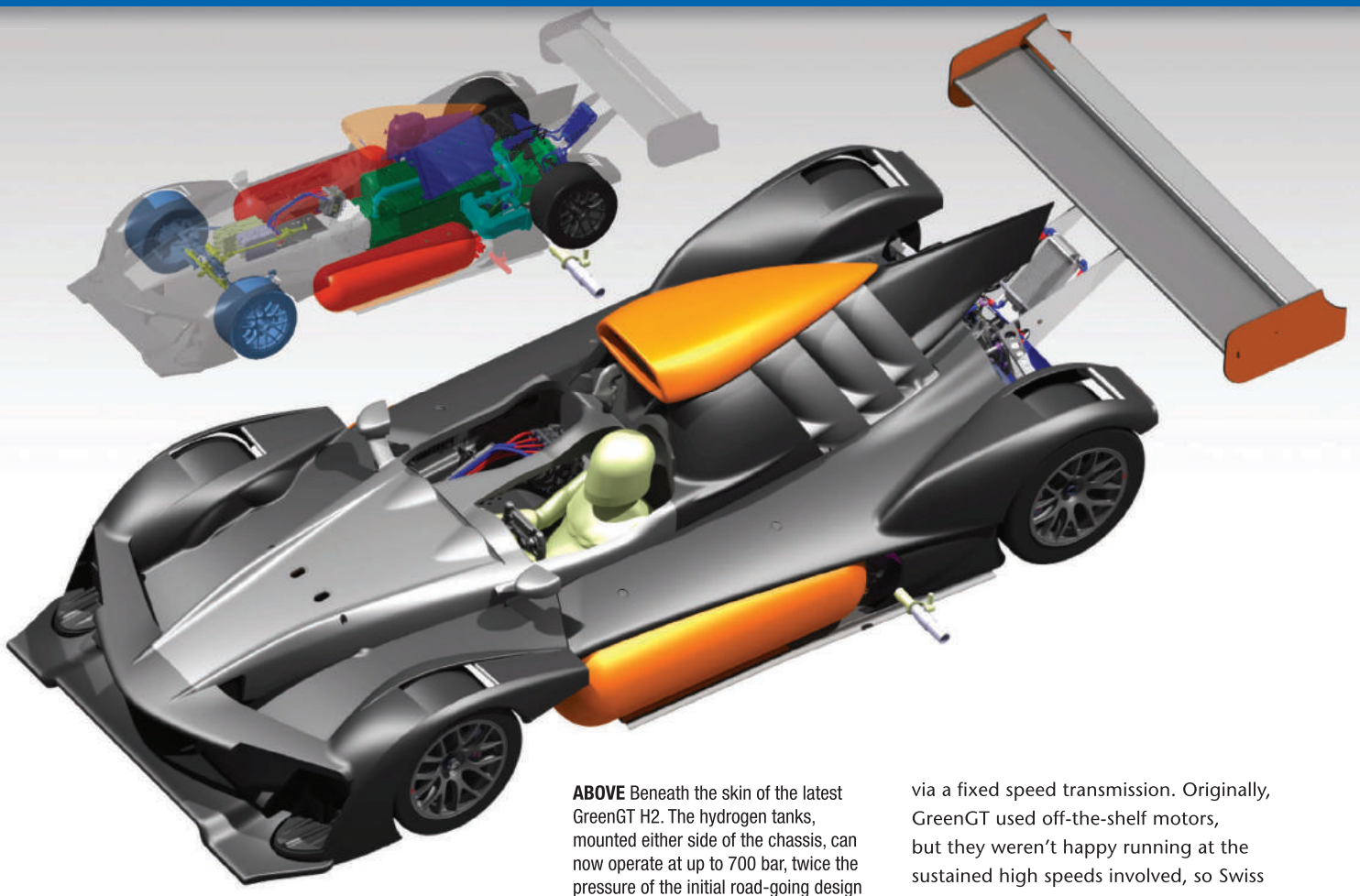
Hydrogen is fed to one side of the fuel cell where it is split into a mixture of positively-charged H^+ ions and negatively-charged electrons using a catalyst. Meanwhile, oxygen is pumped into the other side where a similar process is used to break down the original (O_2) molecules into negatively-charged oxygen atoms.

As everyone knows, opposite charges attract. In between the two halves of the fuel cell, however, there's a membrane that only allows the positively-charged H^+ ions to be drawn through. Here, two of them combine with each oxygen atom. This combination still carries a positive charge, however, which attracts the electrons. Blocked from travelling through the membrane, they have to flow through an external circuit, which creates an electric current.

Eventually, each oxygen atom combines with two hydrogen ions and two electrons to form water vapour. Crucially, the reaction will keep going indefinitely, providing it is fed with a supply of hydrogen (which can be bottled as a gas or liquid) and oxygen (which can be taken from the air).

Even once you factor in the not-inconsiderable mass of the fuel cell itself, you still have a solution that provides a dramatically better energy density than a

BELOW Former F1 winner Olivier Panis guides the GreenGT H2 around an impressive demonstration lap at Le Mans



ABOVE Beneath the skin of the latest GreenGT H2. The hydrogen tanks, mounted either side of the chassis, can now operate at up to 700 bar, twice the pressure of the initial road-going design

lithium ion battery. GreenGT claims the H2 could run flat-out at Le Mans for around 50 minutes, while you'd be lucky to get half that from a battery EV. Plus, once the hydrogen supply has been exhausted it can be refuelled in a short space of time, more or less like a combustion-engined car.

The fuel cell approach isn't without its drawbacks. For a start, capturing industrial quantities of hydrogen usually requires quite a lot of energy in the first place. Fuel cells are also quite expensive – at least for the time being – and still lag some way behind the energy density of an equivalent combustion-engined powertrain. But none of these issues are insurmountable and they all come back to the promise of supercar performance with zero tailpipe emissions and no range anxiety. With mounting concerns over climate change this could very well be the future of motorsport.

So what went wrong in 2013? Perhaps unsurprisingly, given a very short space of time to develop an extremely ambitious project, the GreenGT simply wasn't ready, explains chief engineer, Jean-François Weber.

"We didn't want to go to Le Mans with something that looked like a prototype unless it was going to lap at close to prototype speeds," he says. "In the end, we didn't have time to set up the car correctly and it weighs more than a conventional prototype [so it wasn't on the pace]. We weren't just representing ourselves but the whole hydrogen concept and we didn't want to create a negative image."

That may well be understating the performance gap somewhat, but the weight of responsibility felt by Weber and his colleagues is clearly very real. Even the GreenGT's successful return this year was rather muted – almost as if the team was downplaying its own achievements for fear of an unfair comparison to the top-spec combustion-engined cars.

HIGHLY EVOLVED

The current GreenGT H2, dubbed Version 2, still uses the same bespoke chassis, created for the team in 2013 by Welter Racing. It's essentially a mildly upscaled LMP tub, big enough to accommodate the centrally-mounted fuel cell. Suspension is conventional double wishbones with inboard-mounted pushrod actuated dampers, while a set of Brembo carbon brakes provide the stopping power.

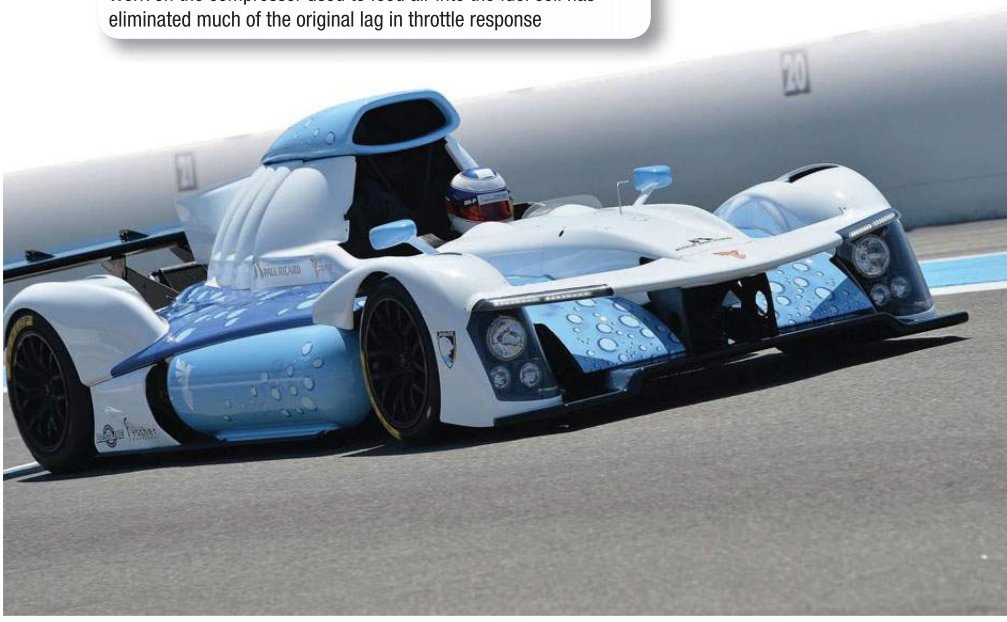
The rear wheels are driven by a pair of three-phase synchronous electric motors via a fixed speed transmission. Originally, GreenGT used off-the-shelf motors, but they weren't happy running at the sustained high speeds involved, so Swiss company Brusa was brought in to develop bespoke items. These experimental units are rated at 200 kW each, giving the H2 a theoretical total of 400 kW (536 hp) and a mildly terrifying 4000 Nm (2,950 lbft) of torque. For comparison, that's almost five times the torque output of the Dodge Viper's 8.4-litre V10. You can't help but feel a little sorry for the BBS wheels and Michelin tyres charged with delivering that to the tarmac, although both torque vectoring and traction control are employed to assist.

The fuel cell is fed by two hydrogen tanks – one mounted either side of the chassis. Initially these were a road-going design, which were homologated to 350 bar, but the team has since developed a new system that's not only lighter but capable of operating at up to 700 bar.

Originally the plan had been to 'hot swap' the tanks for pre-filled replacements, but Weber says it would now be straightforward to refill them: "On the road cars it takes three minutes because they use relatively low pressure, but without those constraints you could easily fill the H2's tanks in under a minute. Liquid hydrogen could also be an option for the future."

To some, the idea of having a car containing pressurised hydrogen travelling ▶

BELOW Version 2 of the car is much improved over its predecessor. Work on the compressor used to feed air into the fuel cell has eliminated much of the original lag in throttle response



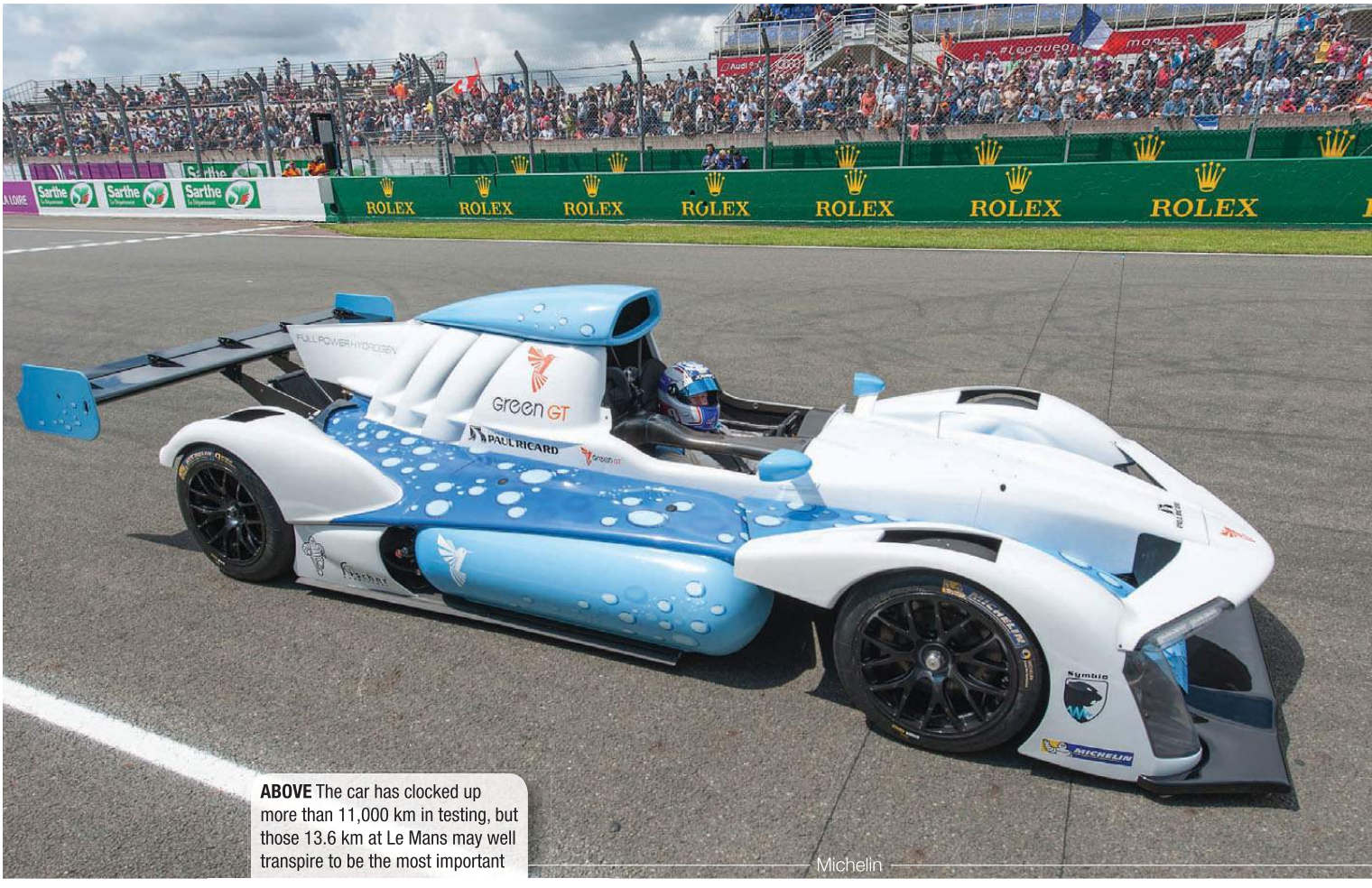
round a circuit at high speed may sound like the recipe for a mini Hindenberg. Not so, argues Weber: "It's less dangerous than a gasoline car. We have two 4 kg hydrogen tanks, as opposed to 65 kg of liquid fuel in a GTE. The tanks are 100 times stronger than the body of the car itself and if they do somehow spring a leak they will empty after one and a half minutes."

The high pressure storage is confined to the tanks. A valve on each tank steps the pressure down to 10 bar, while a third valve reduces the pressure going into the fuel cell to just 2.5 bar. Of course, there's also the electrical side of the powertrain to consider. When it's producing power, the fuel cell output ranges from 300 to 750 volts, but that's only half the story.

"It's not like a battery car," points out Weber. "When a battery car stops [or crashes] it still holds charge, but if you cut the supply of hydrogen or oxygen to a fuel cell you have no more power. It stops straight away. It's more like a combustion engine in that regard."

GreenGT has also carried out a lot of work on the fuel cell in collaboration with French technical partner Symbio FCell. Actually, strictly speaking, it's fuel *cells*. The system is comprised of hundreds of cells, grouped into stacks. A series of plates are used to separate the individual cells, while still allowing electricity to flow between them. These so-called bipolar plates also perform a host of other functions, including distributing the flow of hydrogen and oxygen over the surface area of the membrane.

"At the beginning of the project we used a standard membrane and bipolar plates that came from the mainstream automotive market. We started off with 18 stacks of 20 kW, but now we've designed our own specification cell with a much bigger area for the exchange between the hydrogen ▶



ABOVE The car has clocked up more than 11,000 km in testing, but those 13.6 km at Le Mans may well transpire to be the most important

Michelin

and the oxygen, which means we've massively reduced the number of stacks [down to either two or four depending on the application]," explains Weber. "Each stack requires its own manifold, which is relatively heavy and contributes nothing to the reaction, so if you can use fewer stacks for the same power that substantially reduces the overall weight."

At 166 kg the new fuel cell is slightly less than half the weight of the original design. Combined, the motors are said to be around 112 kg while the gearbox is just under 35 kg. A new in-house inverter design has halved the weight of the power electronics, while also covering a wider voltage range without the need for a DC-DC converter. Overall, the rear half of the powertrain (minus the fuel cell) now tips the scales at 200 kg, while the complete car comes in at approximately 1,370 kg.

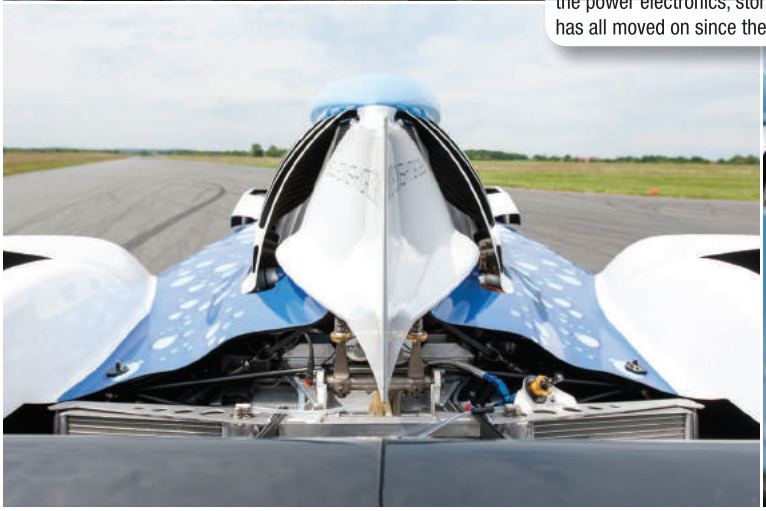
One thing you won't find inside the H2 is a battery. Most fuel cells are essentially fixed output devices, which means they normally require a battery or a bank of super capacitors to help them cope with varying pedal demands. Although the battery doesn't have to be especially large, it still inevitably adds weight. GreenGT, on the other hand, has taken a more fundamental approach: it optimises the design of its fuel cell to respond directly to changes in power demand without the need for additional storage.

