FASTEST FORD RALLY CAR EVER

Behind the radical revamp of the Fiesta RS WRC as Ford guns for VW

RACE TECH

20 YEARS ANNIVERSARY

Driving Technology Into Pole Position

INTERNATIONAL

JUNE 2015 No. 175 UK £5.95 USA $11.99

www.racetechmag.com

Not just a game

Tech stars from F1 and NASCAR defect to build racecars for online gaming

+ BAN wind tunnels? You're having a laugh!

Why 3D printing is the future

www.racetechmag.com

06

9 771356 297055

Not just a game

The challenge that lured tech stars to defect from F1 and NASCAR to build racecars for the online gaming community

COVER STORY Page 30

DRIVING TECHNOLOGY INTO POLE POSITION
RACE TECH
INTERNATIONAL

Volume 22 Issue 7
Published May 2015
The next issue will be published
in early June 2015
ISSN 1356-2975

SUBSCRIPTIONS
Subscriptions from Racecar Graphic Ltd
841 High Road, Finchley, London N12 8PT
Tel +44 (0)20 8446 2100
Fax +44 (0)20 8446 2191

Overseas copies are sent via air mail
Special offer 12 issues for the price of 10
12 issue subscription UK: £45.00
Europe: €97.50, US/Canada: US$127.40
Rest of World: £75.00
All major credit cards accepted. Cheques and money orders only in Pounds Sterling payable to Racecar Graphic.

BACK ISSUES AVAILABLE:
8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174
Price including post & packing:
UK: £5.50, Europe: £6.50, Rest of World: £7.55
You can pay by cheque or credit card but please note the minimum on Switch & Delta is £14

Race Tech (ISSN: 1356-2975) is published monthly by Racecar Graphic Ltd.

Cover image: iRacing

Design & Production:
Maluma Design Associates,

Printed by Warners Midlands plc

ON THE COVER

30 **Engineers go virtual** The days of dismissing sims as mere racing games are long gone. As David Phillips finds out when he talks to two vehicle dynamicists who have traded careers in the likes of F1 and NASCAR to do the same job in the virtual world

42 **The fastest Ford rally car ever** The evolution Fiesta World Rally Car makes its debut in Portugal this month after the most radical overhaul in the car's history. Anthony Peacock talks to the technical brains behind the revamp

16 **Ban wind tunnels? You're having a laugh!** Branded "dinosaur technology" by one team, the subject of a proposed ban by another, wind tunnels are under attack. But our Expert Witness, a knowledgeable F1 insider, says the critics are wrong. Here's why

INDUSTRY NEWS

6 Soft tyre concern in BTCC; TPMS comes to Australian V8s; digital dash on way to NASCAR; Gordon calls for more pit tech; LMP2 to become a spec series; new-generation Hyundai i20 WRC breaks cover; strength of Indy aero kits under scrutiny

FORMULA 1

24 How to enter F1 – and survive! "Welcome to the Piranha Club," was the wry greeting famously extended to one F1 newbie. Matt Youson finds out why Haas F1's entry plan could become the template for all new teams, enabling it to stay afloat where predecessors were dragged under

56 A lot is made of 3D printing being the future of Formula 1 but, as Craig Scarborough points out, the future is already here: a surprising amount of printed parts are utilised on a modern F1 car every race weekend

FACE TO FACE

38 Back where it should be in endurance racing, could Porsche's momentum be continued at Silverstone's WEC curtain-raiser? William Kimberley gets an update from Porsche LMP1 technical director Alex Hitzinger

ENGINE TECHNOLOGY

50 Chris Ellis completes his blueprint for F1 2017. Is this how the GP circus could recover braking energy and credibility at the same time?

TECHNOLOGY SPOTLIGHT

64 William Kimberley finds out from 3D printing expert Stratasys how motorsport's need for speed is driving 3D printer development

SPECIAL REPORT: SUSPENSION

68 Chris Pickering highlights some of the latest developments in suspension technology

PRODUCT NEWS

80 The latest new products released for the motorsport sector

LAST LAP COLUMN

82 The proposed future for LMP2 sees the constructor count pinned at four. But is this a wise decision?


47 Years of Experience Engineering and Manufacturing Racing Fasteners
It doesn't matter where you race, ARP has the fasteners to win championships
Manufactured in the U.S.A.
4,500 catalog items and specials by request
ARP fasteners provide strength and reliability for every type of racing.
ARP fasteners are manufactured entirely in our own ISO 9001:2008 and AS9100 registered facilities in Southern California.
Roush Yates Ford FR9 utilizes both off-the-shelf and custom manufactured fasteners
ARP®
automotive Racing products
ISO 9001:2008 AS9100
Registrar
Registered Firm
ANAB ACCREDITED
Made In USA
www.arp-bolts.com
1863 Eastman Ave • Ventura, CA 93003
Toll-free in the U.S.A 1.800.826.3045
Outside the U.S.A. +1.805.339.2200
Special Orders +1.805.525.1497

DRIVING TECHNOLOGY INTO POLE POSITION
RACE TECH INTERNATIONAL

841 High Road, Finchley
London N12 8PT
Tel: +44 (0) 208 446 2100
Fax: +44 (0) 208 446 2191

www.racetechmag.com

Lessons to be learnt in Formula 1

I HAVE to admit I'm confused, a state I'm often in as a matter of fact, but on this particular occasion it's to do with all the talk about new Formula 1 engine regulations for 2017. To be honest, I'm not sure what's really being proposed and what's a bit of kite flying, but from what I gather, it's the desire to have 1,000 bhp power units while the V8 proposal has come back from the dead despite having been rejected outright by Honda and Mercedes last February. However, when the stars align in the shape of Ferrari and Bernie Ecclestone, F1's commercial rights holder, then it becomes a significant force to be reckoned with and cannot be discounted.

However, let's take a step back a moment and consider just things as they stand now in Formula 1. Mercedes is the dominant force while Renault and to a lesser extend Ferrari are trailing in its wake, saying that it's so unfair that they cannot update their power units to make them more competitive. However, when Renault was ruling the roost and before that Ferrari dominating the scene, I don't remember Mercedes whinging about it. Instead, the engineers put their head down and came up with a beauty of a power unit that deserves all the success it's getting.

1,000 bhp? It's a sexy figure I know but from what I understand, the output of some of these power units is already hovering around 900+ bhp so will another 100 bhp really make a difference to the TV audience. The answer is of course not. Pretty well every aspect of speed is lost when viewing it on a screen while for the circuit spectators it's all pretty much a blur anyway. For me, apart from a purely marketing viewpoint, it's an irrelevant non-starter – as is the V8.

Don't get me wrong, I love that engine configuration, I love the growl and I love V8-powered cars, but in a modern Formula 1 car? Absolutely no way! It's as if some are living in a bubble without any reference to what's happening in the big wide world. We live in an era of downsizing, when the V8 becomes the V6 and the V6 becomes the inline 4, so how on earth can the self-proclaimed pinnacle of the sport be seen to herald the V8 as the great saviour?

From what I gather, one of the issues occupying the minds at NASCAR is how to shift from V8s to something a bit more relevant to the road car and something the car manufacturers want. The difficulty is that the series' DNA is the V8 and the die-hard fans just won't accept it. What should be borne in mind, though, is that this fan base is getting older and shrinking. Do we want that to happen to Formula 1?

In fact, the answer to Formula 1's plight is easy, especially as there is a bright example of what can be achieved with the right set of regulations – and that is the LMP1-H regulations in the World Endurance Championship. Three different power unit configurations, plus diesel and petrol, and yet lap times that are hundredths of seconds apart. Surely it's not a great leap to adapt them to Formula 1.

A few years ago Audi Sport's Ulrich Baretzky was proposing the Global Race Engine concept and while this is not the same, the principles by which an engine can power both an LMP1-H car and Formula 1 car are and this to me seems a better solution, although truth be told, Formula 1 desperately needs some stability and the current regulations should really be in place until at least 2019. However, that's about the time the current LMP1-H regulations will be replaced so maybe there's an opportunity to converge the two. Now there's a thought. RT

William Kimberley
EDITOR
Winner of the 2014 Guild of Motoring Writers Market Engineering Award for the Technology Journalist of the Year

RIGHT The BMR Volkswagens of Colin Turkington and Jason Plato lead the field at Donington, with the rear-wheel drive BMWs visible further down the field

Jakob Ebrey/BTCC

Soft tyre concern in BTCC

Andrew Charman

DONINGTON PARK, UK: New technical rules introduced into the British Touring Car Championship and aimed at equalising the performance of front and rear-wheel drive cars appear to have found general favour, following two meetings and five different winners in the first six races of the 2015 series.

However, some drivers are expressing concerns that a combination of increased success ballast applied to top-finishing cars and the soft-compound tyre that each is required to run in at least one race per meeting could be having an adverse effect.

Maximum success ballast rates were increased for the 2015 season from 45 kg to 75 kg, while drivers are now compelled to mix around during the season the races in which they choose to use the soft tyre – they can use it three times each in the first, second or third races of a weekend over the nine race meeting – the soft tyre is not used during the series visit to Thruxton, Hampshire due to the high-speed nature of the circuit.

Speaking live on ITV television following the second 2015 meeting at Donington Park, Leicestershire, Jason Plato, the BTCC's second most experienced driver having been racing in the series since 1997 and twice champion, questioned whether the new rules had not "pushed things over the edge".

Plato said he was not a fan of the soft tyre. "With it, I'm not pushing until the last three laps, I'm not in the race," he said. "It does mix up the field but all the people who chose soft tyres in the races today weren't in them – I'd like the soft tyre to be a little bit more robust. It would still be a penalty, but we could race. Coupled with the weight increases this year we don't want it to become silly."

Honda's Matt Neal also agreed that the increases in success ballast have made a significant difference. "It hurt Jason and it hurt Flash (Neal's team-mate Gordon Shedden) as well," he said at Donington.

The 2015 rule changes include a requirement for rear-wheel drive cars to carry their success ballast as far forward as possible while over the winter, independent tests were carried out on in-gear acceleration and start-line performance of the cars in a bid to better equalise the two formats.

However, Rob Collard, driver for leading rear-wheel drive team and 2014 driver's series champion West Surrey Racing, believes the changes have disadvantaged his rear-wheel drive BMW. "Handling-wise, we've stepped forward over the winter, but being forced to carry the success ballast further forward is hurting us," he told *Race Tech* at Donington.

"On straightline speed we are not that strong, front-wheel drive cars with the TOCA engines are driving past us on the straight. Downhill through corners our car is good but accelerating out of corners on the flat we are sitting ducks."

He said there was little his team could do to improve the situation. "We are in the hands of TOCA."

However, Plato, last season a fierce critic of a perceived performance advantage in the RWD cars, does not agree with Collard. "When measured on the corner weight scale, the BMW is 200 kg lighter across the front axle than front-wheel drive cars such as our Volkswagen," he told *Race Tech*. "The BMWs have a 50/50 weight distribution, they can run bigger rear brakes and the same size front brakes as us, spreading braking across all four tyres, which we don't. They also spread traction across the rear tyres with less energy on the front tyres and they have a traction advantage off the startline."

Plato also argued that the relocation of the success ballast on the BMWs had been by an insignificant amount, and claimed that their lack of straightline speed was due to them being allowed to run a greater amount of rear wing. "Take the wing off! Add it all up and it makes a significant difference – driven properly the rear wheel-drive cars will be winning races this season." RT

TPMS comes to Australian V8 Series

DISS, UK: Norfolk company bf1systems has won the contract to supply the Australian V8 Supercar Series with its tyre pressure monitoring systems, with immediate effect, primarily on safety grounds allowing teams to detect a deflating tyre before it fails completely. The decision to allow sensors comes via the V8 Supercars Commission after the V8 Supercars technical department validated the system during early season testing.

V8 Supercars is supplying a tyre pressure sensor kit to each team which includes 16 sensors – for four sets of wheels, and a wiring loom to install an alarm in the cockpit so the driver knows he has a tyre issue. The sensors fit flush to the inside rim of the control Rimstock 18-inch wheel and communicates wirelessly via a receiver fitted within the wheelarch.

As a consequence, teams are expected to make great gains in data acquisition having previously only been able to gather tyre data when a car entered the pits. Previously, with sensors not allowed, teams could only gauge hot tyre pressures after a session or race. Tyre grip and durability is a key ingredient in extracting pace from a V8 Supercar.

"This should serve as a bit of a leveller again," Red Bull Racing Australia team manager Mark Dutton told v8supercars.com.au. "We like to think we do our job on the tyres pretty accurately and pretty spot-on and now we are going to learn if we do, or if some of the assumptions we have made through the years are wrong.

"Do we spend more time on tyres than other teams? I don't know, but I do know we put a lot of emphasis on them. So for other teams, if they weren't spending as much time on their tyres, now it is being gift wrapped and handed to them on a platter.

"So this could mix things up a little bit. I am excited about it. I think it's going to be great."

Nissan Motorsport team manager Scott Sinclair endorsed Dutton's view that the set-up opportunities the sensors delivered would be significant. "This puts us more in line with the rest of the motorsport world in terms of the analysis we can do," he said. "For a long time this Dunlop tyre has been a bit of an unknown and to a certain extent the teams have put it on the backburner a little bit and elected to concentrate on suspension and other changes to try and make the car perform better, but this opens up big scope of information that we haven't really had so it's pretty interesting.

"I think the engineering focus in the short term will shift to what's happening with the tyre. Ultimately the tyre is the most important part of the car. I think everybody's understanding of the tyre has been a bit of black art." RT


Dunlop Motorsport

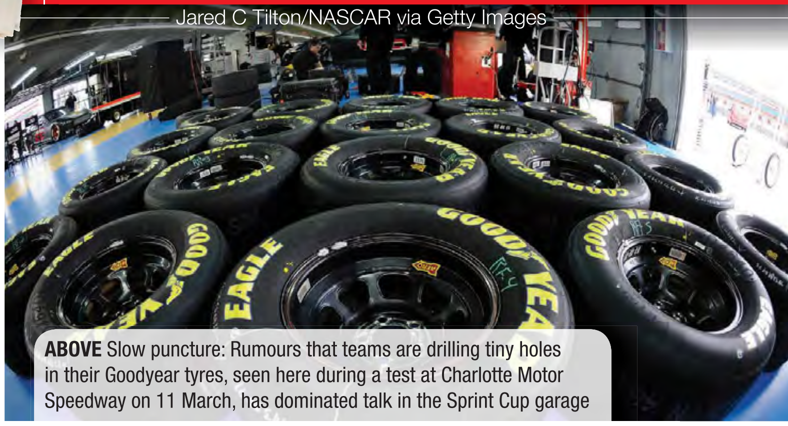
ABOVE With immediate effect, tyre pressure monitoring systems will be fitted as standard to all cars in the Australian V8 Series


TCR International Series

LEFT The brand-new TCR International Series staged its first four races over the weekends of 29 March and 12 April, supporting the grands prix of Malaysia and Shanghai. The series attracted a biggest grid of 15 cars from four brands, with the Proteam Ford Focus entries sidelined by several technical issues generally thought to relate to a lack of testing.

The first meeting saw widely predicted victories from the SEAT Leon entries, the TCR formula evolved from that of the SEAT Leon Eurocup, but at the second meeting in Shanghai, Gianni Morbidelli broke the SEAT domination with his Honda Civic, built for the TCR series by JAS in Italy.

The series now moves to Europe for three meetings during which grid numbers are expected to grow



Jared C Tilton/NASCAR via Getty Images

ABOVE Slow puncture: Rumours that teams are drilling tiny holes in their Goodyear tyres, seen here during a test at Charlotte Motor Speedway on 11 March, has dominated talk in the Sprint Cup garage

NASCAR looking for pinholes?