When we first spoke to Weber and his colleagues back in 2013, the system was still in its infancy, which meant there was a slight delay in throttle response (akin to mild turbo lag, he told us at the time). Now, however, the response is said to be virtually instantaneous.

"We've worked a lot on the compressor that's used to feed the air into the fuel cell," he says. "The fuel cell is a bit like a combustion engine in the sense that you need to keep supplying it with fuel and air, and the power output is basically proportional to this flow rate. In order to regulate the power we use a compressor that runs from 300 rpm to more than 100,000 rpm, coupled to a butterfly valve.

"You can imagine that if the driver suddenly lifts off the accelerator and the butterfly valve snaps shut you're left with a lot of pressure, so we use a wastegate system to eliminate that. We've also had to look very carefully at how we manage the speed of the compressor. At low pedal inputs we run the compressor at a slightly higher speed than we need to, so the pressure is there when it's needed."

Thermal management is another key factor when it comes to successfully integrating a fuel cell, Weber explains. Overall, he says, the H2's cooling demands are not that dissimilar to those of a combustion-engined car, although the way the air is managed is very different. Those hydrogen tanks attached to the sidepods occupy the position that would normally be taken up by the radiators, so instead the large 'snorkel' air intake behind the cockpit provides most of the cooling. The fact that it lends the H2 a passing resemblance to the high airbox cars of the 1970s is merely ▶



ABOVE & BELOW The technology that compromised the power electronics, storage tanks and fuel cells has all moved on since the car was first conceived

a happy coincidence!

Initially, this oversized scoop gave the H2 a slightly cartoonish aspect, but its area has been more or less halved for the second iteration of the car. "When we originally planned the cooling system we built in a very big safety factor, because thermal stability can be critical on fuel cells," says Weber. "Once we started testing the car, though, it became obvious that there was more than enough airflow due to the high speeds."

It also helps that the GreenGT's fuel cell is capable of running at slightly higher temperatures than most existing designs. Typically the stack runs at around 85°C, but it's capable of operating at up to 95°C, and new membranes could stretch this to 100°C or more in the near future.

Nonetheless, a network of temperature sensors embedded within the fuel cell keeps a close eye on everything. The control system will decrease the power output if the cell temperature exceeds 85°C (but that's never actually happened, notes Weber). In fact, the team elected to mask off part of the cooling system in the car's first iteration. They also use a pre-heating system to warm the cell to 40°C prior to each run.

LE MANS AT LAST

The GreenGT H2 has clocked up 55 days of testing and more than 11,000 km on the track. It's now going on to be used as a testbed for the company's forthcoming fuel cell supercar, the H2 Speed. But before that there was an old score to settle.

"It was great to run the car at Le Mans," comments Weber. "It's a very special place and it's also a unique circuit. You have very long straights with a lot of full-power running. It's different to anything we've done on track before."

The car carried out two runs in the hands of ex-F1 driver and GreenGT brand ambassador Olivier Panis – the first between the qualifying sessions on Thursday evening and the second just before the race on Saturday. These mark the first laps of Le Mans ever completed by a hydrogen-powered car.

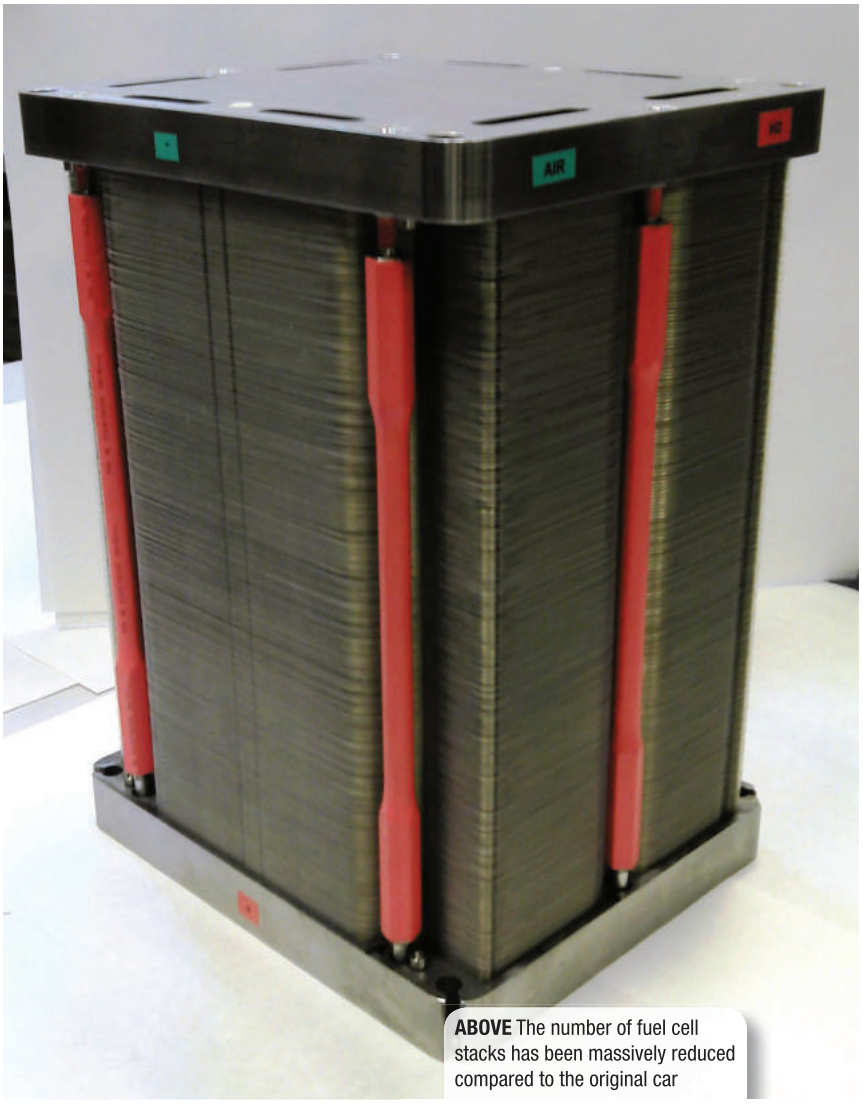
Panis was under strict orders to take it easy, but nonetheless he hit more than 160 mph at times and the on-board video (available on YouTube) hints at the performance on tap. Even on the demonstration drive he had no trouble reeling in one of the Inaltera GTP prototypes that was sharing the track. Weber believes the H2 is capable of lapping at around GTE pace – something that still seems to be a sore point for "a car that looks like a prototype" and he refuses to give a projected lap time.

In a way those laps of Le Mans also mark the end of a chapter. GreenGT plans to market the H2 Speed as a high-end track day car, in a similar vein to the McLaren P1 GTR and the Ferrari FXX. Performance might not be quite as absurd as the existing hybrid hypercars, but the H2 Speed's fuel cell powertrain promises to be the ultimate in tech-credentials for environmentally-conscious early adopters. Unfortunately there are no plans to take the car racing as yet.

"Motorsport isn't our real target with the H2 Speed," says Weber. "We want to demonstrate that it could be a solution for motorsport, but we are a small company right now and we don't have the resources to undertake a race programme on our own. Maybe if a manufacturer wanted to collaborate it would be a possibility, but the H2 Speed is really intended as a track day car."

Whether or not GreenGT will ever return to Le Mans with a hydrogen fuel cell car remains to be seen, but it seems highly likely that someone will do. The H2's laps were a huge achievement for a small company taking on such a mammoth technical challenge and they open the door for others.

With several companies rumoured to be interested in developing a fuel cell-powered racing car – notably BMW – we'd put money on one of them turning up as the Garage 56 entry in 2018. After that, who knows? Maybe one day we really will look back on the GreenGT's demonstration runs as the start of something big. RT



ABOVE The number of fuel cell stacks has been massively reduced compared to the original car

The need for *Speed*

IF the aim of the H2 programme was to showcase GreenGT's technology to potential partners, then it appears to have succeeded. Legendary Italian design house Pininfarina recently turned to the Swiss company in search of a fuel cell platform for its latest concept car.

Unveiled at the Geneva Motor Show earlier this year, the GreenGT H2 Speed is pitched as a high end track day toy. It uses a carbon fibre monocoque based on that of the H2, with a two-stack 210 kW fuel cell and a pair of electric motors producing a combined 370 kW (496 hp).

Like the earlier car, it uses a single speed transmission without a clutch, employing a torque vectoring system to distribute power between the rear wheels. Where it differs, however, is the use of a 20 Ah battery to provide a regenerative braking capability.

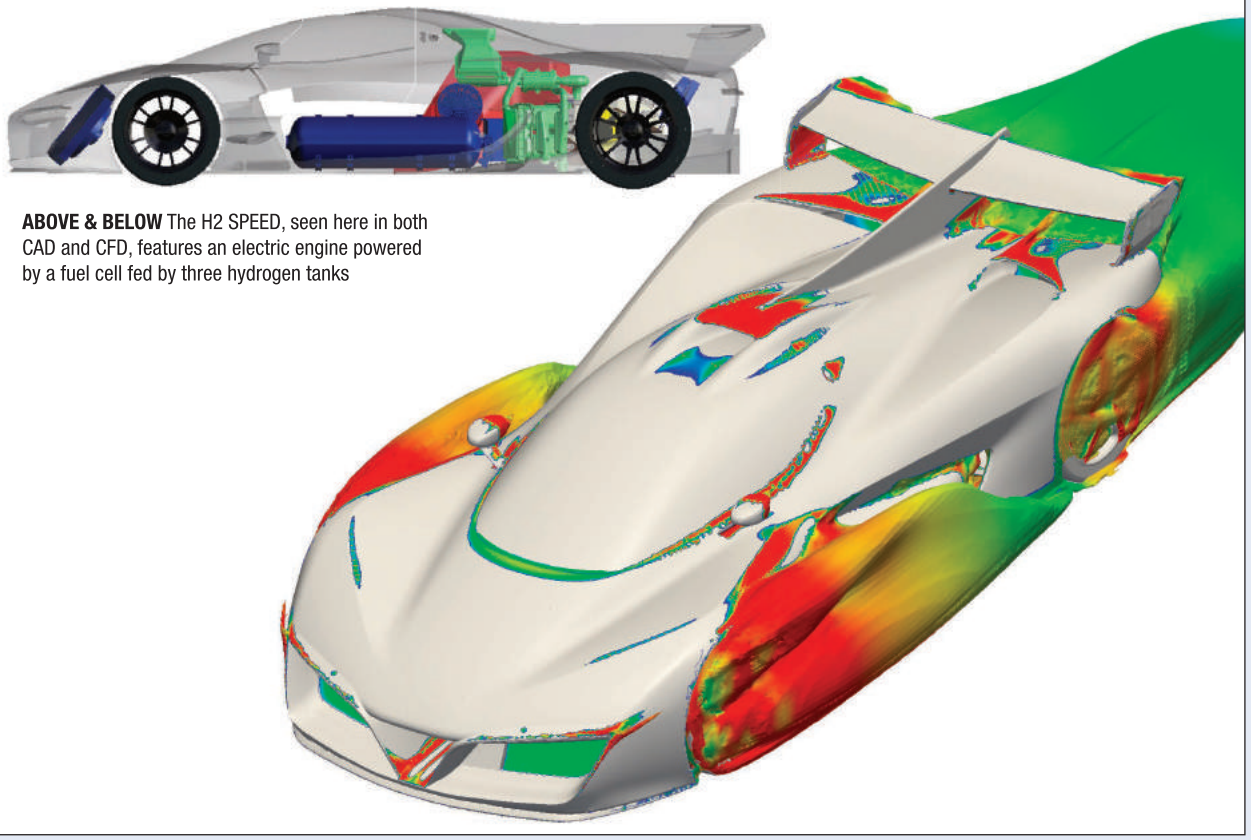
ABOVE The Pininfarina-styled H2 SPEED caught the eye at Geneva

The Speed is slightly heavier than the H2 at 1,420 kg, but still comfortably lighter than the Porsche 918 Spyder if those stats are to be believed. Performance is consequently brisk, with a 0 to 62 mph time of 3.4 seconds, a top speed of over 186 mph (300 kph) and a quarter-mile time (or 400 metres, to be precise) of 11 seconds.

The biggest question mark is the price. Weber says the company knows how much the powertrain will cost, but it won't be releasing a figure for the total price until all the details have been confirmed about the chassis. It's likely to be six figures at least, although the cost of producing fuel cell vehicles is coming down.

"We expect the price of fuel cells to decrease dramatically in the next five to 10 years," says Weber. "They use widely available materials like iron and polymers, so you're not dependant on things like lithium which could become expensive in the future. If they were put into production we expect they would come down to €50 to €100 per kW."

Motorsport may not be the aim for the H2 Speed, but don't rule out the possibility of it happening if the project is a success. The world's first one-make hydrogen race series? It's not out the question. RT



ABOVE & BELOW The H2 SPEED, seen here in both CAD and CFD, features an electric engine powered by a fuel cell fed by three hydrogen tanks

THE FINAL COUNTDOWN?

The end of the line for the internal combustion engine? You're having a laugh. **William Kimberley** talks to Mahle Motorsport's Fred Türk about how lessons being learnt in racing are being applied to road cars

"WE need to somehow prepare for the future, but on the other hand in my view will still have a couple of decades to go with the internal combustion engine." This is the view of Fred Türk, the highly regarded vice president of Mahle Motorsport and Mahle Powertrain. "Maybe we are too European-minded and too extreme in our views, especially in Germany with the Volkswagen problems, but for the rest of the world it's different."

As a senior engineer in a company that makes a living out of producing engine components and systems, not just for motorsport but also for production cars, you could suggest that he would say that anyway, but Türk is an intelligent man and it is always worthwhile listening to what he says.

"One thing is the technology itself, the other is the infrastructure," he says. "We have alternative energy generation by wind and water in the north of Germany which is currently consumed in the south, but we're having huge problems moving it from north to south – and it's difficult to store. I think that things are going to change, but not that fast."

While he believes that alternative solutions will become more viable over time, he thinks that the internal combustion engine will remain the paramount methodology when it comes to transport systems – and that motorsport has a large part to play in maintaining its supremacy.

He then goes on to say with the development of components and systems changing quite dramatically, not only in Formula 1 but also in other areas of motorsport such as the World Endurance Championship, it's the eternal quest for more data that is the greatest challenge.

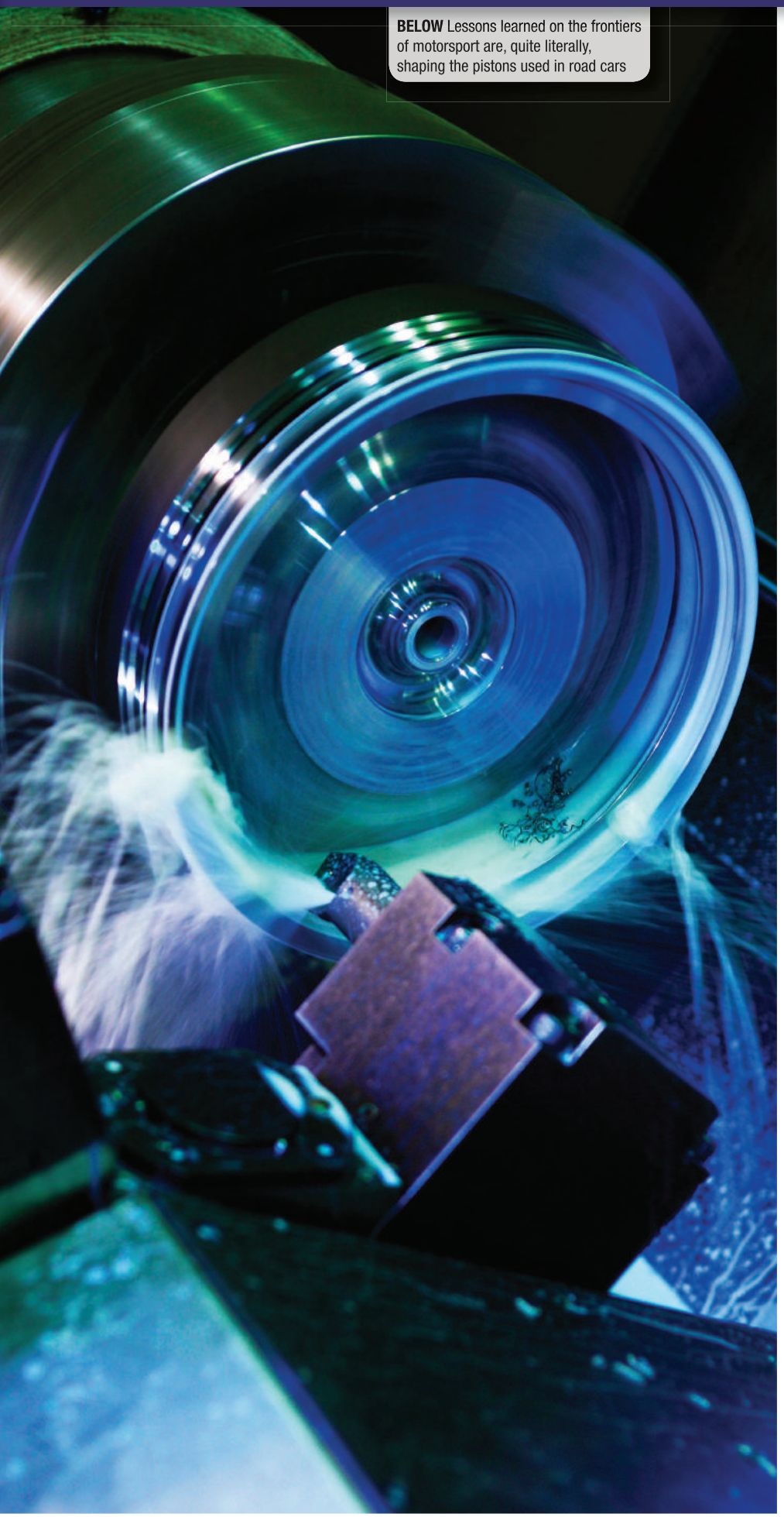
"With the power output we are generating out of the internal combustion engine, it's really a challenge so we need to be able to better predict the load cases, the terminal stresses and therefore simulation dynamics as well as the mechanical components which are increasingly more important. It means that we have to work extremely closely with our partners, sharing very sensitive data in order to be able to establish appropriate FEM models and do dynamic calculations. In the past with the naturally aspirated engines a lot was done in combination with higher revs and friction."

HEAVY KNOCKING

Türk then delves into the specifics of a Formula 1 engine: "The bore size is significantly bigger, now we are at 80 mm in Formula 1 and we have the fuel flow limitation and a maximum tank capacity. We need to run extremely lean in qualifying and we have heavy knocking conditions which is something a piston doesn't appreciate at all! You have to define measures to make the components reliable as well in the extreme conditions for a limited time period. In the end an engine has to last five or six races.

ABOVE Steel pistons were initially developed for endurance racing for the 2008 season. Eight years later, the company sells millions for passenger cars

Friedman/LAT



BELOW Lessons learned on the frontiers of motorsport are, quite literally, shaping the pistons used in road cars

In each race we have three sessions of qualifying and you need to be able to get the same performance out of the engine in the fifth or sixth qualifying session as well as the race. That's a real challenge, but on the technical side it's extremely interesting."

On the plus side, Mahle is learning a considerable amount from this. Türk says it is adding to the company's knowledge bank, which will be useful and relevant for production road cars in the future: "I'm a fan of high-revving engines obviously and a lot of cylinders, but if we look at what is really needed to push the efficiency of our road car engines, what is current now is the right thing to do. I'm convinced that we are developing things that we may see in the near future in road cars."

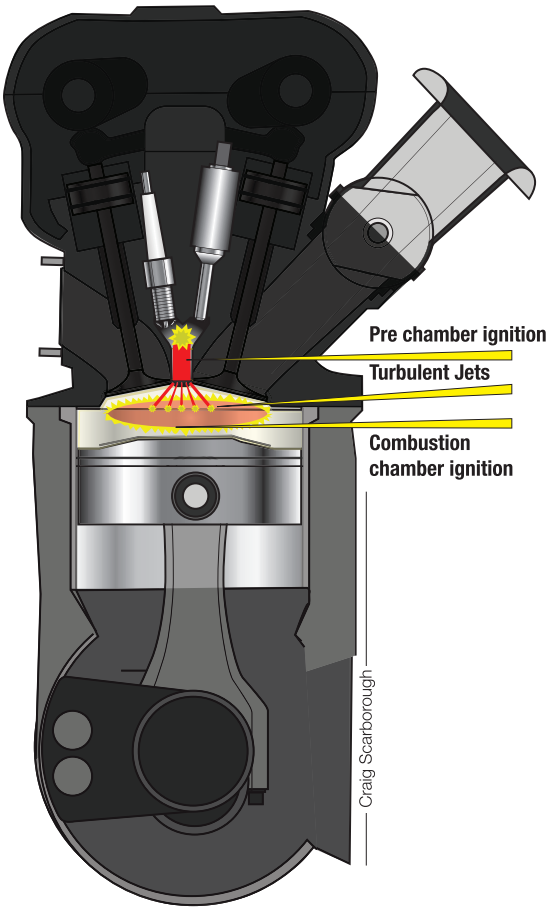
> *"At the heart of a quiet combustion chamber revolution"*

He gives as an example the first use of steel pistons at Le Mans with Peugeot in 2008 and then with Audi in 2009. "Initially the take-up is low volume as it's for the niche market of high-performance road cars, but then there's the opportunity as with the steel pistons, for example, to take it to the mass market," he says. "At the end of 2014 and the start of 2015, Mahle launched its first mass production manufacturing line for steel pistons. Basically six or seven years later we do millions of steel pistons for passenger cars – not for trucks, for passenger cars!

"This is one example of having something developed specifically for motorsport and then seeing it a few years later in mass production offering good benefits with regard to fuel efficiency while being extremely durable."

As we reported in the July issue of Race Tech (188), Mahle has been at the heart of a quiet combustion chamber revolution in Formula 1 with its Turbulent Jet Ignition technology that provides faster burning and combustion. "It's more efficient so you raise peak pressure and at the end it's a performance gain," he says.

"The interesting thing is that we gained performance yet we're running leaner. It's contradictory but it works and is pretty important at circuits where you struggle with the fuel limit. If you can start with five or 10 kilos less it also obviously contributes to lap time reduction. Conversely, it gave ▶



us some headaches on piston reliability. We needed to define a different piston crown shape that had to be coated for protection due to the increased stress.

"It's something we are currently developing further on our downsized 1.2-litre three-cylinder engine. We have just built a high-performance engine with 160 kW per litre which is basically what the niche market manufacturers are heading for at 140-150 kW per litre with the top engines looking at 160-170 kW per litre and we need to know what this means for our components.

JET IGNITION TECHNOLOGY

"The next step for this engine will be to put the Mahle Jet Ignition technology in so we have to redesign the cylinder head, ports and combustion chamber itself. Here we are looking for an increase in power output, beyond 170 kW per litre, and extreme lean burn so we expect to run lambda values of 2 to 2.4. It's definitely a technology I expect to see on road cars in high volume, and it's also interesting as well for liquid gas. Additionally it will hopefully be a milestone as it will make gasoline engines as efficient as diesels or maybe even better. In the context of the (Volkswagen) exhaust scandal, it offers a very interesting solution.

"We expect to be ready with this engine sometime in summer. Then we are going to publish some results out of that. This is really a push forward and very interesting."

There will be some design changes from the Formula 1 application to when it becomes productionised, says Türk. "In motorsport and Formula 1, there's the limitation of being allowed to run only one injector so we have to feed the pre chamber by the compression stroke with a clever design of the nozzles and the proper volume. For road car engines we'd design a different pre chamber, so we have a combination of a spark plug and a mini injector inside the pre chamber, therefore in transient conditions we are able to provide a very low fuel amount that's needed, around 3% of the whole chamber.

"This is more difficult in Formula 1 as there isn't an injector in the pre chamber. Therefore we can run significantly leaner with the second injector than with the single injector. In Formula 1 obviously lambda two is not possible, but it is for road cars." RT

ABOVE & BELOW Turbulent Jet Ignition technology, introduced with Ferrari in F1, has proved invaluable at tracks where cars are marginal on fuel consumption

Ford's domination of the Norwegian round of the World RX series, staged at Hell, raised alarm bells. The Swedish event that followed confirmed rivals' fears: the new Focus RS RX is a genuine contender for the title. **Hal Ridge** explains why

LEFT & RIGHT Big deal: the Focus RS RX has blown away claims that the car was too big to succeed

A MESSAGE FROM HELL

USED together, the letters R and S are synonymous with motorsport history and the Ford marque to which they are attached.

Think Rothmans Ford Escort MkII (RS1800) winning the 1981 World Rally crown in the hands of Ari Vatanen. Think too of the legendary Group B RS200. Or the Focus RS that rally legend Colin McRae so nearly secured a second world title in on more than one occasion and the 2006 version of the Focus RS that won the WRC Manufacturers' title.

For this year, in a works-backed effort, the RS name is back and winning again at the top of World Championship motorsport.

In early 2016, Ford released its new Focus RS onto the consumer market and at a similar time revealed the tool with which it will promote the new car in competition. While Ford Performance (the American marque's competition arm) has a long and established history with rallying, for this project it has ventured into the FIA World Rallycross Championship, together with American star Ken Block, his Hoonigan Racing Division team and British firm M-Sport, which has headed up Ford's rallying programmes since 1997.

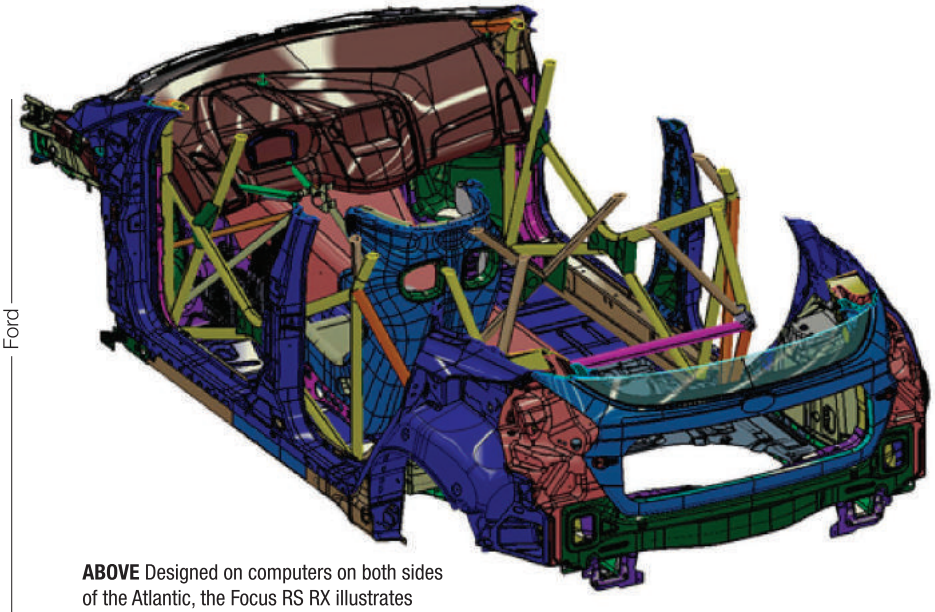
Ford Performance has already tasted success in World RX since its inception in 2014, as supporters of a programme with Swedish team OlsbergsMSE, but truly Ford-involved projects such as this one have been few and far between in RX. Even legends like Martin Schanche and his RS200 had commercial support or importer backing, but were by no means factory efforts.

This car however, is part of a project with serious American muscle behind it. The Focus RS RX was designed from a blank canvas, and is a joint effort between Ford Performance based in Dearborn, Michigan and M-Sport's UK home in Cumbria.

> *"A project with serious American muscle behind it"*

Rallycross has changed in recent years, not only in the promotion, the names involved and the television coverage, but also how the cars competing are devised and constructed. It's possible to count on one hand the number of years since almost every car on the grid was developed by trial, error and tried and tested methods. To a certain extent that is still the case today with any build process, and while there are ▶

FIAWorldRallycross.com


Ford

ABOVE Designed on computers on both sides of the Atlantic, the Focus RS RX illustrates how the World RX game is changing

cars finishing on the podium in World RX that are evolutions of concepts that were winning almost a decade ago, the game is changing. Ford's Focus RS RX proves just that, designed on computers across both sides of the Atlantic Ocean, with personnel like M-Sport's chief designer Christian Loriaux heavily involved.

Similarly, historically it hasn't been the norm for manufacturers to use the dual-surface discipline to actively promote a brand new road car, until now. While cars developed for rallycross have previously been chosen based on requirements on track, Ford Performance has started with what needs to be promoted, and adapted it to suit the desired application.

"A HUGE DEAL"

"To bring the Focus RS back into competition and to tie up with the road car as best possible, we felt that rallycross was the best way to do that. It's been a collaborative effort between Ford Performance with M-Sport on concepts, designs and changes from the very start," says Brian Novak, Ford Performance's rallycross technical supervisor. "We've applied a lot of our processes to this car that we normally use for our road cars, all the pre-work we do before we ever see a prototype. Generally a prototype is exceedingly expensive, so the more work you can do on the computer for the little bits of optimisation, the better.

"The RS brand is something that has been a huge deal for Ford over the years and if we go racing, we want to do it in such a way that the car we are racing applies to the consumer. A lot of effort went in to make the car look as much like the road car as we can. Obviously there's some optimisation to improve it for the rules and performance, but certainly what we have done applies directly to the Focus RS. It's got all-wheel drive, launch control and all those things we have in the road car to show that essentially we're taking a little from the road car and putting it in this and they apply back and forward to each other."

The Focus RS RX does indeed look like its road-going cousin and is visibly larger than its rivals in the World RX field. Novak recognises that this presented a tough assignment: "It was certainly a challenge at the beginning of the process because you know that you're starting with a bigger, longer car than the rest of the field. Maybe you start out with a little deficit, especially with a series like this where the cars yaw so quickly and rotate so fast, but I think the significant amount of work we did on the COG (centre of gravity) and suspension geometry means that the car rotates just as well as the rest of the cars in the field. We're clearly as competitive as the other cars – I don't think we're hindered at all."

The RS RX is currently the only five-door car in the World RX field and boasts a number of unique bodywork features, highlighted by the louvers in the rear quarter panels, behind the rear wheels. Although the finished car has never been in a wind tunnel, aerodynamics have been thoroughly considered in CFD (computational fluid dynamics).

"The rear quarters have been designed with ▶

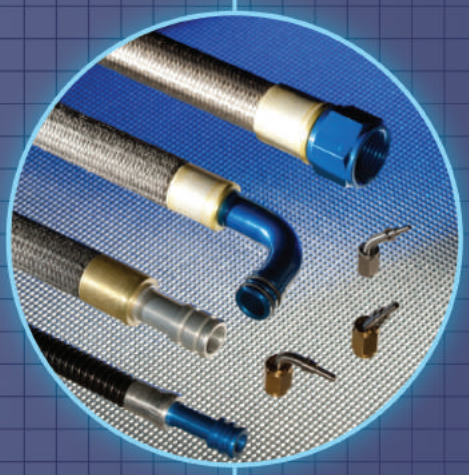
Ford

ABOVE The RS RX on the Kinematics & Compliance rig

Hal Ridge

ABOVE The rear spoiler draws on M-Sport's WRC experience

INTELLIGENCE CONNECTED



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the aero very much in mind. We've worked a lot with that, to make everything as efficient as we can. Everything has been done with analysis, with the help of Ford in the US, to make it as good as possible. Ultimately the base car is the base car, we have a choice over things like the spoiler and the small areas like that where we have looked to optimise as much as possible," says Tim Jackson, chief engineer for rallycross at M-Sport, and overall team engineer at HRD.

Although regulations are strictly controlled in World Rallycross, the homologation process is more open than for the World Rally machines that M-Sport has most experience in building. Jackson says that openness doesn't fully stretch to the bodywork and silhouette of the car. "The regs are quite tight on what you're allowed to do, so you can't go out there and do a Pikes Peak-type special. Certainly from a bodywork perspective it's just a case of making everything as good as possible," he says. "Generally the rules are slightly more open (than for a WRC car), but I think probably more strict than people believe.

"People think you can do whatever you want – historically that was more the case. The FIA are trying to make things tighter, but yes there is still more freedom compared to projects such as the WRC and R5, which is refreshing."

Aside from the larger wheel arches and aggressive styling, the RS RX's rear spoiler sets it apart from its road-going cousin. Developed using know-how gained from the WRC and rallycross Fiestas previously built by M-Sport, the Focus' spoiler is unique to the rallycross programme. The RS RX was completed just a couple of weeks before the opening round of the World RX in Portugal, in April. The first images to be released of the car, in plain white livery at Kirkbride airfield in Cumbria, gave a first indication of the unique driver's seating position in the Focus, the driver sitting adjacent to the B-pillar of the car, underlined by the wing mirror position, which is halfway down the driver's door.