Andrew Charman

FONTANA, CA: The ever-present battle between NASCAR's rule makers and teams trying to exploit potential regulation loopholes appears to be focusing on tyres.

Following the Sprint Cup race in California on 22 March the Richard Childress Racing no 31 team of Ryan Newman was handed down penalties at NASCAR's second most severe level 'P5', for what was described as "manipulation of tyres".

Crew chief Luke Lambert was suspended for six races, as were the team's tyre technician James Bender and engineer Philip Surgen. Lambert was also fined $125,000 while car owner Richard Childress and driver Ryan Newman were each penalised by 75 championship points – a race win is worth a maximum of 48 points.

The penalties were announced after NASCAR took tyres from several cars – including Newman's – following the races in California and Phoenix. The tyres were sent to an independent laboratory for evaluation.

NASCAR did not describe what form the RCR team was deemed to have manipulated its tyres. Speculation in the NASCAR garage this season has suggested some teams are drilling tiny holes – 0.001 to 0.002 of an inch in diameter – in the sidewalls of the tyres, which allow them to bleed out air pressure and reach their operating temperature more rapidly, improving grip.

Tyre supplier Goodyear has criticised any potential modifications, Goodyear race director Greg Stucker telling FoxSports.com that such practices could damage the integrity of the tyre.

"You run the risk of damaging the structural members of the tyre itself – the tyre has cords; it has fabric that creates its structure, if you damage one of those cords, then you lower the integrity of that component," said Stucker. "You certainly have a high risk that the tyre could fail because you've damaged one of the components."

He said that Goodyear's tyre pressure recommendations were made based on the known loads at a specific track and the construction of the tyre. "Those two work together to carry the loads that the car is going to see – if you try to manipulate that you could be operating outside the envelope where the tyre is meant to operate."

Childress appealed the NASCAR decision and after a hearing the points penalties were reduced to 50 points and Lambert's fine cut to $75,000. However the suspensions remained and as *Race Tech* went to press Childress was making a final appeal.

* Suggestions that teams should be permitted to fit tyre bleeder valves, allowing manual bleeding of pressure during pit stops, have been rejected by NASCAR, which says the technology is too inconsistent and the failure of a bleed valve could produce a catastrophic tyre failure. RT

Digital dash on way to NASCAR

Andrew Charman

DAYTONA BEACH, FL: NASCAR Sprint Cup teams have begun testing a digital dashboard, which is set to be mandated for the series in 2016. Some teams are expected to race with it later this season, the NASCAR rule book allowing use of the digital unit after 6 August.

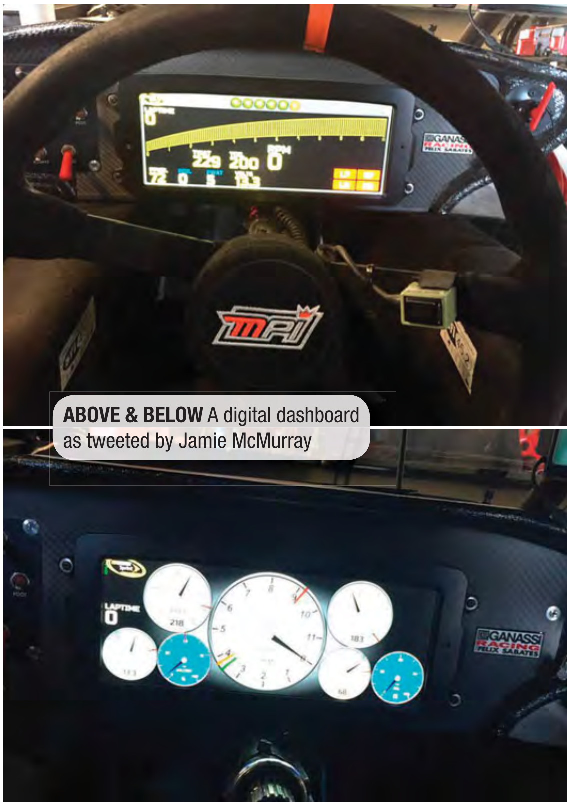
Driver Jamie McMurray revealed the existence of the unit when he tweeted two pictures of it during Goodyear tyre testing at Kentucky on 13 April. He showed his Twitter followers how he could dial through pages from a rev counter curve to a page of traditional-style dials but in a digital format. "It's way different to what we've been using, I really like it," he said.

Speaking on SiriusXM NASCAR Radio, the sport's chief racing development officer Steve O'Donnell said that the change was aimed at putting more information in the hands of drivers and teams, but also eventually spectators.

"If you're sitting at the race track, and you're on your device, we want you to essentially be in Denny Hamlin's car and be able to see what he is seeing and react to it," he said. "It's evolving, and it's something that we think can be a real game changer for the sport in terms of us showcasing technology.

"There's also some proprietary information – we want to make sure we keep that with the teams from a competitive standpoint, but we have some really cool stuff potentially coming for '16 and I think the fans will ultimately enjoy what they see."

NASCAR has to date released no further details of the dash, its construction or supplier. RT



ABOVE & BELOW A digital dashboard as tweeted by Jamie McMurray


180 MPH WITHOUT MOVING AN INCH

Gordon calls for more pit tech

PHOENIZ, AZ: Four-time NASCAR Sprint Cup champion Jeff Gordon has called for the elimination of timing lines in the sport's pitlane. Drivers are regularly penalised for not maintaining the pitlane speed limit by trying to gain an advantage by speeding between the measuring lines. Gordon maintains that with the video-based pitlane officiating technology introduced for 2015 it should be possible to require drivers to maintain the mandated speed limit along the entire pitlane.

"We've got to get rid of these speed lines – it doesn't make any sense," he said. "The speed limit is the speed limit, you should never be able to break it. You should carry the speed limit all the way down pit road."

Responding to his comments, NASCAR's chief racing development officer Steve O'Donnell agreed that the driver had a valid point. "The timing loops really play into our current timing and scoring system, so we believe it's the most fair system to have today," he said, "but as we look forward, and as we integrate our timing and scoring system potentially with the Pro System and a lot of the new technology at the race track, I think you could see us evolve to that potentially in the future."

Meanwhile studying data after six rounds of the 2015 NASCAR Sprint Cup reveals that the new pit road officiating system had resulted in 45 penalties caused by pit crews.

More than half of the penalties, 23, were the result of tyres being judged not to be in the control of a crew member. The second most frequent penalty concerned pit crew jumping over the wall too soon, called 16 times.

NASCAR has now ensured that teams penalised for a pit lane issue will be able to view official video of the incident almost immediately, on their pit box. Previously the video was generally sent to team transporters that had the necessary internet bandwidth to view it. RT

Russell LaBounty, LAT for NASCAR

ABOVE Running jump: Team pit crews have needed to time their jumps perfectly since the arrival of new technology in the pitlane, such as here at Phoenix on 15 March

LMP2 to become a spec series

William Kimberley

LE MANS, France: As anticipated in *Race Tech* 174, the Automobile Club de l'Ouest (ACO), IMSA and the FIA have announced that LMP2 will become a spec engine series in 2017. The number of car constructors will also be limited. According to the official press release, the aim is to secure the long term future of the class by reducing costs and improving stability.

The rationale behind it is that with the number of different chassis currently available to customer teams – some manufacturers supplying just one or two cars – the cost per car is far higher than for a manufacturer supplying 10 cars to several teams. By limiting the number of manufacturers, the business case is far more sustainable for the supply of cars plus teams will receive a better quality product with lower associated maintenance and operational costs.

"The LMP2 category has been one of the great motorsport success stories, and the ACO is very proud of what has been achieved," said ACO president Pierre Fillon. "We are in consultation with the manufacturers and the teams to find the best solution for the new 2017 regulations. We must remember that LMP2 is for teams and drivers, it is not a manufacturer category outside of North America, and we must build a sustainable business model for teams, cars and engine manufacturers."