UNIQUE SEATING POSITION

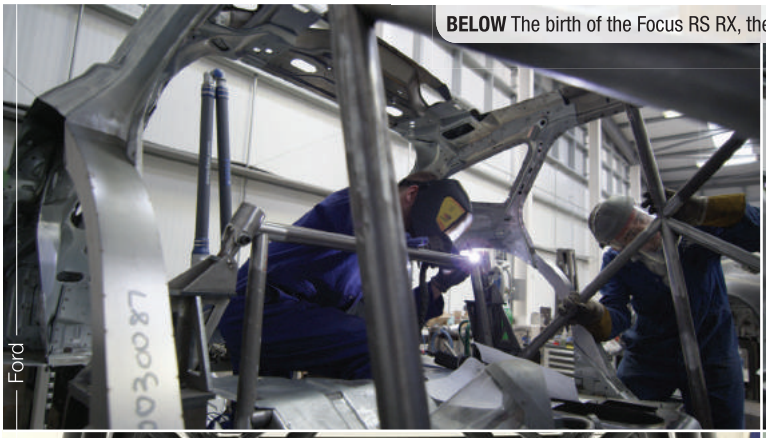
"Obviously we position the driver in the best place for the centre of gravity of the car and I think this also looks a little more extreme than it is because the car is five-door," explains Jackson. "The B-pillar position is quite far forward compared to a three-door; maybe that gives the impression that the driver sits further back. Effectively the driver is the second heaviest part of the car – aside from the engine – so we put them where it is best for performance."

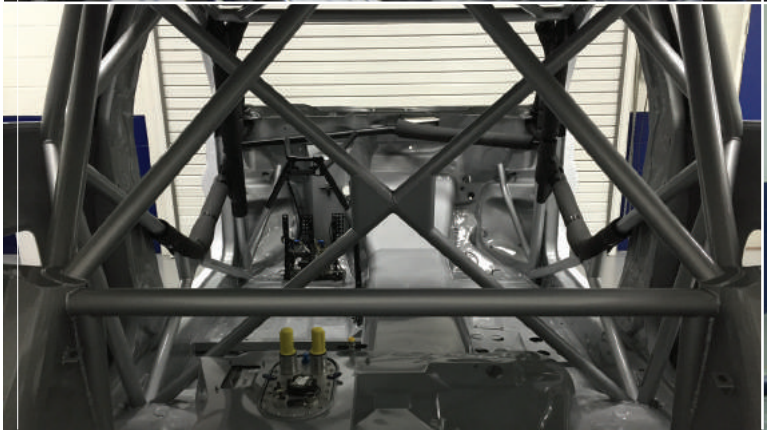
Behind the driver's seat in the cockpit of the Focus is the fuel cell mounted below the floor, and a pair of beautifully formed ducts, flowing air from inlets in the rear quarter panels to the rear-mounted radiator. Unlike most rallycross Supercars, the Focus doesn't have a roof-to-floor rear bulkhead, the carbon arrangement of ducts and covers doing a good enough job of sealing the required components from the cockpit that an additional bulkhead isn't needed. Further carbon ducts are used to take the warm air from the radiator out through an aperture in the carbon boot panel.

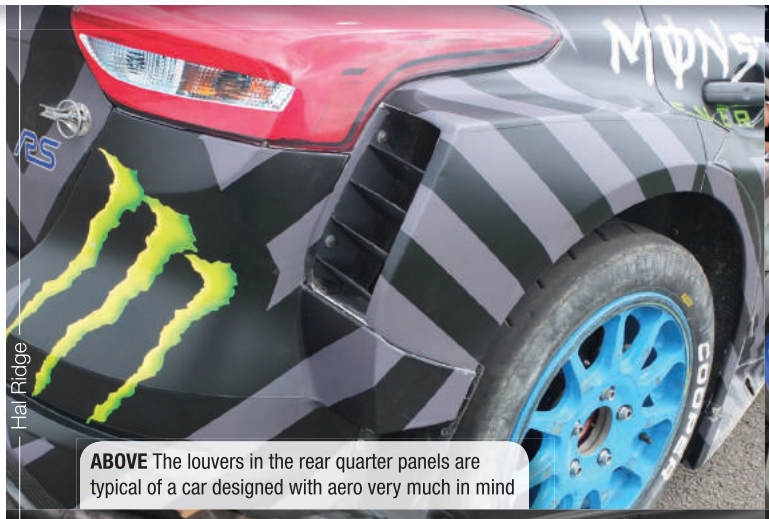
"Primarily the radiator is in the rear from a damage point of view," notes Jackson. "We don't want any damage to it if the car has a frontal impact. Equally, when gravel gets thrown up from the car in front it could potentially block the radiator. We want to make sure from an engine performance point of view that it's safely tucked out of the way. Plus it gives us a big area at the front (where the radiator would traditionally be located) that we can use for the intercooler to make that as big as possible. The more air at the front, the better."

The radiator is angled steeply, facing ▶

BELOW The birth of the Focus RS RX, the only five-door car in the World RX field

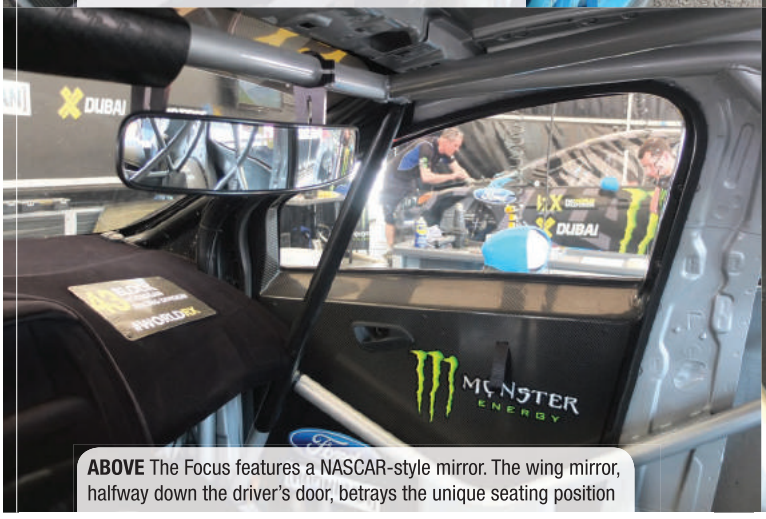




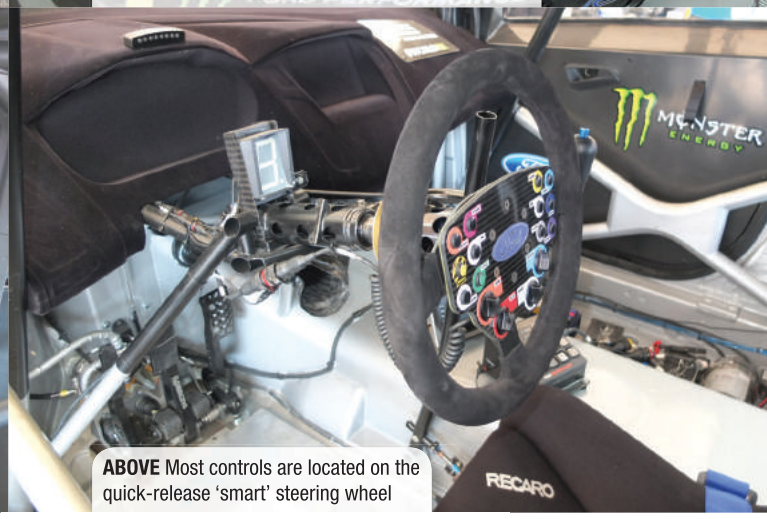

Hal Ridge

ABOVE The louvers in the rear quarter panels are typical of a car designed with aero very much in mind

ABOVE The M-Sport engine is laid back in the chassis, hidden from view by an array of carbon ducts



ABOVE The Focus features a NASCAR-style mirror. The wing mirror, halfway down the driver's door, betrays the unique seating position



ABOVE Most controls are located on the quick-release 'smart' steering wheel

down towards the boot floor. Jackson says that attention to detail is indicative of the car's philosophy: "Generally, we've tried to make everything as efficient and lightweight as possible, and focused a lot on the centre of gravity for ultimate performance from minimum output. That's an ethos that has been carried all the way through the project, and that was the best way of packaging the radiator." British firm PWR are used for both the radiator and intercooler on the Focus.

Like many teams in the World Rallycross paddock, the Focus uses Reiger dampers, attached to bespoke steel uprights, designed and made in-house. But, while the car's predecessor, a derivative of M-Sport's Fiesta WRC – used by Block in the Global Rallycross Championship and a handful of World RX events – sported McPherson suspension all round, the Focus is double-wishbone. The best solution for suspension design is one of the areas up for debate within different teams in World RX, between double-wishbone, McPherson or a combination of the two (as highlighted on Münnich Motorsport's SEAT Ibiza in RT187). The Focus RS RX is unique in being double-wishbone and having a transversally-mounted engine.

"Because we're not limited like in the WRC (where you have to run McPherson-type suspension), in the rallycross you have a little bit more freedom. We looked at various options and determined that this was the best package to suit the requirements of our car and the demands of the sport," explains Jackson. "We have a good relationship with Reiger and they have experience in both rally and rallycross, so that makes sense for us to use them and we're happy to have their expertise." The three-way adjustable dampers are fitted with Eibach springs, with a custom-designed anti-roll bar front and rear.

Four-pot Brembo brakes are used front and rear. The team see ▶

Focus RS RX Spec

Bodyshell	M-Sport
Bodywork	Carbon fibre and steel
Engine	2000 ccm, 4-cylinder, 16v, twin cam
Radiator	PWR
Intercooler	PWR
Management	Cosworth
Dash	Cosworth
Steering wheel	Designed by M-Sport, built by Cosworth
Seat	Recaro
Harnesses	Sparco
Pedal box	AP Racing
Gear indicator	M-Sport
Fuel cell	ATL
Transmission	Sadev
Clutch	AP Racing
Brakes	Brembo
Pedal box	AP Racing
Dampers	Reiger
Springs	Eibach
Wheels	OZ Racing 17"
Wiring harness	M-Sport
Tyres	Cooper Tyres*
Fuel	P1 Racing*

*Fuel and tyres are control items in FIA World Rallycross Championship.


Hal Ridge

BELOW M-Sport has opted for double wishbone suspension and Reiger's '4618' coil-over dampers with Rebound Control Valve and adjustable hydraulic bump stop

the braking package as one of the tuneable areas on the car from circuit to circuit. "The package that Brembo has suits the rallycross application really well, so we've kept using them with this car. Disc size is one of the tuneable things; we're always looking to make things as competitive as possible on each different track. Springs, brakes and things like that are tuning options, so why not use them to the best of their potential. Using experience M-Sport has from other formulae, we know what works to a wide degree but to be honest we're not afraid to try things that perhaps appear a little outside the box too. We work with what we think will be best; we're not about following the trend of everyone else."

Brakes are a constant juggling act in rallycross. Where startline performance is key, a balance has to be struck between unsprung rotational mass and braking efficiency on the 1300 kg machines, which will be another consideration for the team when selecting its 'stoppers' for each circuit.

French firm Sadev is regarded as one of the preferred options for rallycross transmissions, especially in vehicles with transverse-mounted engines. It provides the four-wheel drive transmission in the Focus from the outer CVs through driveshafts and differentials to the input shaft on the custom-designed six-speed sequential gearbox, before a triple plate carbon AP clutch engages and disengages drive from the engine's flywheel. "The transmission is similar to what we had in the Fiesta; it's a known product, but it is unique to this application too," says Jackson. "We know it can take the loading that rallycross demands, which a lot of other transmissions can't do."

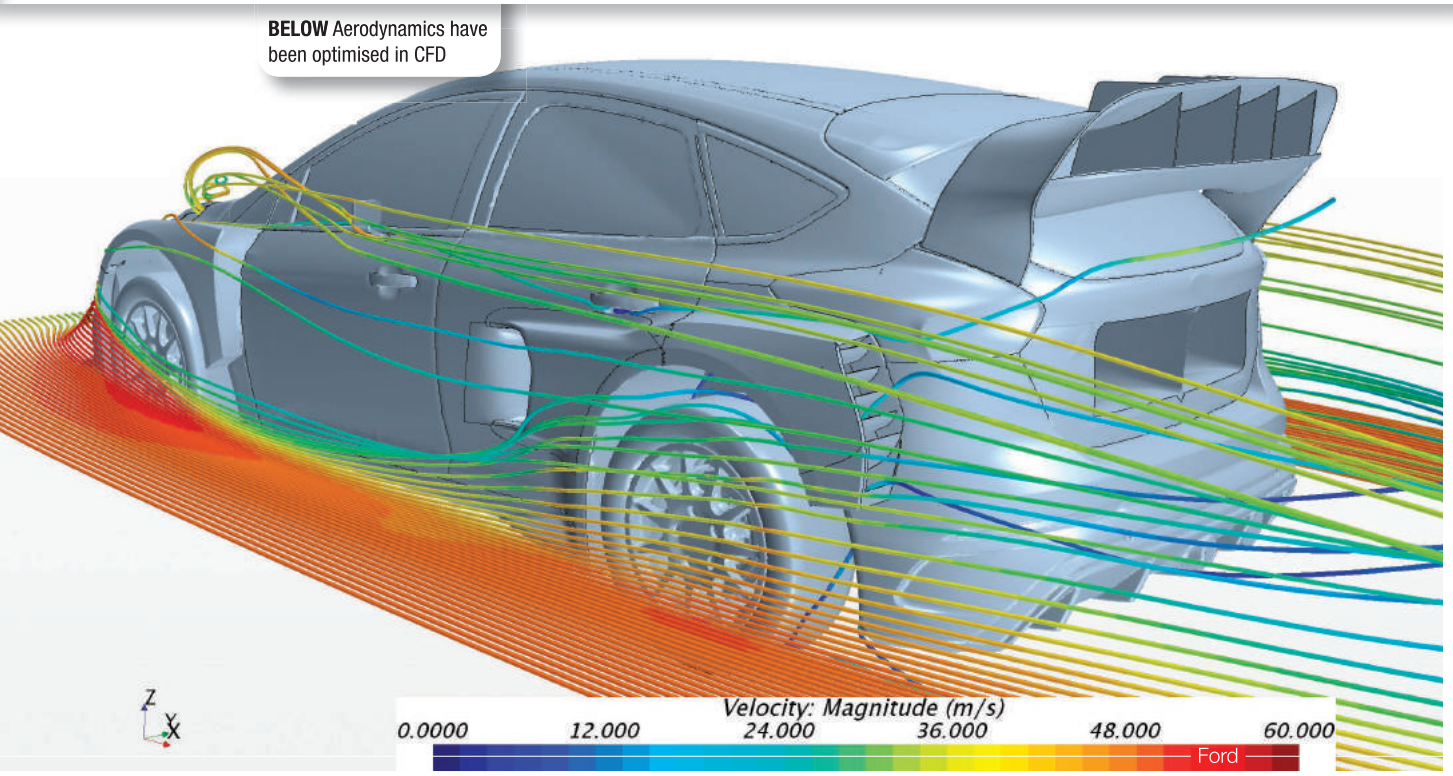
Engine orientation in World RX is another debate, between transverse and longitudinal, but the RS RX's unit is 'as standard' and transverse, mimicking the road car. A big investment for M-Sport in recent years has been to produce engines in-house. The engine in the Fiesta previously used by Block was from French supplier Pipo, but fitted to the Focus is M-Sport's first in-house two-litre, 16-valve, turbocharged rallycross engine. While many new cars are using the 'custom engine' regulations in rallycross that allow for a bespoke block and head to be constructed within strict dimensions and weights, the Focus uses a standard road car block, part of the aim of keeping this project as inline with the road car version as possible. "We do all our own WRC and GT engines, so from that we've had experience to work ideas into this concept. We've built something we hope will be reliable but then also gives the performance. We think we have a strong package there," says Jackson.

NOT 'FIT AND FORGET'

A Garrett turbocharger is attached to the engine, with the regulation 45 mm restrictor. Jackson says that using some known, consistent quantities was important to the speed at which the project could come together: "We worked with Garrett on the Fiesta rallycross project so it's good to use their expertise going forward. But, we have our own dyno and developments we can do throughout the year too. Going to suppliers we know, especially when we've done the project on a very short timescale, is good. That's not to say it's fit and forget, but you know they will be good from the start.

"We're happy with where we are, we're always looking to make improvements of course, but where we're at now, we're in a really good place. We're limited to three engines per year, so some developments are fixed, but there is also scope to develop within those engines, because you're not restricted by homologation like you are in the WRC."

Jackson won't be drawn on the exact figures of the engine, but rallycross units generally operate in the 550–600 bhp/650



BELOW Aerodynamics have been optimised in CFD

lbs torque region.

The engine is laid back in the engine bay to the maximum of the regulations, at 35 degrees. You can't actually see the engine through the open bonnet due to the array of carbon ducts that cover it. "Again, we've tried to make the package as efficient as possible. For sure everyone knows the bigger the intercooler and the more air you can get through it then the more performance from the engine you can get, so we're basically looking to maximise, but also get heat away too," he says.

Utilising an in-house built M-Sport wiring loom, the car features an engine management system and dash from Cosworth – another of the rally team's longstanding partners. The dashboard itself is mounted on the transmission tunnel. As part of the FIA's aim of controlling the use of any prohibited traction control systems, all ECUs and the software used have to be homologated (see RT186) and the gear display indicator cannot be part of the dash. Therefore, all Block and his young team-mate have in front of them in the RS RX is the gear display indicator.

The interior of the Focus is remarkably uncluttered and most controls for the driver are mounted on the quick-release 'smart' steering wheel. "That's to make it user-friendly really," says Jackson. "The races are short, sharp and pretty hectic, so really the less thinking the driver has to do and the more intuitive we can make things then it has to be better. It's all within easy reach so things like wipers and starter can all be controlled off the steering wheel. If there's an incident on track or they stop, then they're not looking for a button below them to start the car; we've tried to keep the ethos of keeping it simple."

Above the driver in the centre of the car is a large convex NASCAR-style mirror to offer the best chance of seeing which World Champion currently competing in rallycross is hot on their tail. At their feet, meanwhile, an AP Racing floor-mounted pedal box is fitted. The handbrake lever and gearstick have been fitted to the right of the steering wheel in each car to suit both Block and Andreas Bakkerud's individual preference. The drivers are protected by the FIA-certified roll cage and steel driver's door – the only non-composite panel on the car (aside from the roof).

ATTENTION TO DETAIL

The doors also have beautifully-formed carbon door cards, another nod to its road-going brother and again underlining the attention to detail with the project. As per the regulations, the side windows are polycarbonate and to save weight the windscreen is too. The screen is cleaned by a centrally-mounted single wiper arm that has two washer pipes to fire water onto it. "If you can't see, it doesn't matter how much power you've got," laughs Jackson.

While the RS RX is a fresh new design, it is clearly built on knowledge gleaned from M-Sport's previous experience of both the WRC Fiesta and rallycross variants. Novak says that experience has been key to getting the Focus up to speed in such a short period. "Obviously the Focus RS is a slightly different beast, but the Fiesta certainly gave us a very good base to start with," he says. "It was a good car and we knew the areas that we needed to improve upon and the speed the Focus came out of the gate with shows that everybody did their homework well."

The Focus hasn't been faultless in its maiden half-season, a number of niggling problems having arisen as with any new car that had completed less than 20 laps of testing en route to its first event. Nevertheless, issues have been resolved quickly and efficiently. Block scored the RS RX's first podium in only its second event, at Hockenheim, but Bakkerud is the driver to really shine. He won the fifth and sixth rounds in Norway and Sweden on genuine pace and has climbed to third in the drivers' standings.

With only the Canadian round at the start of August punctuating the summer break from July to September, the HRD team has time to evaluate and build on its strong start. "Everybody is getting better and better with every event we do," says Bakkerud. "We're breathing down the neck of (title contenders) Petter Solberg and Mattias Ekstrom. They should be worried."

And he isn't wrong. The established order needs to keep an eye on the Focus RS RX squad in the second half of 2016. Despite racing a car initially branded 'too big' by some, the project went from blank canvas to track in nine months and was a winner just two months later. RT

DAWN OF A NEW *ICE* AGE?

Exclusions, heroics and F1-size egos, this year's Formula Student had it all – even, for the first time in five years, an internal combustion engine-powered winner! **Seb Scott** picks out some of the highs and lows

THE 19th Formula Student UK, held at Silverstone again this year, had everything a motorsport technology event could desire. It featured drama, surprises, innovation, a wide variety of high-tech machinery and, on the whole, sportsmanship.

Regardless of a team's pedigree, budget or sponsors, Formula Student UK failed nobody in terms of its camaraderie. Oxford Brookes, for instance, opened up its lab at three o' clock in the morning for the University of Southampton to fix its front wing. The University of Dundee exemplified this quality too, by simply refusing to give up despite initially, and somewhat ludicrously, being instructed by the health and safety executive for the university that the car couldn't run as it is too dangerous!

For the first time since 2011 the internal combustion engine triumphed over the electric motor brigade, with the RennTeam University of Stuttgart taking overall honours. Its powertrain was a developed version of the unit the German team utilised to reach third overall (highest placed IC car) at Formula Student 2015: a four-cylinder, 600 cc, 2003 Yamaha R6 engine.

Would Stuttgart have won had rivals not been excluded from the Endurance event, which counts for a high proportion of the overall points? It matters not: as chief technical scrutineer Dan Jones points out, "It is the responsibility of the teams to ensure that their cars comply with the rules at all times during the event."

EXCLUSION ZONE

In total five teams were disqualified, all from the endurance event, which carries a potential of 350 out of a total of 1000 points that are available throughout the competition.

Of the five, Class 1 design winners ETH Zurich (car 33) transgressed by inadvertently running on the wrong power setting. Formula Student UK event rules stipulate a lower power limit for 4wd cars that is different to the one set at European events, which is what the Swiss outfit ran in the endurance event.

The other four teams – Delft University of Technology (car 1), OTH Amberg-Weiden (car 23), Universität Stuttgart EV (car 26) and TU Munich IC (car 41) – were disqualified for various aerodynamic infringements. Each of them subsequently lodged a protest against its disqualification but to no avail.

"It wasn't the same for all of the teams," explains Jones, who is also vice chairman of the FSAE rules committee. "Two infringed just on front wing width, one on rear wing overhang and one infringed both the mid

IMechE

ABOVE Technology and teamwork are part of the fabric of Formula Student

ABOVE Formula Student Class 1 overall winner, the University of Stuttgart

wing height and front wing width."

The moment the terms 'infringement' and 'aero' are uttered together, whispers begin and before you know it the word 'cheat' is bandied about. In this case finger-pointing doesn't appear to be justified; rather, there was a great lesson to be learned thanks to what seems to have been underestimations of suspension geometry.

The initial question raised within the paddock was, 'well how did the cars pass scrutineering in the first place?'

"Passing technical inspection isn't a guarantee that you will pass parc fermé checks," says Jones. "When we scrutineer the cars the first time through, teams are allowed to make legal setup changes to various things. That could mean that what passed technical inspection doesn't pass a later check because perfectly legal changes have been made on the car but, as a consequence, they have made the aero fall outside of allowable dimensions. Suspension geometry can affect the positioning of the outside edge of the tyre, so ride height changes, tyre pressure changes, different sets of tyres, lots of different things have an influence."

Jones continues, adding that, "You've also got to do your tolerance stack up on all of the manufacturing tolerances. Don't forget these cars are prototypes, they're not mass produced. They are very well put together, but they are student-manufactured.

"A good handle is needed on a team's manufacturing tolerances for it to push right up to its limits without leaving too much margin. It's all about risk-reward: an extra 5 mm on wing width is going to make very little difference on the downforce that it generates but if you go over the limit and get disqualified, you've lost up to 350 points from the endurance test."

TAKE THE SHAME

Formula Student is a fantastic platform to showcase your talent as a student, an engineer, a university, a businessman and, most importantly, as a team player. However, it is not Formula 1. It has forged its reputation as a design event to allow the world to see just how brilliant student engineering is. As such, those involved are unaccustomed to the tomfoolery displayed by TU München, which had an aversion to anyone taking a close look at its car or seeking to snap a photo. ▶

ABOVE The University of Sussex car might be basic but the business plan is anything but

Despite the event primarily focusing on design and engineering, it also shares much common ground with motorsport, which by nature, is a *sport*. This requires those involved to display sportsmanship, regardless of the result; when the event finishes you applaud, shake hands and congratulate not just the winners, but every competitor.

There was a feeling of great disappointment when TU Delft, after having its protest heard by the judges for its disqualification, did not respect the decision. It declined to collect its awards for Design runner-up or for winning the Sprint event. It was a shame that a team known for its incredible success in this event should now be remembered for poor sportsmanship.

DAVID V GOLIATH

The expectation on established teams is now higher than ever. It comes from a history of innovation and success which, together, give a team its pedigree. In essence it allows a team to negotiate with more partners and suppliers, opening doors closer to the boundaries and limits of motorsport technology. It almost begs the question of, what's the point? Yes, the level of innovation and engineering by some teams is interesting; however is this innovation directly overseen by a group of students or simply given to them via a raft of both commercial and technical partners?

Gazing further down the order, to the point where some cars are struggling even to pass scrutineering, is where you can find some true ingenuity and innovation, encapsulating the entire basis of what Formula Student stands for. This incredible pool of rudimentary, yet nevertheless impressive technology boils down to one factor: the vast majority of teams have no choice, for lack of partners or resource, other than to think outside of the box.

Electric vehicles (EVs) are a common sight at FSAE events around the world, especially at Formula Student. One of the few criticisms of the technology is the inherent cost associated with designing and building one. This hasn't stopped less resourced teams from trying, though, spawning unique ways to save on costs and showcasing engineering and design talent.

Ruben Doyle, post graduate supervisor of the Imperial College London team, explains its cunning solution for its in-house designed and built 'E-box' (control electronics).

"Last year it was an absolute rats' nest; it was a nightmare!" he says. "Debugging was impossible, running was difficult and every time we had to do anything you had to take off 10 bolts to get inside. A lot of other teams have talked about this as well: one fuse goes and it takes you half an hour to change."

A common theme with any team running an EV is trouble-shooting and repairing the control electronics. If designed in-house, more often than not the circuitry layout is a compromise between packaging, cooling and weight, making any repairs or maintenance incredibly difficult.

"We moved to designing everything ourselves," adds Doyle, explaining that ▶

Into the dragon's den

ATTENDING Formula Student as a business presentation judge for the first time this year, William Kimberley was impressed with what he saw.

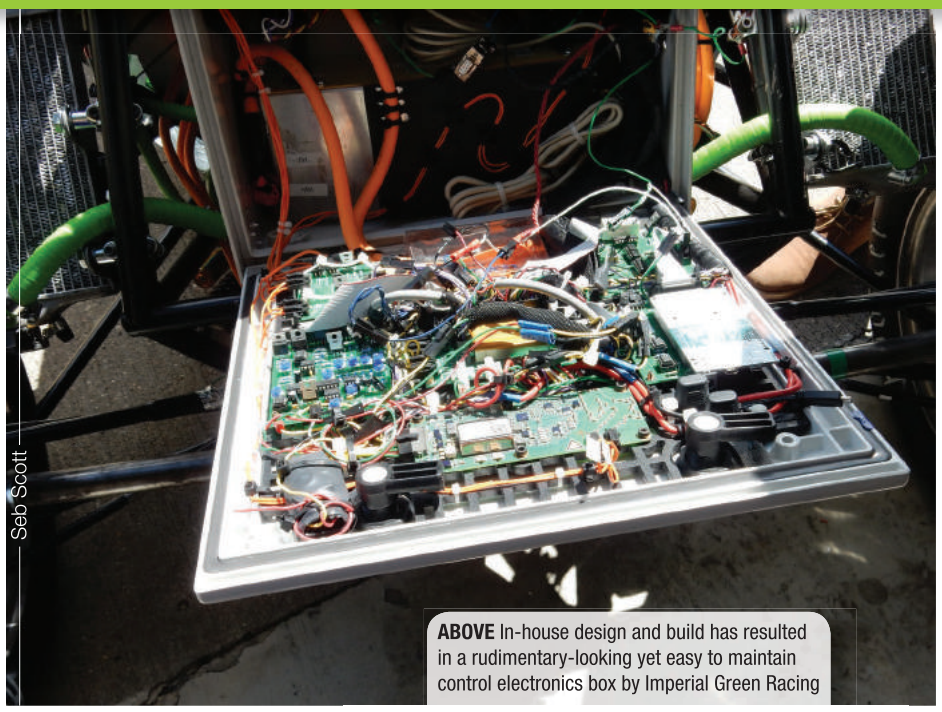
"Getting the car to the event in one piece and through scrutineering is stressful enough, but so in its own way is giving a business presentation to a panel of judges," says Kimberley. "The scenario is that the students are pitching *Dragon's Den*-style to get an investment in their company.

"The car represents the prototype, the premise being that it will be going into limited run production, anything from 20-30 cars to a few hundred, so the teams need to describe the car and its properties, the manufacturing location and processes, the market for it, sustainability, recycling and so on. Although the students do not get sight of it, the scoring system is comprehensive and runs to many pages when it comes to marking the presentations."

The pressure is on then as teams are faced with the daunting task of convincing the experts, compounded by having to be proficient with the time of the presentation, Kimberley explains: "The presentations have to last 10 minutes – if they run too short, they are penalised, and the same goes for overrunning, the pressure is therefore immense in trying to relay all the information in the allotted timespan. This is difficult enough for English language teams but more than doubly difficult where English is a second language. However, they all manfully struggled through the process.

"What stood out were those teams like the University of Sussex – and I happened to be on the judging panel for that one – which won the event outright. The two presenters absolutely knew their business and what they wanted to say. The proposition was first class, as was the delivery and interaction between the two presenters and the judging panel, and all the material they had prepared as a business document answered many questions. They stood in stark contrast to some other teams that showed no sign of thought, an unstructured presentation and a muddled proposition.

"It may not seem to have much in common to designing, building, developing and preparing a car, but the business presentations are a valuable part of the whole Formula Student experience." RT


Seb Scott

ABOVE In-house design and build has resulted in a rudimentary-looking yet easy to maintain control electronics box by Imperial Green Racing

designing everything in-house is exactly that. "All the printed circuit boards (PCBs) are designed in-house and then sent off to be manufactured; the PCBs are linked by SATA effectively, so that there are ribbons through everything. Rather than having to take out 20 cables per board, you only have to take out two."

The development of the E-box has been a cross-discipline affair, resulting in mechanical and electrical engineering students working together. "I'm a mechanical engineer and designed the mechanical side of the E-box," Doyle explains. "The electrical guys who are in their third and fourth year in electrical engineering, they went from first principles and designed it all from the ground up.

"There's six boards in there not including the IMD, all designed in-house. It's pretty cool, we've decentralised everything so that if one thing goes you can just replace it out and you can debug quite easily because everything is modular. One board goes and you can swap it out within 10 minutes and no worries.

"The problem is we've had some core electrical issues which meant we lost some running," he says. "While the system is a lot better, it's not perfect so there's work to do. We run liquid cooling into the box, where it is then managed. The heat is dissipated through the radiators with the motor coolant; this is something that's completely different to every other team I've seen."

Simplicity is the driving force behind the design plans for the E-box, which is why the entire package is detachable from the chassis, allowing work to be carried out separately, yet simultaneously on both chassis and electrical aspects of the car.

"The motor controller sits in the E-box with the rest of the low voltage stuff," adds Doyle. "It's just one package; when you take it out there's no other electrical stuff in the car apart from the loom."

INSPIRATION

An inspiration to all, the University of Moratuwa, Sri Lanka, picked up the award for best newcomer to Class 1 with its driver, Induwara Munasinghe, collecting the award for top individual driver. The team itself had a tall order in simply just getting a car designed and built, not to mention finding the finance and planning the logistics of sending a team of students and car and spares halfway around the world to a country hardly any of them has visited before.

The car's standout feature was its paddleshift system, designed, manufactured and developed in-house with only essentials such as the wiring being bought in. "When we decided to use a paddleshift, we searched for the best way that we could do it," says head of chassis, Nushen Senevirathna.

"There were pneumatic actuators and solenoid actuators. We couldn't find any pneumatic actuators in the market with a small enough compressed gas canister, so we decided to use a solenoid. ▶

ABOVE & BELOW The University of Moratuwa car featured a home-made solenoid shift mechanism, above left, designed and built without the help of CAD, FEA or automated machining. Above right, the actuator connecting solenoid to gear shifter

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ABOVE Willem Toet and Pat Symonds traded the F1 paddock for Formula Student

"We checked the available solenoids on the market but in Sri Lanka we couldn't find many solenoids and none with enough power to move the shift lever."

Due to the lack of resources available in Sri Lanka itself, Senevirathna and the team had no choice really other than to study the entire system of an electronic sequential mechanism to then design, build and manufacture one completely in-house.

"I calculated the torque required to do it by measuring the force needed to operate the shifter with a Newtonmeter with its respective moment," he explains. "I then had to build a much bigger solenoid to generate this force. We mounted it twice, the first time the power was on the limit of the required force.

"One issue was within the coils. The permeability of the coils was less than I expected and the force was not enough to pull the shift lever consistently. Sometimes it would work and sometimes not. I used thicker gauge wire on the coil and now it works fine."

INGENIOUS SOLUTION

Aerodynamics specialist Willem Toet could be spotted throughout the entire event at Formula Student, as a great ambassador for the competition and always a figurehead for honest and insightful advice.

> *"A lot like being in a business, you have to figure out how to work with people you don't necessarily like"*

"Just like with any other formula you need to start with your set of regulations, and optimise to them," is Toet's first piece of advice for Formula Student teams. "The next thing is picking your team with the aid of the university. A really big part of it is what's the university's attitude to Formula Student? Try to see if they can help in some way.

"In Formula Student you see a lot of different sizes of teams," he explains. "A really big team does have to be structured in a different way to a small team.

"A good big team might be TU Delft; a really good successful smaller team might be Zurich who've got fewer people and organise themselves in a different way. Being a Formula Student team is a lot like being in a business: you have to work with people that you don't necessarily like; you have to figure out how to get on and you have to find the money."

Toet made quite an interesting observation during the event when, visiting the University of Iceland team garage, he spotted an incredibly clean and smooth finish on one of the wings. Such a finish, he pointed out, is yet to be achieved even in Formula 1.

The lady in question behind this new manufacturing technique is Solrun Trausdottir, a second year Mechanical Engineering BEng student at the university. "We put thin sheet metal on top of this for the clean finish," she explains. "To be able to do that, we have to have a positive [male] mould for the wing.

"One of the great advantages of our wings, is that we can make it one piece by making the positive mould. All the others, such as TU Delft, Zurich and other great teams, make two moulds for the upper and lower halves of the aerofoil and then join them. This means that they combine at the leading edge, which is really bad for the airflow, but we keep it clean at the end to preserve flow."