Twenty-one engine manufacturers were consulted about the best way to reduce costs and the universal opinion was that the only effective way forward was to have a single supplier. This was recently announced by the World Motorsport Council and the tender process for this will begin in the summer with further development due to be announced at the ACO press conference at Le Mans.

The reaction to the announcement has been greeted with off the record hostility by a number of potential suppliers. RT

BELOW If things turn out badly for Strakka, the new Nissan-powered Dome S103 could be redundant by 2017 under the new proposed regulations

New-generation Hyundai i20 WRC breaks cover

ALMEIRA, Spain: The Hyundai Motorsport team completed a four-day test of the new-generation i20 WRC car in the Spanish region of Almeria in mid April. The test marked the next important phase of development for the car, which will make its debut in the 2016 FIA World Rally Championship. Work focused on engine and chassis development, as well as altitude testing with the latest iteration of the car, which has been upgraded compared to the version used in previous tests.

Hyundai Motorsport has established a detailed testing plan for the new generation i20 WRC and had hoped to introduce the car later this season. However, there has been a change on the planned homologation of the New Generation i20 WRC due to production schedules. The team will now shift the target to debut the new generation i20 WRC at the start of the 2016 FIA World Rally Championship at Monte Carlo rally.

In addition, a series of further upgrades will be introduced to the current Hyundai i20 WRCs in the remaining rallies of 2015 in a bid to help the team fight for podiums regularly in only its second season in the competitive World Rally Championship.

ABOVE The new-generation Hyundai i20 WRC undergoing tests in Spain, but it will not be seen in the World Rally Championship until next year

"We had a very detailed week of testing planned in Spain recently, as we put an upgraded version of our new generation i20 WRC through its paces in the Almeria region," said team principal Michel Nandan. "Kevin and Thierry worked on engine and chassis development, as well as altitude tests, which will help us to further develop the car as we move through 2015. We had hoped to introduce the new car later this season but unfortunately an issue with the homologation schedule – related to production of the three-door road version – will delay our programme. We have therefore opted to continue focus on the five-door version of the new generation i20 WRC which will compete at Monte Carlo next year. This revised schedule gives us extra time to ensure the car is where we want it to be performance-wise. At the same time, the current Hyundai i20 WRC will undergo a number of important updates which we hope will keep us in the fight for podiums this season." RT

New Škoda Fabia R 5 takes up the mantle

Mladá Boleslav, Czech Republic: The new Škoda Fabia R 5 has been successfully homologated for rallying. Since the start of the project, Škoda Motorsport has invested 15 months of intense development work to fine-tune the car and ensure that the ultra-modern components interact perfectly.

ABOVE The new Škoda Fabia R 5 that continues the Czech company's long rallying tradition

Based on Škoda's new production Fabia and is the successor to the Fabia Super 2000, the new four-wheel drive car is powered by a 1.6-litre turbo engine in compliance with FIA regulations and mated to a 5-speed sequential gearbox. Its weight is at least 1,230 kg as stipulated in the regulations.

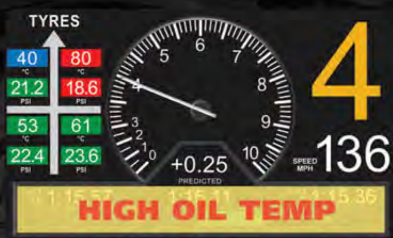
In the run up to homologation, about 10,000 kilometres of testing were completed on a wide range of roads and conditions, including in the Czech Republic, Austria, Germany, Italy, France, Greece, Spain and Finland and in recent months, it has been subjected to a comprehensive approval process, which has now ended successfully with the approval from the FIA.

"We are delighted that the FIA has given us the green light," said Škoda Board Member for Development Dr Frank Welsch. "Now we can prove just how good our new rally car is in the race series.

"When working on the third-generation production Fabia, which enjoyed an extremely successful start, we incorporated some of the genes from our rally cars and developed the most emotive Fabia ever. Conversely, the production model now formed the basis for the new Fabia R 5." RT

Motorsport. Redefined.

Highly Evolved.



Actual Screen Images

The STACK LCD Motorsport Display is the next evolution of driver communcation and data acquisition. Designed specifically for the harshest of environments, the carbon composite housing is IP67 sealed against water and dust intrusion and will easily withstand 20 g of continuous vibration and 50 g of shock. Our 7" LCD panel ensures easy visibility under all circumstances with a retina level pixel densisty, unmatched brightness and an optically bonded lens for extreme glare suppression. The display layout is fully configurable to your individual specifications. The system will accomodate four programmable data bus channels (2 CAN and 2 serial) in conjunction with a nearly limitless amount of discrete analog sensors and its integrated 3 Axis Accelerometer. Data collection can occur at up to 1 kHz and the internal memory allows for practically infinite recording time. User defininable warnings take advantage of super bright, multi-coloured LEDs placed around the perimeter of the chassis to alert the driver to critical onscreen information. Quite simply, everything else suddenly seems a bit dated.

World Class Instrumentation

stackltd.com

IndyCar

Strength of Indy aero kits under scrutiny

Andrew Charman

ST PETERSBURG, FL: The manufacturer-designed aerodynamic kits introduced by the IndyCar Series for the 2015 season have come under scrutiny following several breakages in the season opener, during which a spectator was injured by flying debris.

A woman was walking behind the grandstands, around 100 yards from the track, during the race at St Petersburg, Florida on 29 March when she was hit on the head by a piece of carbon fibre that had come from one of the competing cars. Local media reports suggested she suffered a fractured skull and was hospitalised. IndyCar immediately launched an enquiry into the incident while the spectator later declared her intention to sue over the injury.

Many predicted the opening race would be littered with debris cautions caused by contact between cars and resultant breakages on the aero kits introduced by Honda and Chevrolet, both of which feature a number of small winglets reminiscent of Formula One practice. In fact, 22 of the race's 110 laps were lost to cautions, mainly to recover pieces of carbon fibre from the track.

Before the second round of the series at NOLA Motorsports Park, Louisiana on 12 April, both manufacturers were permitted to add extra strength to their kits. Honda strengthened the front wing end plate by adding extra panels on its outer and inner faces and a curved plate to the base of the assembly, and also stiffened its rear wheel guards.

On the Chevrolet kits an extra strengthening piece was added to the base of the front winglets, and an internal rear bodywork stay glued in for extra strength.

IndyCar competition president Derrick Walker praised the quick response of Honda and Chevrolet to the issue. "With a quick turnaround from St Petersburg, our partners were very diligent in making these enhancements in time for this weekend's event," he said. "We will continue this collaboration and expect additional improvements in the future."

These came quickly, more changes being requested by series officials before the third round of the series at Long Beach on 19 April. Chevrolet was made to remove the winglets from its front wing assembly until a tethering system had been designed for them, while Honda was required to make additional reinforcements to its rear wheel guards. RT

750 wins and counting

BAHRAIN: The Bahrain Grand Prix saw AP Racing take its 750th Formula 1 victory as a supplier of racing brake and clutch components, a sequence that started in the 1967 Dutch GP. Since then it has supplied its components to every single F1 championship winning car and currently supplies its components to every F1 team this season.

"AP Racing offers brake and clutch products of the highest quality to its Formula 1 customers and works very closely with them to offer the most innovative solutions," said Charles Bolton, AP Racing managing director. "The whole team at AP Racing is delighted with this achievement which is a testament to their continued hard work." RT

IN BRIEF

ACCORDING to rumours, the latest VW Group boardroom shenanigans that is reported to have slightly sidelined VW chief Ferdinand Piech, who was adamantly opposed to coming into Formula 1 while Bernie Ecclestone was involved, it could mean that a F1 entry could get the green light. CEO Martin Winterkorn, who came out the winner with an extended contract, is said to be much more open to the idea. When he was Audi chairman, he was a big supporter of its racing projects in sportscars and the DTM and Audi, which last year employed three key ex-F1 staff members, is widely understood to be the most likely to undertake an F1 programme.