Justifiably, the team was proud of its simple and ingenious solution. ▶

Seb Scott

BELOW The Iceland car's one-piece aerofoil

FORMULA 1 2014/2015 Technical Analysis

Giorgio Piola

Size: 24,3x27 - Pages: 128 - Photos: over 400 technical drawings in colour
- Softbound with jacket - Text: English
EAN: 978-88-7911-623-7 - Price: £32.00 + plus post and packaging

RADICAL changes in terms of technology and regulations marked the 2014 season, with the cars being equipped with 1600 cc, six-cylinder turbocharged engines with dual internal combustion and electrical power delivery (the so-called Power Unit) in place of the classic naturally aspirated V8s. Electronically controlled rear braking and a series of aerodynamic restrictions were also introduced, the latter having a major influence on the external appearance of the cars which were very different to their predecessors. These changes and innovations also had significant sporting repercussions with the Mercedes of Rosberg and Hamilton undisputed protagonists of the World Championship, the surprising Daniel Ricciardo doing better than his teammate Vettel and the Maranello team featuring in another grey season with Fernando Alonso already heading towards McLaren. Revealing the technical secrets of the 2014 cars and providing a broad preview of the season to come is as ever Giorgio Piola who, drawing by drawing, illustrates and describes in the most minute detail the entire World Championship field.

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ABOVE The University of Edinburgh celebrates successful maiden Class 1 endeavour winning the *Race Tech* Spirit of Formula Student award

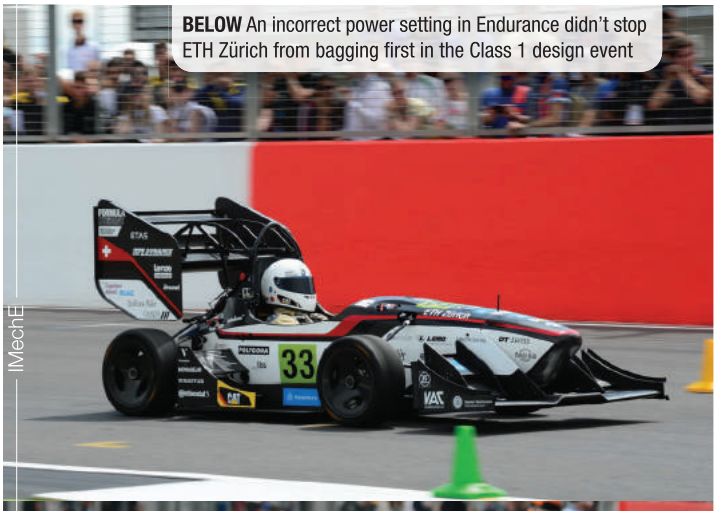
SPIRIT OF FORMULA STUDENT

A special final mention has to go to the University of Edinburgh, inaugural winner of the Race Tech Spirit of Formula Student Award. Coming away from a previous Formula Student, William Kimberley was incredibly impressed by Philadelphia University, Jordan, and its attitude throughout the event. It inspired him to ensure that, from that point on, a team performing such heroics should be recognised for its efforts. This team did not have the best car, or anything technically exciting for that matter. However, it had faced all odds and so the sense of its achievement was perhaps of the same magnitude as those taking overall honours.

"I'm buzzing. It's amazing, it's our first year here," beamed Sam Dryden, team leader of University of Edinburgh. "We're all here to do as best we can and we want everyone to do well, we don't know what things go on here."

This lack of experience led the team to come somewhat over-prepared and despite not requiring its own extra parts or tools, it found that students up and down the paddock came calling. "This is our very first car. We didn't know what we were going to break, so we brought all sorts of stuff to basically build a Formula Student car," explains Dryden. "Word got out around the paddock that we had all sorts of spares. We helped other teams but the favour was returned above and beyond what we gave out.

"When we came to the event, we didn't know what locking wire was! Everybody helped us. It was just absolutely phenomenal, we loved it."



BELOW An incorrect power setting in Endurance didn't stop ETH Zürich from bagging first in the Class 1 design event

ABOVE The University of Bath repeated its success of 2015 by taking fourth overall and top British team honours

Formula Student 2016 Results

Class 1 Winner	Car 3	University of Stuttgart
Class 1 Second	Car 68	Karlsruhe Institute of Technology
Class 1 Third	Car 53	TU Graz
Best Newcomer In Class 1	Car 27	University of Moratuwa
Endurance	Car 3	University of Stuttgart
Class 1 Design	Car 33	ETH Zürich
Class 1 Design Runner Up	Car 1	TU Delft
Overall Dynamics	Car 3	University of Stuttgart
Sprint	Car 1	TU Delft
Skid Pad	Car 33	ETH Zürich
Acceleration	Car 68	Karlsruhe Institute of Technology
Most Efficient Car	Car 32	Universitat politecnica de Catalunya
Most Efficient Combustion Engine Car	Car 53	TU Graz
Top Individual Driver	Car 27	Induwara Munasinghe
Race Tech Spirit of Formula Student	Car 88	University of Edinburgh

RECORD BRAKING

Grunt and courage are the two essential ingredients when going up Pikes Peak at full throttle, but there's a third element that needs to be added to the mix if you want to do the job properly, as **William Kimberley** discovers

PIKES Peak is a very special event, something that the world may pass by but for true-blooded enthusiasts, it is the only competition that counts, perhaps up there with the Isle of Man TT and the Nürburgring 24 Hours in terms of sheer madness. To some it is just pounding up a 4,301-metre (14,110 ft) hill, so where's the fun in that? For others, though, it combines all the challenges that can be hurled at car and driver.

For engineers, it represents a set of hurdles that become progressively higher every one of its 12.42 miles with the changing thermal conditions that include much thinner air, let alone all the stresses put on the vehicle as it twists and turns its way up the tarmac strip with cavernous drops on either side.

While this year Sébastien Loeb's astounding record of 8m 13.878 seconds set in his Peugeot came nowhere near to being beaten, two cars did break the nine-minute barrier. Romain Dumas, fresh from his Le Mans triumph with Porsche, took fastest time in the HPD-powered Norma M20 RD Limited at 8m 51.445s. Rhys Millen, son of Pikes Peak legend Rod Millen who himself had set an overall record in 1994 that stood for 23 years, drove his electric e0 PP100 to second place with a time of 8m 57.118s, faster than any electric car has done.

A development of the 2015 car that enabled Millen to win the event outright last year with a time of 9m 07.222s, the 2016 car was powered by a 50 kWh lithium-ion battery feeding seven YASA-400 electric motors. Total system output is a massive 1,190 kW (1,596 hp), with peak torque pegged at 2,520 Nm (1,859 lb/ft). The whole package sits on four-way adjustable shock absorbers, attached to 18-inch wheels shod in 320/710 slick tyres and is very capably engineered by drivee0's Kristaps Dambis. An important part of the whole mix, though, was the braking system, Alcon having a long history with Pikes Peak having originally provided some of the brake systems on the fabulous Audi Sport Quattros in the late 1980s.

The involvement of Alcon on the car – that has been designed and developed by drivee0 in Latvia with the assistance of the Californian-based Rhys Millen Racing – began in January this year when sales director Jon Edwards and colleague Alex Hargreaves were on a business trip to the country attending an off-road event. "We met with Tom Hartley, Rhys' engineer, and within the week we were given the thumbs-up and invited to join the project," says Edwards.

"The first thing we requested was some technical data on the car so that we could size the brake package. So we received data in terms of vehicle mass and where it's placed within the car as well as the performance levels so that we could start to understand what would be needed. We knew that Rhys had struggled with his existing brake package although he still went very quickly last year, so we had some data which suggested that we needed to improve in some areas."

As Edwards describes it, the issue with Pikes Peak is both the length of the course and the scale of the gradient. It starts at 9,390 feet, climbs 4,720 feet and finishes at 14,110 feet. In between the steep climbs there is also a challenging mid-section from Glen Cove through some fast switchbacks known as the "W"s, which is where the problems showed themselves last year on Millen's car. While it could be looked upon as a breather for car and driver, it is in fact extremely testing as there is not enough cooling air.

THINNING AIR

"Last year, Rhys' car suffered from very high calliper temperatures and high brake fluid temperatures," says Edwards, "and this gave us scope to make improvements with the switch to Alcon brakes for 2016."

What he and his team had to take into account when developing the brake package was that due to the gradient there is up to 60 per cent more of the car's mass over the rear axle compared to when it is being driven on the flat. Another issue was the thinning air as the car ascended the hill. When it comes to an internal combustion car, it can lose up to 40% of its torque as the air thins out but this

ABOVE With zero run-off and huge drops, confidence in the braking package is crucial if a driver is to attack the hill

doesn't apply to an electric car that retains its full 100% torque from start to finish. At the same time the thinner air means that the aero devices on the car become much less effective so the terminal velocity of the car just keeps increasing. All this means that more and more onus is put on the brakes when it comes to an electric car.

a speed of 148 mph and while some cars go quicker on a race track, this is on a public road surface that twists and turns and climbs. That top speed would have been achieved at around 13,000 feet, so no aero drag to help reduce the speed or lack of engine power, it was just the brakes.

"This is why the electric vehicle is just a little bit harder than a conventional one because the performance is still there and doesn't reduce. So what we had to do was to engineer a brake solution that was large enough to cater for the energy inputs that are required, but also provided relatively instant feel from the bottom when cold and a good balance front to rear up the hill on the gradients that vary from seven to 11 per cent. Our solution was the same 6-piston front and rear, which isn't untypical but it's a fairly substantial rear brake setup."

> *"Up there with the TT and Nürburgring 24 Hours in terms of sheer madness"*

"Another issue to add to the mix," says Edwards, "was keeping the brakes cool, so altogether it really was a tough engineering challenge to ensure the brakes remained as effective as possible. From the perspective of the brakes, controlling all that energy on a vehicle that's reasonably heavy by race car standards at 1200 kg is quite a task. At the same time, at one point on the hill it recorded

Edwards confirms that 380 mm diameter discs were used front and rear, the front being slightly wider as they take a little bit more energy, and a slightly thinner disc at the rear than the front but the same brake torque with some fine-tuning on the balance bar, the master cylinders and the bias adjuster knob. "It's a relatively unusual brake spec for a circuit car that would swap ends on the flat relatively easily," he says, "so it requires an incredible amount of driver feel because starting at the bottom he has to be relatively sensitive about the brakes with the gradient not being so severe. This is where working with Rhys was fantastic because his feedback was absolutely world class. And whilst the drivee0 team led by Kristaps is a relatively small one, changes were implemented quickly and efficiently with extremely positive results." ▶

BELOW Alcon relishes tackling an event that poses a tough engineering challenge

BELOW 380 mm diameter discs were used front and rear

Quite an aggressive brake pad was used with a material that is unique to Alcon and gave instant bite. "It's come with sprint brake spec on a traditional hillclimb that has to hang in there for quite some time with little or no cooling," says Edwards. "Carbon-carbon is next to useless for this kind of application, although I gather Peugeot used it in 2013. It doesn't have the feel and the bite at the bottom but this is where we are going to explore opportunities for next year, looking at a lightweight carbon-based solution."

The disc material is of the highest grade of alloy that Alcon uses for its competition products. "We supplied the best cast-iron rotors that a car can use for international competition," says Edwards. "Part of the reason for that was that it's a slightly wider disc at the front that features some unique internal vane patterns to help pump air through it and dissipate the hot air, bearing in mind there's little good air coming into the disc. The vanes aren't unique for Pikes Peak but they are the best we could utilise in terms of pumping air and giving us surface area."

The car features fairly standard brake plumbing while using the highest grade of brake fluid. "We pay particular attention to it in terms of the callipers which themselves are quite special internally as they are designed to protect the brake fluid from ▶

BELOW Millen celebrates going faster than any electric car has done before

eO PP100 Specification

- All-wheel drive
- Seven YASA-400 electric motors with eO controllers
- Peak power 1190 kW/peak torque 2520 Nm
- 700 V/50 kWh lithium-ion battery pack with BMS
- Single reduction gear/limited slip axle differentials
- Steel tubular spaceframe with carbon fibre body
- Electrically-assisted power steering
- 4-way adjustable shock absorbers
- Alcon 6-piston brake callipers and ventilated brake discs (380 mm front/380 mm rear)
- Hankook 320/710 R18 slick tyres
- HRE 13" × 18" wheels
- Kerb weight 1200 kg
- Top speed 260 km/h

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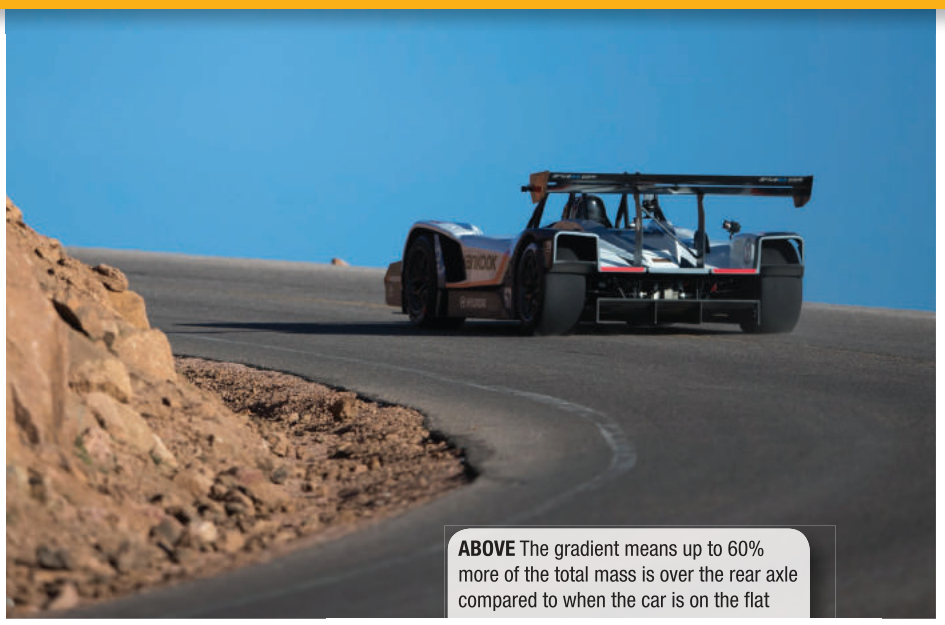

ABOVE The gradient means up to 60% more of the total mass is over the rear axle compared to when the car is on the flat

the energy input," he explains. "If There's excessive heat soak throughout the run, resulting in a long pedal, it's not only hugely distracting for the driver but also downright dangerous when you take into account zero run-off and huge drops! So we ran a unique piston arrangement to protect the brake fluid from the high-energy inputs, which was unique to Pikes Peak."

MIMIC THE MOUNTAIN

Before going to Pikes Peak the team had a test session at Willow Springs in California. "Where we couldn't mimic the effect of the altitude of the mountain itself, we were testing in extreme temperatures so we artificially created a scenario where we knew that if we could run there for a number of laps, then heat wouldn't be an issue," he says. "The circuit also has some interesting elevation changes as well that enabled us to assess the brake balance of the vehicle and the team to study the traction from the four-wheel drive system via the motors."

The target for next year, says Edwards, is to reduce weight: "The pace in the car this year sadly didn't materialise on race day due to tyre issues in the very hot weather. We'll be looking at all the feel and all the thermal capacity that we need for the package to reduce the weight. It means that we will be also looking for alternative disc material, probably carbon ceramic."

> *"A package that can work cold and have instant bite yet withstand extreme temperatures due to lack of air flow"*

According to Millen, in terms of the unique challenges of Pikes Peak, the biggest requirement from the braking system is finding the balance between a package that can work cold and have instant bite yet withstand extreme temperatures due to lack of air flow based on atmospheric conditions. On top of this the course design is very abusive with multiple heavy braking zones with little or no straightaways to allow for temperature recovery.

While Edwards says that it may not be apparent, there is some relevance from what is learnt on the Pikes Peak cars and road car brake systems. Rhys Millen confirms that, "While road and race cars are worlds apart, where electric motors are concerned, where braking performance is concerned, there is a relevance to how the performance works on both. It provides feedback to the engineering teams on chassis, driveability and handling inputs, throttle trace, motor rolling coast down and steering inputs versus road feel. I think this is one of the reasons that companies like Hyundai and Honda were at Pikes Peak."

Edwards is very enthusiastic about the Pikes Peak experience, saying: "I think it's a fantastic environment for electric vehicles to test. You are talking huge peak powers, everything is liquid cooled and learning how to control these vast amounts of energy, they can equate it to how road cars behave. One statistic I learnt is that 50 kW/h worth of energy for a 12.5-mile run at Pikes Peak illustrates the energy requirement at race speeds; an equivalent amount of energy would give a Tesla Model S a 160-mile range at normal road speeds." RT

Double delight

ALCON was in the record book twice at this year's Pikes Peak as its brakes were fitted to Robb Holland's Gurit Carbon/Rotek Racing Audi TTRS that took the front-wheel drive record with a time of 10m 56.878s

ABOVE With a massive system output of 1,596 hp and no loss of torque in the thinner air, an electric car puts more onus on the brakes than conventional rivals


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FUEL'S GOLD!

Fuel and lubricant technology is the secret battlefield in top-tier motorsport but, as **Seb Scott** reports, advances filter down to all levels

IN the hunt for engine power and efficiency, which have become intrinsically linked, engine builders and developers are seldom seen without an official fuel and lubricant partner. These partnerships are very rarely formed for purely commercial purpose; if anything, quite the opposite: they offer a unique opportunity to capitalise upon ground-breaking technical research.