INDYCAR engine supplier Chevrolet was fined 220 points following the opening round of the 2015 series at St Petersburg, Florida on 29 March for making a "non-minor repair" to its engines. Chevrolet revealed that a potentially faulty batch of valve springs led to them being replaced, with IndyCar's prior approval, on 11 of the manufacturer's 12 engines competing. Each change resulted in a 20-point penalty according to the lifecycle-based engine regulations. Chevrolet had earned 128 points in the race.

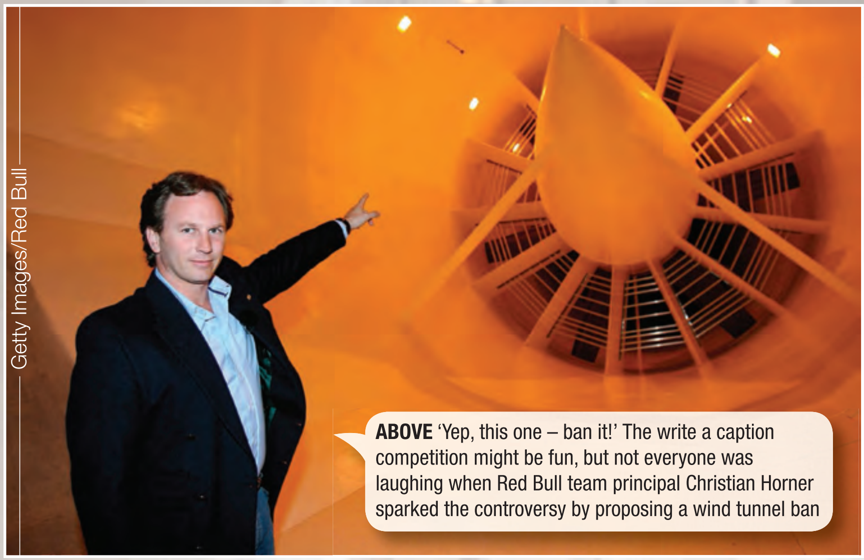
THE 8th International Business Day that takes place in Le Mans on the 10/11 June in the run-up to the 24 hour race, has confirmed that 3A, Citroën Racing, KA Sensor, Peugeot Sport, Pyromeral Systems and Stäubli Faverges have all registered for the event while Rebellion Racing has agreed to host delegates in the paddock on the afternoon of the 10th.

Why this ‘dinosaur’ still rules

Branded “dinosaur technology” by one team, the subject of a proposed ban by another, wind tunnels are under attack. But our **Expert Witness**, a knowledgeable F1 insider, says the critics are wrong. Here’s why

Mercedes GP

ABOVE As wind tunnel restrictions began to bite, technical innovations meant that teams have been able to achieve more in less time



Getty Images/Red Bull

ABOVE 'Yep, this one – ban it!' The write a caption competition might be fun, but not everyone was laughing when Red Bull team principal Christian Horner sparked the controversy by proposing a wind tunnel ban

IS THE Formula 1 aerodynamic community under threat of extinction? Is this peril genuine, justified, only applied to experimental testing, i.e. a wind tunnel ban, or is it just another vested interest-fuelled political statement? I am going to try to sort out the real stories in here, what has happened so far and why, and reveal where the likely future may be...

PIONEERS

When motorsport pioneers started down this route, there was an immediate understanding about drag reduction. The slipstreamed teardrop shapes of the earliest cars showed an appreciation from aviation and nature that smooth organic forms with minimal frontal area improved performance, particularly on some of the banked, high-speed tracks of the day.

It wasn't until the late '60s that the concept of taking the aerofoil design, again from aircraft, and inverting them to push racecars into the ground, improving grip and cornering speed, led to aerodynamics starting to really gain prominence. Even in those early designs, active aerodynamics – to give downforce or braking improvement in the corners, but then move to reduce drag on the straights – were prevalent. Over 50 years later, our high-performance road cars have sported this technology because the requirements still remain exactly the same. Once the genie and its power to improve lap time is out of the bottle, it is very hard to get it back in again, particularly if it is industry-applied and relevant.

TOOLS OF THE TRADE

The track environment was where it first started, experimenting with parts on the real car. This remains to this day the fundamental place where the car competes, is measured and results must be achieved. The problem is the time and cost full-scale parts take to make, that they have to have structural integrity and that you would prefer to know what they are going to do – that they are beneficial and, most of all, safe – before they go anywhere near the circuit. In those early days of evaluation where the driver was the sensor, this was the brave and only design of experiment to try and make progress. ▶

> ***"Once the genie and its power to improve lap time is out of the bottle, it is very hard to get it back in again"***

The wind tunnel, already used for military then commercial aviation, came next. The ability to evaluate multiple designs and settings on a model in a carefully-controlled environment meant you could be confident of a modification's performance before full-scale manufacture. The initial challenge was to update these facilities to provide an accurate enough environment for automotive, with rotating wheels, moving ground and boundary layer control all enhancing the correlation to the track.

It wasn't until the '90s that Computational Fluid Dynamics were utilised. The computational power and software development has escalated in a similar way to Moore's Law, making the technology increasingly capable and accessible to racing teams. In my view, and there has been strong evidence to support this, the tool is different and complementary to the wind tunnel. They have alternate strengths and weaknesses.

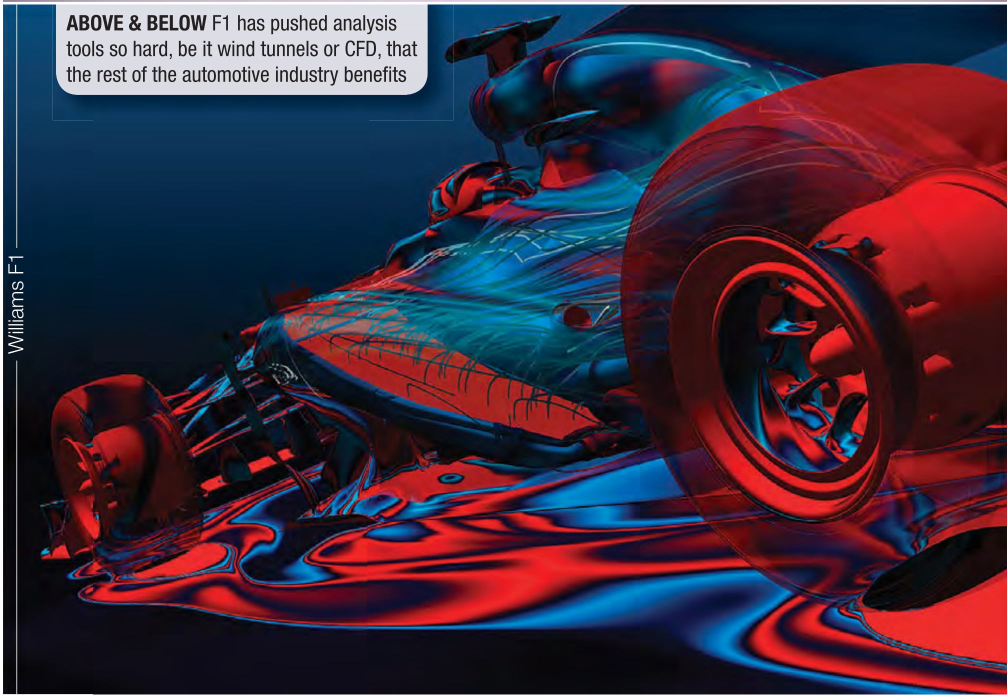
CFD's strength is its ability to explain flow fields and pressure distributions in 3D, allowing a result or characteristic to be better explained or understood. It also does not require the capital investment of a wind tunnel or model, or model parts to be made. Nor does it use as much electricity. *But*, despite all of the progress, it still remains a much, much slower aero development technology. Let me try and explain.