NANODRIVE RELAUNCH

Millers Oils is about to relaunch its Nanodrive brand, which won the MIA and *Race Tech* World Motorsport Symposium innovation awards, but now incorporates new improvements.

"In 2008 and 2009 we developed low-friction lubricant formulations for transmissions," explains Martyn Mann, the company's technical director. "More recently we have done the same things with engine oils. That work has then gone on from there and the trend has been for higher levels of efficiency so we're sort of retaining durability with a low-friction lubricant but going into thinner viscosities. Where 540 and 1050 was always the oil to go to at certain levels, we're down to 530 and 030, 520 and 020 but still with the high level of durability from the low-friction aspect of the formulation."

The award-winning Nanodrive range now has new chemistry, in some cases new nanoparticles, to improve the efficiency by another 15%.

"We often retain traditional aspects of the chemistry so with the ZDDP (zinc), the anti-wear package that you find in engine oils, the trick is to find chemistry that sits alongside them and doesn't hinder the performance of ZDDP. Particle size is very important because you're often down at molecular level; some of the chemistry that we have is five to 10 nanometres."

A key feature of a lubricant is its additives, each with unique characteristics that have particular strengths and weakness, but as Mann explains, the key is to pick the right ones. "The trick is to get all the additives to work in harmony with each other as they all respond to temperature, pressure and a combination of the two. Certain ones work in low temperatures and pressures while others are better in extremely high temperatures and pressures such as those we use in transmission oils.

"We have equipment – basically a friction testing kit – where we can program a temperature profile and measure the friction over the whole range as it warms

BELOW & LEFT The Nanodrive range has new chemistry, more efficiency

Matt Woods Photography

ABOVE Fuel has become an important weapon in a team's armoury. These are barrels of Sunoco fuel, distributed by Anglo-American

up. It starts at ambient and then increases to 200 to 300 degrees Celsius if needed although quite often 150 or 160 degrees is enough with specific loads.

"The net effect of Nanodrive is that it cuts friction," continues Mann. "If we measure standard engine oil from an everyday motoring store, it would have a friction coefficient of around 0.12 to 0.14. The sort of chemistry that we engineer into our Nanodrive products means that we can halve that friction coefficient, so 0.07 is not uncommon and can be fairly easily achieved. Reducing the friction leads to more power as less energy is being wasted on turning the engine over.

"From dynamometer tests we usually see a shift to the left in power and torque graphs coming in slightly lower down the rev range because you've not got that energy being wasted turning the engine. The drivability of a car therefore improves due to the broader power and torque delivery."

PUSH FOR EFFICIENCY

Anglo-American is one of those independent companies that can be found offering their services at race tracks around the UK. As the European and Middle Eastern distributor of Sunoco and Driven Racing Oil, it has a portfolio of products that put it at the heart of the motor racing community.

Over the last few years it has been involved in a good many product launches, the theme always being the same: reducing fuel consumption, increased efficiency – friction reduction – and of course enhanced power.

"We had a lot of new products coming out on the market two of three years ago when we developed two new leaded historic MSA and FIA race fuels," says Anders Hildebrand, Anglo-American's personable managing director. "They've been extremely successful so it was a good move to bring them to market. Our focus is to provide optimum fuels at the best possible price.

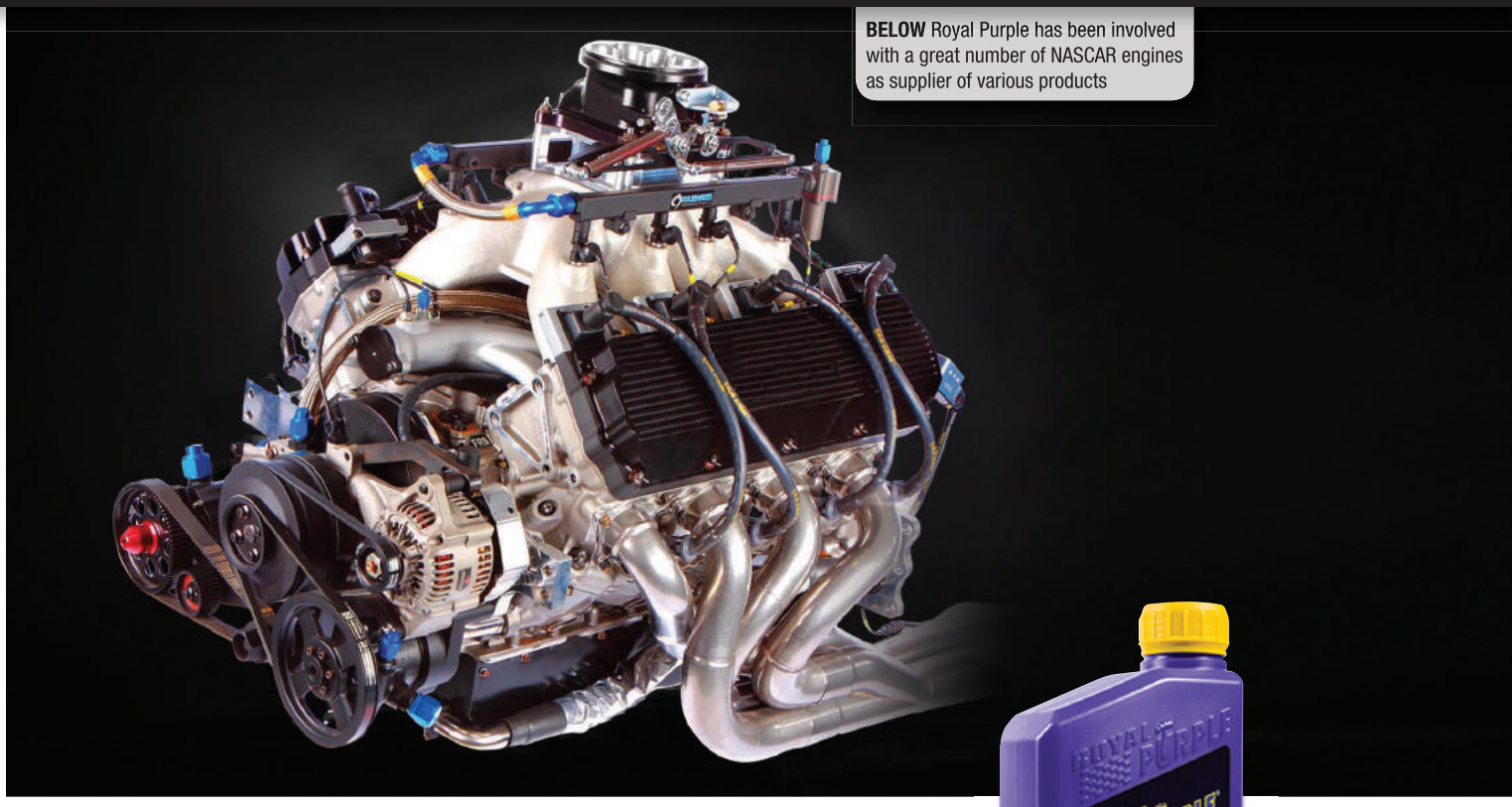
"You can easily claim to be making the best fuel and the price will just run away, but a customer doesn't really appreciate the incremental power increase and having to pay three times the price for it."

When it comes to increased efficiency, he says that it's fundamentally a question of cleaner fuels and better thermal conditions. "Unfortunately the tricky part with cooling comes from two parts. One is a clean burn leaving little residue which you achieve by using a higher degree of single bonded hydrocarbons that reduce carbon build up. Secondly, the introduction of oxygenates further improves the combustion efficiency to achieve a very complete burn. The downside is that both single bonded hydrocarbons and oxygenates are very high in octane, therefore push octane levels high.

"With oxygenated fuels you get more power and a better burn and cooling, especially if you use methanol or ethanol as an oxygenator. However, this could result in an increase in fuel consumption unless you know some tricks around that. To get a more fuel-efficient engine you basically need to optimise the fuel and engine together. If you could run fuels that were of a higher octane than what the MSA and FIA dictate and allowing engines to run higher compression, then you can get much better fuel economy," he says.

Hildebrand relates this with racing events and how Sunoco fuel raised eyebrows in V8 Supercars. "In most racing, small differences in fuel consumption do not seem to matter as the fuel usage is not a limiting factor. The only time people talk about fuel consumption is actually in motorcycle racing with regards to the Isle of Man TT where fuel consumption is critical.

"I know that the Sunoco CF FIA race fuel that we supply to British GT is very efficient, something that was proved when we became the official fuel for the Italian V8 Supercar series that had previously been using a different fuel brand. At the first race at Monza in 2014, I was asked about its specific gravity along with other pertinent ▶



BELOW Royal Purple has been involved with a great number of NASCAR engines as supplier of various products

information that they use to calculate how much fuel they should put in. They were amazed after they finished the 40-minute race that they could pump out six litres of our fuel, whereas before they were getting fuel surge on the last lap."

Hildebrand brings up the question of the increasing difference between engine and gearbox oils designed for road cars that have to meet API and ACEA standards and racing oils. Road oils are designed for vehicles driven at 10-15% of their capacity and to last up to 18,000 miles between oil changes, which of course is good for the owner's wallet and the environment.

"You can summarise road oil development that with every new standard there are less anti-wear additives and more detergents in the oils," he says. "However, a competition engine which is run at 100% under much more stress asks far more of the oils than road oils can cope with. This means that proper race oils, such as the Driven Racing Oil, have a completely different design than road oils. Stressed engines with more point-to-point loads need more anti-wear additives such as ZDDP and also to be able to cope with much more heat without falling apart.

"Driven's XP range is today one of the most advanced race oils with one of the widest range of viscosities on the market. Uniquely Driven is using a new type of synthetic base oil named mPAO which has a very high viscosity index of just under 200. Typical results are lower oil temperature, maintained oil pressure, increased power due to special friction-reducing additives, and reduced internal wear.

"Going back to fuel consumption, racing engine and gearbox oils reduce friction and as you can use thinner oils compared to road oils, internal losses are minimised resulting in improved power and better fuel efficiency."

FILM STARS

Texan company Royal Purple produces a wide range of high-performance lubricants for nearly every consumer and industrial application. In its home country it has been involved in a variety of motorsport activities from NHRA Pro Stock to the US Subaru Rally Team, while in 2015 it was the official lubricant supplier of the Red Bull Global Rallycross series. In the UK, Royal Purple's products are distributed by Advanced Lubricant Solutions.

The film strength of a lubricant is its inherent ability to withstand the effects of load, speed, temperature and pressure without breaking down or rupturing, thus enabling the lubricant to maintain an unbroken film between lubricated surfaces under operating conditions.

The company claims that its Synerlec-enhanced products provide exceptional film strength and improve combustion for greater power while optimising fuel economy and reducing emissions. It therefore enables the oils to carry much greater loads in more extreme conditions.

High film strength also dramatically reduces

ABOVE The product line features Synerlec additive technology

wear that the company says allows Synerlec-enhanced products to improve the condition of metal surfaces by remaining long after other lubricants would have been squeezed out under pressure. It not only reduces the likelihood of the film being broken but also helps gently micro-mend the asperites, creating a smoother surface which then is easily separated by the oil film.

Another product from Royal Purple is its XPR (Extreme Performance Racing) synthetic motor oil that has been specifically formulated for the demands of multi-platform racing environments. It combines the highest quality synthetic base oil with its Synerlec additive technology along with additional performance enhancers that the company claims maximise horsepower and torque while providing the highest level of protection against the extremes of heat and wear.

Specially designed to extend gear and bearing life, Max Gear provides what Royal ▶

Purple claims is superior corrosion protection over competing conventional and synthetic gear oils. It outperforms ordinary gear oils by combining the highest quality synthetic oils again with Synerlec additive technology.

FUEL ON DEMAND

P1 Racing Fuels, a limited liability company based in the Republic of Ireland, focuses on the formulation, manufacture and supply of premium component racing fuels throughout Europe, Asia, Australasia and the Americas.

"Our products are high-quality, high purity racing and control fuels specifically designed for a range of motorsport applications," says Dan Coxall, P1 Racing Fuels' chief commercial officer. "Our gasoline, gen2 bio-ethanol and racing diesel blends have all been developed to meet the growing need for component-based fuels with superior performance at a competitive price. Our R&D department was the first to develop an FIA Appendix J (2014) compliant formula. We are committed to working closely with series organisers, manufacturers and engine build/calibration specialists."

One issue that arises when it comes to fuelling is availability at events. Sometimes only select brands are available unless it is possible to organise a refuelling service, something that P1 Racing Fuels offers.

ABOVE P1 Racing Fuels offers 'on event' refuelling services through its support arm, Race Republic

"We provide fuel transportation and 'on event' refuelling services through Race Republic, the wholly-owned support arm of P1 Racing Fuels," says Coxall. "Race Republic is well known throughout mainland Europe as a highly experienced distributor with a long history in rallying, and together we offer a complete end-to-end solution for all major national and international circuit and dirt series as highlighted by P1 Racing Fuels' appointment as the spec control fuel supplier to the FIA World Rallycross Championship, FIA F3 Intercontinental Cup and the FIA GT World Cup."

ENTER THE TITAN

Fuchs Lubricants manufactures Fuchs Titan Race, a range of race-ready engine oils, gear oils and grease to provide optimum performance and reliability throughout the lubrication process. Its products can be found across a wide range of motorsport disciplines with oil samples being studied from the British Touring Car Championship, British Rallycross Championship, Pick-Up Truck Championship and many others.

Its Titan Race engine oils, available in a wide range of viscosities, are designed specifically to minimise internal frictional loss, maximise power and torque whilst also providing wear protection and engine durability. High-speed performance engines provide a real challenge with Fuchs claiming to have found the correct balance between outright performance and engine protection.

The Fuchs Titan Race Gear oil range is said by the company to provide protection to the next links in the drivetrain. Maximising power in the engine is no use if it cannot be transferred efficiently through the gearbox and the final drive to get the power onto the track. Its range of gear oils provide the performance and efficiency to protect highly loaded gears, ensure smooth gearchanges and enable as much power as possible to be utilised. As with the race oils, Titan Race Gear oils are available in a variety of viscosity grades and performance levels including synchromesh.

ABOVE The Fuchs Titan Race range operates in many disciplines

IT'S A MINI ... OR *IS* IT?

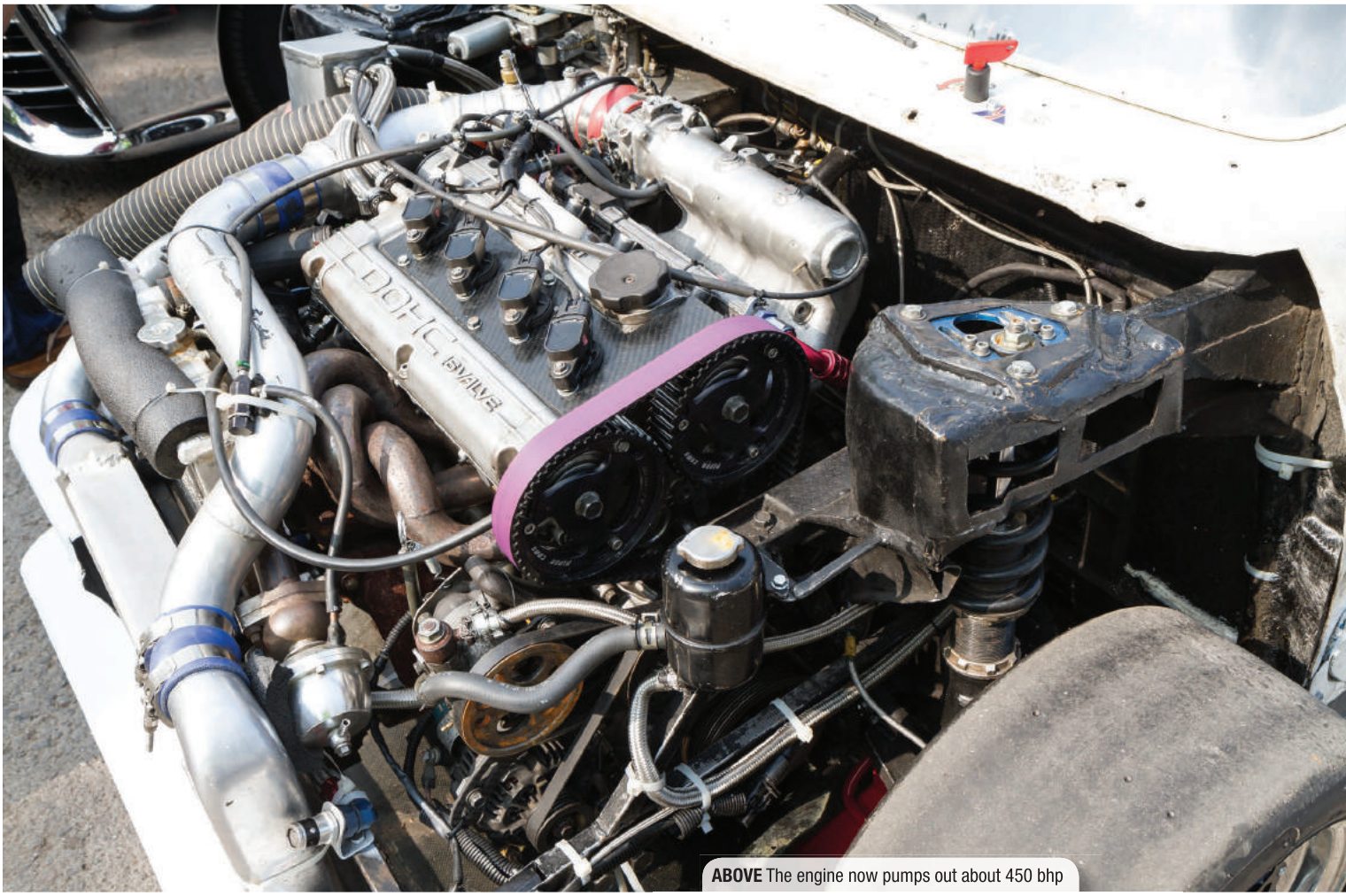
Sort of, is the answer. **David Finlay** examines one of the most compelling cars in the British Hillclimb Championship

THE Mini Evo, one of the most eccentric and crowd-pleasing cars regularly competing in the British Hillclimb Championship, is the work of Allan McDonald, who could be described as being part of at least two long-standing UK motorsport traditions.