Both systems require a new component to be designed in CAD, ideally in a way it can then be made or meshed (usually both) depending on the discipline. This next part takes some time, even with automated systems/scripts and 3D printing technology and is hugely dependant on the component complexity and structural requirement.

To test the part a wind tunnel can measure the new item over a range of ride heights, yaw, roll and steer angles, mimicking the track conditions, in a matter of minutes. A whole car CFD case to assess a similar set of configurations would take up to a couple of weeks to complete. The outputs are different: the tunnel gives broadly a data output, depending on how instrumented the model is; the CFD gives data, but also post-processing of the flow to compare and contrast to understand why it is different to before.

The next issue is correlation, the tool's ability to produce full-scale components that give an identical result or characteristic


Mercedes GP


Williams F1

ABOVE & BELOW F1 has pushed analysis tools so hard, be it wind tunnels or CFD, that the rest of the automotive industry benefits

to that expected on the track. Traditionally the wind tunnel was the system that produced and signed-off all the components before manufacture. CFD has improved greatly in this regard, but is still some way off achieving the same level of confidence in the results. Therefore a 100% CFD-based system is more likely to produce components that do not correlate.

The last area is simulation, which has two types: offline, where the calculation is completely computational; and Driver In Loop (DIL) where test and race drivers provide additional input and feedback compared to the real car. The former is best utilised to get optimum wing and downforce/drag levels, as well as other car parameter sensitivities for the tracks on the calendar. The latter utilises the driver's development skills to both develop the simulator, but also learn tracks, prepare and provide support for races, analyse component updates and even understand impacts of new regulations.

THE CHALLENGE

Why is aero so important? From all of these combined tools it is quite simply performance. More than that, it is one of the most fertile areas within the team's control, per unit of resource, to improve it. Over time other areas such as tyres, electronics, control systems and even powertrain have either become prohibited or frozen or the same for everyone. For a while aerodynamics was left ▶


SILVERSTONEPARK™
SILVERSTONE PARK™
A global destination to create, develop and succeed.
2.7 million sq ft of planning consent and accommodation available to let.
FROM HERE WE CHANGE THE WORLD
For a viewing and further information, please contact:
DTRE
020 3328 9080
www.dtre.eu
James Watson
Email: james.watson@dtre.eu
To find out more visit:
silverstone-park.com
@SilverstonePark
MEPC

relatively accessible and unchecked – if you wanted proof of its performance value, then here it was.

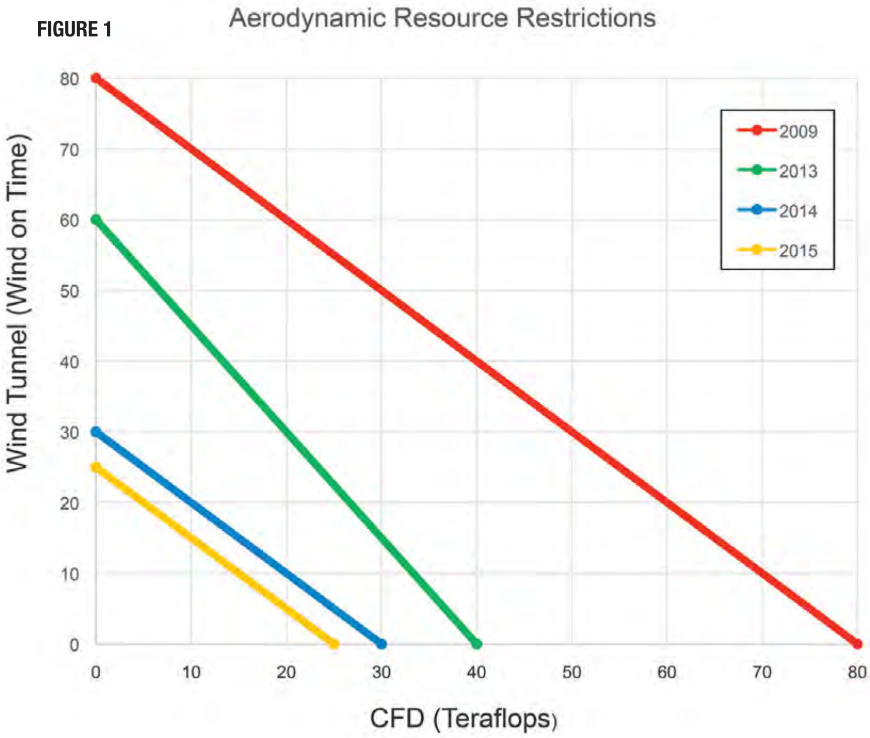
Teams would initially test in a wind tunnel one week in three, and have an aero department of perhaps 10 people. Within three years the amount of hours and staff had multiplied by five, swiftly followed by weekend and night shift running until all the 168 hours of the week were occupied.

CFD computational power and staff also followed this expansion trend to the point that some of the largest hardware in commercial hands (i.e. not government or military) was now in the possession of Formula 1 teams. Experimental development did not stop there, either.

With no space left in one wind tunnel, the obvious next step was to test in multiple facilities, often also at a 24-hour, seven days a week schedule. At its peak the rumoured maximum was four facilities. Logistics, design, manufacturing and management of the situation was extremely difficult with aerodynamic departments of up to 140 people in size, purely dedicated to F1.

It could not continue unchecked. The governing body started to audit and control the CPU capacity of the CFD clusters and the wind on-time permitted in the wind tunnels. Initially at a gradient limit of 80 teraflops of CFD or 80 hours of wind on-time per week, averaged over an eight-week period, or a compromise between the two. (See Figure 1.)

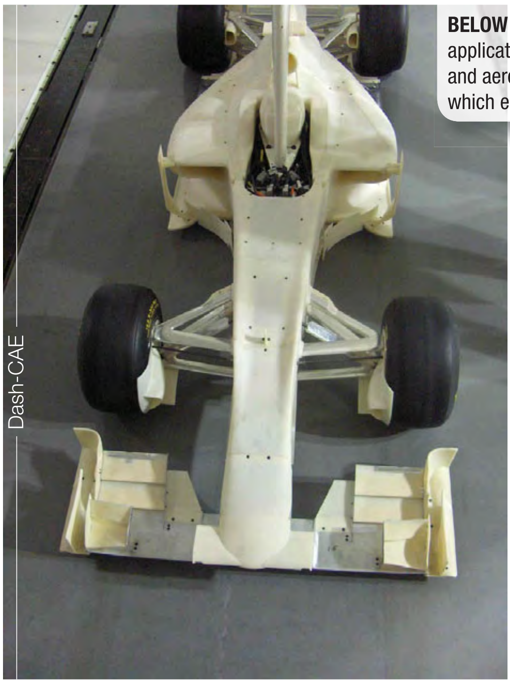
FIGURE 1



Over time these values have dropped to 40/60, then 30/30 in 2014 and 25/25 in 2015, with added controls on a single nominated wind tunnel being used. The number of wind tunnel runs and wind tunnel occupancy time are also now being limited.

This changed the game again, driving a secondary efficiency revolution in technology to extract far more information, quality and speed of data from the new reduced capacity and run times. The same quantity of development was generated with almost a quarter of the capacity. The limited occupancy was also intended to allow facilities to be shared, helping to offset the capital investment already made into those tools by the teams generating commercial revenue.

My argument would be simply this: if there was not the performance benefit from aerodynamics, the push to invest and develop in this direction would not exist the way it has. Controls have already been ▶



Dash-CAE

Mercedes GP

BELOW LEFT & RIGHT The vastly increased application of rapid prototyping to wind tunnel models and aero components is part of an efficiency revolution which enabled teams to outsmart testing restrictions www.racetechmag.com

DRIVING TECHNOLOGY INTO POLE POSITION

RACE TECH

INTERNATIONAL

WORLD MOTORSPORT SYMPOSIUM

30th Nov - 1st Dec 2015

www.racetechmag.com/wms

“This will change our sport for the better”

Ben Bowlby, Director of Motorsport Innovation, Nissan

ABOVE Top row, from left to right: Dr Sam Akehurst, BEng(Hons) CEng, Reader in Advanced Powertrain Systems, Powertrain & Vehicle Research Centre, Luca Marmorini, engineering consultant, Ulrich Baretzky, head of engine technology, Audi Sport, William Kimberley, Race Tech editor, John Iley, technical director, Caterham F1, Steve Eriksen, COO, Honda Performance Development, James Key, technical director, Scuderia Toro Rosso, Kirsty Andrew, sales director, Cosworth, David Lapwirth, technical director, Prodrive, Sergio Rinland, managing director, Astauto and Blake Fuller, president, Braille Battery.

Bottom row , left to right: Gilles Simon, engineering consultant, Arnaud Martin, director powertrain, RML Group, Dominic Harlow, Dominic Harlow Consulting, Dialma Zinelli, head of aero, Dallara Automobili, Bernard Niclot, FIA technical director, Soheila Kimberley, Race Tech publishing director, Andy Cowell, managing director of Mercedes AMG High Performance Powertrains, Roger Griffiths, Andretti Autosport’s director of motorsports, Willem Toet, head of aerodynamics, Sauber F1 and Russ O’Blenes, senior manager performance & racing engines, GM Powertrain Advanced Engines

www.racetechmag.com

ABOVE The size of the grid at Melbourne's season-opener should have acted as a wake-up call for a sport torn apart by vested interest

Etherington/LAT

introduced, and continue to be refined, in order to drive efficiency rather than huge spending to achieve aero goals. This should continue to be the case.

> ***"Having stockpiled the entire supply of the best CFD chip for F1, you might push for more CFD-orientated aero development?"***

COST v VALUE

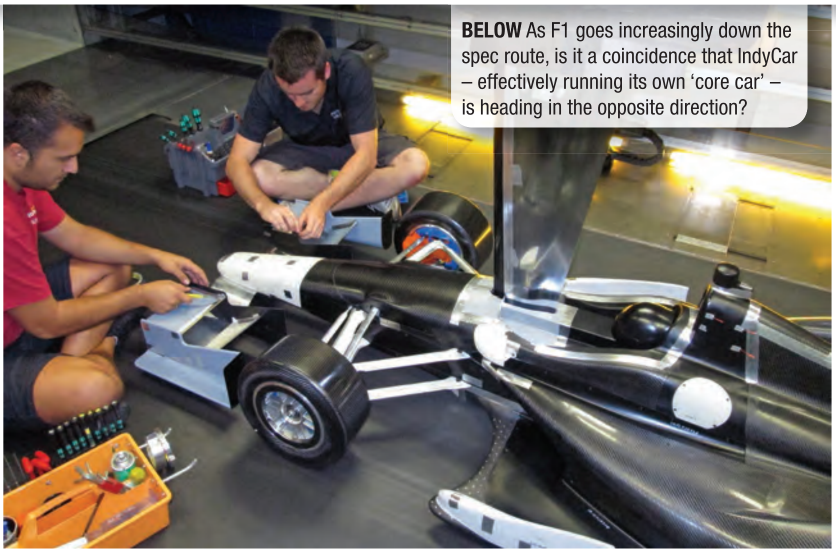
So the question has to be why has the debate arisen now, who in particular is pushing it and for what motivation? Well F1 clearly has a financial challenge at the moment: the small size of the field at the first race this season was a shock to everyone, even if there were extenuating circumstances. The new powertrain regulations are now over a season old and while the hybrid and energy recovery technology is broadly correct, it clearly contributed to pushing some teams up to or even over a financially sustainable limit. With long-term commitments and costs associated to this, where are further cost savings going to come from? Are aerodynamics and the wind tunnel the right place?

Red Bull's Christian Horner ignited the debate by suggesting a possible ban on wind tunnels to cut costs. Force India's Bob Fernley then further fanned the flames by supporting the proposal and referring to tunnels as "dinosaur technology". So let me offer a couple of 'hypothetical' scenarios.

- You are a team that was very successful, but now seems to be struggling in this new much more powertrain-orientated formula. Worse still, your technical head and aerodynamic expert is stepping back to look at other things. However having carefully analysed the opportunities in the regulations, you have stockpiled the entire supply of the best CFD chip type for optimum F1 case calculation. Perhaps in that situation you might push for some sort of powertrain equalisation, or in the interests of cost saving a much more automated CFD-orientated aero development?
- You are a team with your own wind tunnel, but it is not at the optimum required level for F1; attempts to get the substantial backing required to build your own new one did not reach fruition. You have had an extremely challenging winter financially and, although you are a customer now renting time in a state of the art wind tunnel facility, there were some cash flow issues that meant your car development was severely compromised. In this situation it would be understandable to feel that competitors who have invested in wind tunnels already have an uncomfortable advantage over you. Banning them would level that playing field.

So it is feasible, if this was the case, that the arguments are not as straightforward as they first seemed. Inevitably you will try to look after your own team's interests for performance, of course, but even more so for financial survival.

Therefore if the teams are always doing this, I would suggest you need a strong,



BELOW As F1 goes increasingly down the spec route, is it a coincidence that IndyCar – effectively running its own 'core car' – is heading in the opposite direction?

impartial, powerful central entity to preside over them. This would ensure there is still innovation, technical choice and sustainability for the category going forward.

VERDICT

The wind tunnel, combined with CFD, simulation and track correlation, remains the best way to develop the aerodynamics of an F1 racecar today. The speed of development required and the fact that wind tunnel technology has not stood still waiting for other systems to catch it, means the accuracy, quantity and correlation it gives per unit of calendar make it essential.

A concern for everyone would be with ever decreasing aerodynamic scope, the 'core car' may ultimately become 'GP1' with little or no differentiation or technical contribution. Is it coincidental that IndyCar has just adopted the freedom of bodywork kits around its version of the 'core car'?

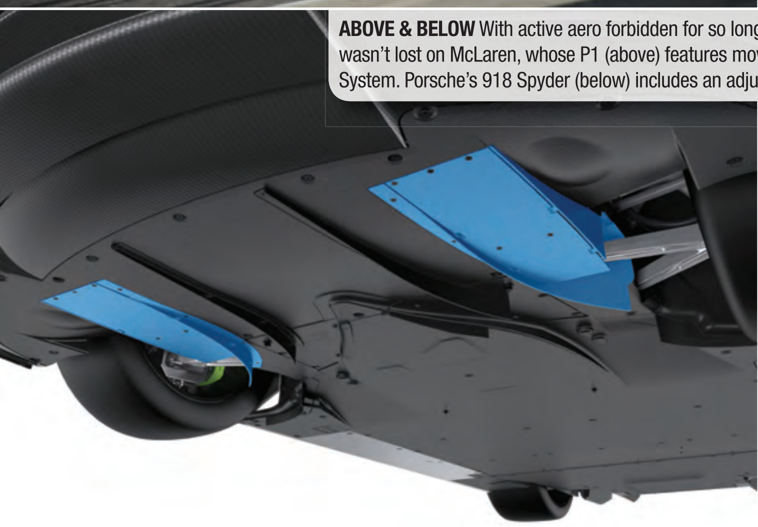
The OWG (Overtaking Working Group) was formed prior to the large F1 aerodynamics regulation change in 2009, with the intent to make sure outright performance was not only reduced, but the stability and wake of the flow was improved to create better racing. This type of analysis work to make the aerodynamic contribution relevant, improve the show and sustainability should be integral to any evolution going forward.