He would certainly have fitted in very well to the Super Saloon and GT scenes of the mid-'70s onwards, where inventive fellows created amazing devices that bore some slight resemblance to road cars but shared little or no technology with them.

His work also recalls that of builders from 80 and more years ago – John Bolster and Basil Davenport being just two examples – who achieved great success with cars they had cobbled together at home and went on to develop intensively, largely on a trial and error basis.

McDonald is now in his sixth season of hillclimbing with the Mini Evo. He came to



ABOVE The engine now pumps out about 450 bhp

> *"Part of the car's perverse appeal is its strange and frankly unattractive appearance"*

the sport relatively late, having raced motorcycles very effectively. His career, which included winning several Scottish Championships and the 1988 Manx Grand Prix, lasted for 17 years. It might have been more but, he explains, "I was in hospital for a very long time."

As an unorthodox way of keeping himself occupied during a period of convalescence, he went banger racing in various Minis (he's quite enthusiastic about them, having had one as his first road car). Everything he has competed in since he took up hillclimbing has been a Mini of some sort, or at least looked vaguely like one.

The first used a regular steel shell but had a 2-litre Vauxhall 16-valve engine. The next was a Suzuki Hayabusa-powered Z Cars spaceframe. Then came something based on the floorpan and transmission of a Subaru Justy 4x4 with a Suzuki Swift GTi engine "and a Mini welded on top".

COULD I DO BETTER?

McDonald's opinion of the latter was that, "I could do something a damn sight better than this." Having made contact with DMW Motorsport of Queensland, Australia, during his time with the Justy-based car, he learned that DMW had fitted a Swift with Mitsubishi Evo running gear. "I thought, if an Evo would go into a Swift, it would go into a Mini!" he recounts. "I was told I should use an Evo 7 or later, but even a burnt-out 7 would have cost 10 ▶

ABOVE The beast, affectionately dubbed 'Bad Wolf', in action

ABOVE BC Racing coilovers have replaced the original Evo 2 suspension

ABOVE Tight fit: the running gear of a Mitsubishi Evo 2 is shoe-horned into that shell

grand. I got an Evo 2 for £1200 and started glueing it all together."

The body and spaceframe chassis, built by TDK Racing's Dave Kimberley, were "third-hand but unused". As well as the engine and transmission, the Evo 2 also provided the suspension. McDonald knew the springs would be too stiff for the lighter car and bought a set 30% softer. They seem to work well. He has since fitted a set of coilovers supplied by BC Racing and still uses the same spring rate.

OVER 70 HEAT CYCLES

McDonald accepted Avon's suggestion of using its very soft A15 compound slicks, which last the best part of a season. At a rough estimate, this may equate to over 70 heat cycles. He would replace them more often, but doesn't see the point given the opposition in the almost-anything-goes Sports Libre category: "The fast ones are so far ahead it's not worth me trying to get a quarter- or half-second improvement."

When he bought the Evo 2, the engine already had a 1 mm overbore and was producing around 350 bhp. The bore was increased by a further 1 mm following a blow-up which also inspired McDonald to fit a longer, 100 mm stroke crankshaft bought from Ross Sport in Ely, raising the capacity to just over 2400 cc. The number of fuel injectors started at five, then went to four when McDonald switched from petrol to methanol in 2013, then to eight and finally to "four big ones" – ID 2000s again supplied by Ross Sport.

Right from the start, the car ran with "the wildest Kent Cams you can use with hydraulic lifters". The turbo is a 20G unit bought through eBay for £200. "The description on the ad suggested it was quite good," McDonald comments drily. It originally ran at 1 bar boost, but now delivers 1.3. He has used 1.5 occasionally but doesn't like doing this because "there's no point creating problems". He fabricated his own exhaust, considering the original one to be "a great big heavy thing, full of silencers". Passing noise tests has not been a problem.

The estimated output is now 450 bhp in a car weighing about 790 kg. This is far from the best power-to-weight ratio in the sport, but almost nothing other than Nic Mann's ▶

ABOVE Almost nothing can cover the first 64 feet of a hillclimb course as quickly

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ABOVE Yes, the carbon fibre rear diffuser is mounted too high, but it seems to work. The enormous rear wing was originally intended for a single-seater

extraordinary Mannic-Beattie (another home-built four-wheel drive racer) can cover the first 64 feet of a hillclimb course as quickly. At Shelsley Walsh, which has the steepest start of any British Championship venue, it can cover this ground in 1.9 seconds or less on almost every run. The top single-seaters in the sport can rarely do it in under two. Sixty-four feet in two seconds from a standing start on flat ground equates to acceleration of 1G, so the Mini Evo is clearly doing better than this, though the exact figure won't be known until someone measures how steep this part of Shelsley actually is.

One reason the car is so quick off the line is that it has exceptionally low gearing. McDonald believes it is actually excessive, at least in first and second, but the ratios in the box, which went through an Albins sequential-shift dog-gear conversion in time for the 2014 season, are the only ones available. The engine is so flexible that he usually changes up at 5000 rpm, though at some hills he has to rev beyond 7000 in fifth because there are no more gears left.

THE UGLY TRUTH

Part of the car's perverse appeal is its strange and frankly unattractive appearance, which McDonald has no intention of changing. "I have no sponsors anyway, so why make it look great?" he asks. "It won't be any quicker." Perhaps its most distinctive feature is the enormous rear wing, made by 2001 and 2002 British Champion Graeme Wight Jnr, who originally intended it for one of his Raptor single-seaters. "It came out of the mould a bit heavy, so he sold it to me cheaply," McDonald explains. "He thought it might be a bit wide. I thought it should be wider. How can you have a car this stupid if it doesn't look a bit silly?"

The rear diffuser is the way it is for a similar reason. McDonald knows it's mounted too high, but thinks it looks better that way. And it seems to work. The first time he used the original self-built aluminium one, he was within a tenth of a second of his personal best on his first practice run at Shelsley, and went under it on every run after that. The one now fitted to the car, otherwise identical, is the third carbon fibre component McDonald ever made, following the bootlid and bonnet.

To an outsider, or a viewer of the in-car videos on YouTube, the Mini Evo looks a real handful. McDonald reports, however, that it "likes the twisty bits. It's very good up Wiscombe Park, even in the wet, and through the Doune Esses. It doesn't feel like it's trying to bite me. With the four-wheel drive you can be quite ruthless. You can use the green bits if you want to. Sometimes I do that for a laugh, to see if I can get away with it."

Recently it has been handling better than it did before. "Graeme Wight watched one of my videos and said, 'There's something wrong,'" he admits. It turned out to be bump steer, which McDonald hadn't noticed because the car still has the Mitsubishi's power steering. "I measured it and it was horrendous – several inches out," he says. The problem was fixed for the 2016 season.

It may by now have struck you that no genuine Mini parts have been mentioned so far. In fact there are some; the door hinges came off a "real" Mini, but there's a twist: the thing they hinged wasn't a door but a bootlid.

While the very thought of it may send professional engineers into cardiac arrest, the Mini Evo is remarkably effective, capable of competing on equal terms with more refined Sports Libre machines such as Keith Diggle's WEV HCS (essentially an off-set single-seater with mudguards), David Seaton's Pilbeam MP43-BMW V8 and Mike Manning's ex-rallycross Ford Puma, reported to have in the region of 650 bhp. Its performance is matched both by its spectator appeal and by the popularity of McDonald and his wife Grace, who travel to events all over the country from their home in Dalbeattie in south-west Scotland and are almost always the cheeriest people in the paddock. Without the McDonalds and their curious machine, hillclimbing would still be a wonderful sport, but at the same time a duller one. RT

BELOW The spartan interior of the spaceframe chassis

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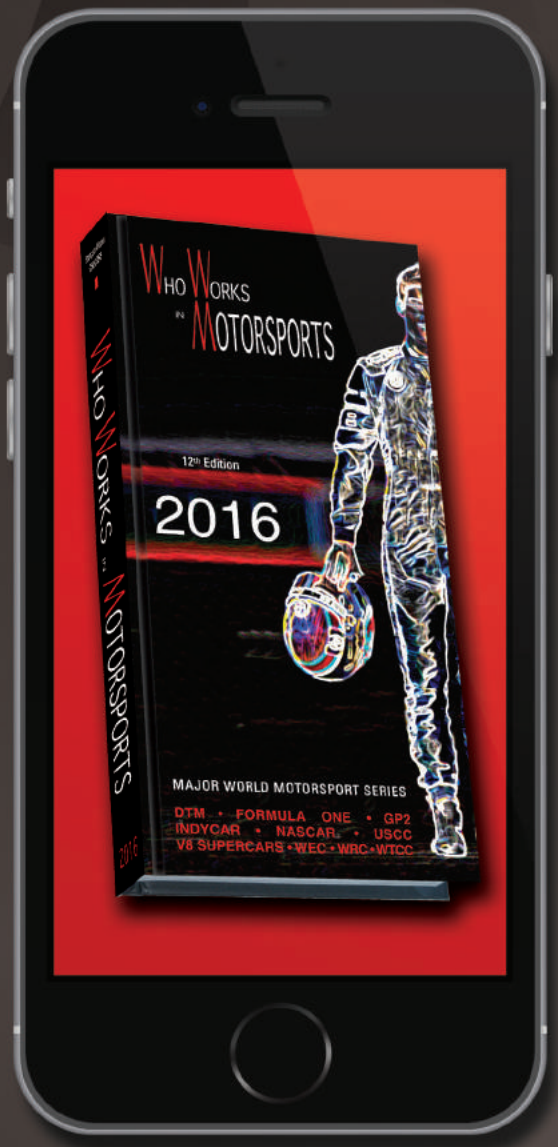

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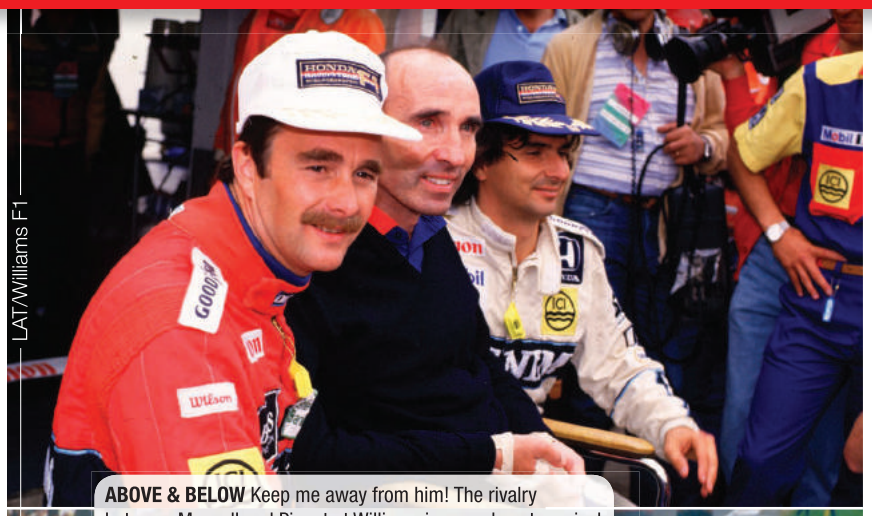

LAT/Williams F1

ABOVE & BELOW Keep me away from him! The rivalry between Mansell and Piquet at Williams is now almost comical

Piloti, che gente!

The latest bust-up between Lewis Hamilton and Nico Rosberg triggers a flashback for **Sergio Rinland**, who found himself between a warring Nigel Mansell and Nelson Piquet

WHEN Enzo Ferrari wrote his book *Piloti, che gente* (Drivers, what kind of people!), he knew very well what he was talking about. He was a former racing driver himself and the most manipulative, Machiavellian team boss when it came to pushing his drivers to the limit.

When you put two top drivers with similar ambitions in the same team, you are asking for trouble. More so if they are driving the fastest cars, as is the case with Lewis Hamilton and Nico Rosberg today in F1.

We have witnessed plenty of cases of bitter rivalry in the history of F1. There have been very few exceptions to the rule, and those had a lot to do with the personalities involved. We have seen Andretti-Peterson – only Ronnie was not allowed by contract to fight Mario – Lauda-Reutemann, Reutemann-Jones, Villenueve-Pironi (which finished tragically for Gilles), Mansell-Piquet and the famous Senna-Prost fight.

There were different triggers for those rivalries, but it all concludes with them both wanting the same thing and there is only room for one of them to have it. Team owners either could not control the situation or, as in the case of Enzo Ferrari, they encouraged it.

I witnessed a few of these feuds; the one that sticks with me is Mansell-Piquet. There you had an astonishingly competitive, hard-working and tenacious driver fighting for what was perceived as his 'national team', and a 'bon vivant' Brazilian with enormous talent and a wicked sense of humour, which was not everybody's 'cup of tea'. Piquet came to Williams with two World Championships under his belt, so there it was: the national hero of the time wanted desperately to get his own – a recipe for disaster!

The technical debriefings were somehow funny. Neither of them would speak. The engineers would say very little regarding settings and then each driver and his engineer would go into a quiet corner to discuss the car's problems, possible solutions, setups and strategies. At one point, when I was Mansell's engineer, Nelson came to talk to me in Spanish, about nothing at all, just to upset Nigel. Now, looking back at the situation with the benefit of time and distance, it was hilarious.

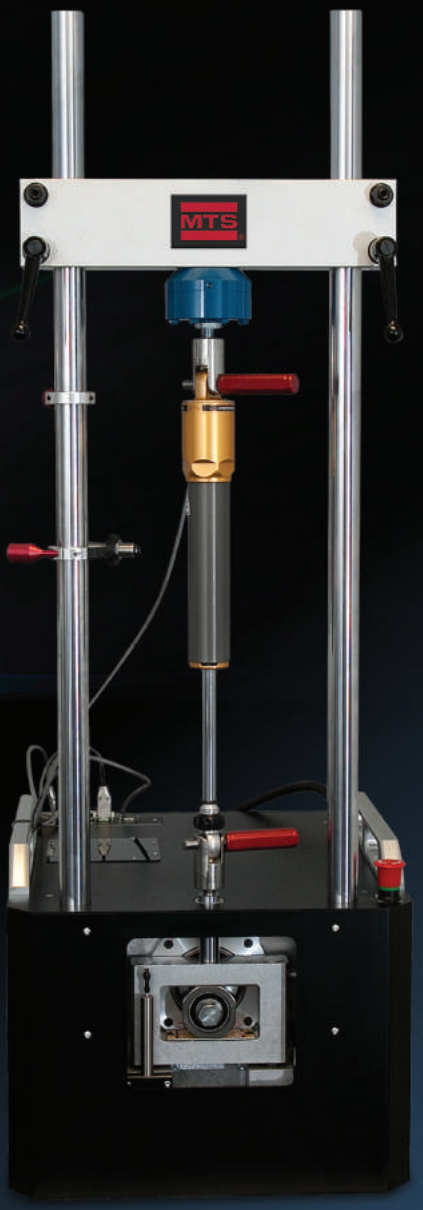
At Brabham, even though we did not have a winning car, we had two Italian drivers competing for their piece of national recognition. So, at the beginning, the situation was similar. At the same team a few years later I had the pleasure of working with Martin Brundle and Mark Blundell, two true gentlemen. They were very competitive on the track but absolute team players working together and still friends today.

A similar circumstance marked the Fangio-Moss relationship. The Master and the Disciple, rivals on track but again friends till the end. There was a mutual respect and very little between them when it came to talent and raw pace, but there was never ever bad blood between them.

We could analyse many situations, but all of them had a degree of wanting to be on the same step of the podium. When it comes to the Hamilton-Rosberg situation, it was going to happen sooner or later. The story could come from a film script: two drivers who are rivals from 'kindergarten karting', competing in every promotional formula until they got to F1, and now they are team-mates – two different characters, backgrounds, lifestyles and driving styles but a common ambition.

So far, Hamilton has managed to get the upper hand. Will Rosberg keep his cool and win the championship this time around? We will have to wait and see, but I do not believe that any 'corporate-style' meeting or threats from Niki Lauda or Toto Wolff will improve the situation. Neither of them is Enzo Ferrari; he was unique when it came to dealing with drivers. RT

The Original



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