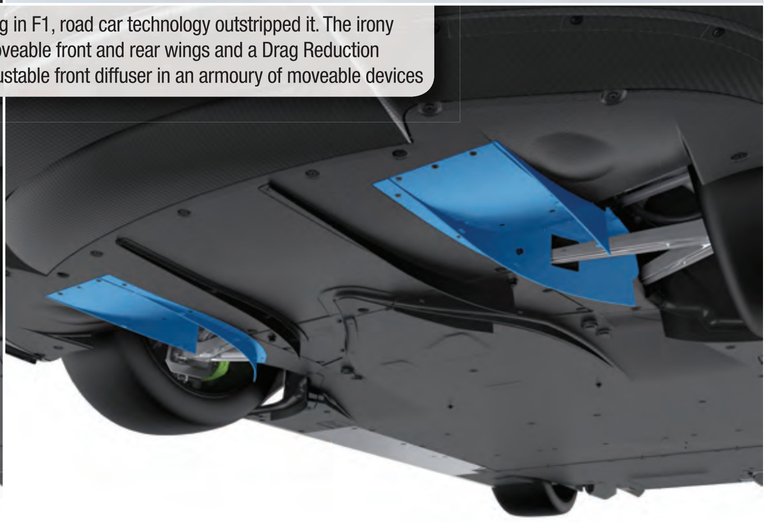
The more interesting question or framework would be to agree on a budget or cost control, probably the only definitive way of keeping spending in check. Make it an engineering not a spending competition and let the teams decide where best to allocate their budget in order to achieve maximum benefit from it.

Remind me why that didn't progress before? The teams couldn't agree.

Perhaps it is about time the category looked a bit more at the big picture of overall cost being imposed instead of being unable to agree where it should be saved? For the good of the sport, before there are further casualties. RT

ABOVE & BELOW With active aero forbidden for so long in F1, road car technology outstripped it. The irony wasn't lost on McLaren, whose P1 (above) features moveable front and rear wings and a Drag Reduction System. Porsche's 918 Spyder (below) includes an adjustable front diffuser in an armoury of moveable devices





BELOW F1's inner circle has looked impenetrable in recent years but Gene Haas is confident his business model will help him succeed where others failed

READY FOR THE PIRANHA CLUB

"Welcome to the Piranha Club," was the wry greeting famously extended to one F1 newbie. **Matt Youson** finds out why Haas F1's entry plan could become the template for all new teams, enabling it to stay afloat where predecessors were dragged under

THIS isn't a good time for the smaller teams in Formula 1. Admittedly, history would suggest it's rarely a good time for smaller teams – but the current environment seems particularly harsh for those at the back and, indeed, at the back of the middle. It seems, in short, not the climate to encourage new entrants, but less than a year from now, if all goes to plan, Haas F1 will line up on the grid. The impolite question is: why? The better one is: how?

Team principal Günther Steiner has been a regular visitor to the F1 paddock in recent months. The former Red Bull Racing technical director insists his new charges come into the sport with eyes open. He suggests the assumptions of Haas F1 are rather different to those under which the last tranche of teams – Campos/Hispania, Virgin/Marussia/Manor, Lotus/Caterham and USF1 – entered, or failed to enter, the sport.

"We analysed those other teams, and how they did it, and in a way we were privileged because we weren't entering the sport a few years ago," he suggests. "I don't think their troubles are all their own fault. They were under the illusion that F1 was going to get cheaper – and it didn't. In fact it got a lot more expensive – especially with the new engines – and a lot more sophisticated. They were also maybe under the illusion that a cost-cap was coming in. Those were different times. It's a tough business, Formula 1."

$40 MILLION FAIRYTALE

The Haas model, explains Steiner, has two fundamental differences to that espoused by the Class of 2010. The first, as stated above, is that F1 isn't likely to impose an upper-ceiling on spending, and the pipe dream of running a team for $40 million per season remains the stuff of fairytale. Then, as a corollary to this, Haas isn't attempting to enter the sport as a fully-fledged independent entity. It will, instead, enjoy a technical partnership with Ferrari, exploiting opportunities for cooperation to the maximum currently allowed in the regulations.

"The start-up teams – though you can't really call them that if they were in business for up to five years – they did it how we *don't* want to do it. We would not have come in working like that, doing everything for ourselves. I know how difficult that is. You cannot announce a team and say you're going to build an F1 car from scratch in six months. These cars are highly complicated.

"You can work alone if you have enough time and enough money – but enough

> *You can work alone if you have enough time and enough money – but enough time is a long time and enough money is a lot of money"*

ABOVE A technical partnership with Ferrari is the cornerstone of the new team's gameplan, enabling it to exploit F1's tech sharing opportunities to the maximum

time is a long time and enough money is a lot of money. We decided to partner with somebody to use their experience as the starting point. I think this is the way for F1 in the future. If you want to start a team, you have to partner-up."

Haas announced its intention to use a Ferrari power unit in September 2014 – though the strong suggestion at the time, particularly from Marco Mattiacci, then Ferrari team principal, was that the Scuderia was interested in developing a partnership that "has the potential to evolve beyond the traditional role of supplying our power unit and all related technical services." It will see Haas using Ferrari as a supplier of those parts not expressly proscribed by the slimmed-down Appendix 6 of the F1 sporting regulations – in effect purchasing suspension and steering systems from Ferrari as well as various ancillary mechanical components.

The value to Ferrari of the relationship is vague. Haas Automation sponsorship appeared on the F14T a few months before the power unit deal was announced, and it has been suggested – though not confirmed – that, in the longer term, the Scuderia sees potential not only in the value of having another development avenue for its power unit but perhaps also in having a semi-detached 'B-team': in effect a diluted version of the technical relationship between Red Bull Racing and Toro Rosso with which it may try out new ideas.

This is slightly contradicted by Steiner's assertion that over time Haas F1 will probably take more responsibility in-house – though he also stresses this is still a nebulous aspiration rather than a date-specific plan.

"I think we will start to manufacture more bits," he says. "When you start a relationship like this you don't know how it works. We adjust the plan as we go along. At the moment there is no plan that in year two we design the suspension and the gearbox. But could we manufacture suspension and bodywork? Absolutely. We don't want to 'delay our failure'. We don't ▶

> *This is the way for F1 in the future. If you want to start a team, you have to partner-up"*

want to make announcements claiming in two years all of a sudden we'll be clever and will do it ourselves.

"There's so much to be done. It's not only Year One. I repeat, the teams that folded, they didn't go down the first year. It isn't about the first year or the second. You need to have a good, stable plan for at least five years. We hope… we more than hope… we have got a good plan in place."

Another aspect of the plan is a collaboration with Dallara. Original reports suggested the Italian chassis manufacturer would be central to the project and, had Haas debuted in 2015 as originally mooted, that would likely have been the case. But with Haas developing facilities of its own, that particular link appears to have been downgraded. "We will use their consultancy – they will be a consultant – but they will not run the project," confirms Steiner.

Like any prospective F1 entrant from the United States, Haas F1 has a fine line to walk. On the one hand, a team based in the US is able to excite considerable interest and sponsorship opportunities; on the other, it faces the headache of being isolated from the Formula 1 mainstream with the attendant issues that causes in attracting personnel and sourcing third-party expertise. The Haas solution is a twin-centres ▶

BELOW The F1 team's headquarters (seen right) are located in Kannapolis, North Carolina, next door to the NASCAR factory

Getty Images/NASCAR

BELOW Gene Haas isn't just a businessman, he knows racing: pretty well if the success of the Stewart-Haas Racing NASCAR team (Kevin Harvick is pictured left) is anything to go by

approach, with headquarters and design based in Kannapolis, North Carolina, and a European base in Banbury, Oxfordshire, formerly the home of the Marussia team and recently purchased from the administrators (Manor having relocated to its ancestral dwelling in Dinnington, South Yorkshire).

EUROPEAN BASE

Had the Marussia factory – itself formerly the base of Ascari – not become available, Haas F1 would have secured comparable facilities in the region, having taken the logical decision to set up shop in England's motorsport valley. The cars will be assembled in Banbury, which will also be a logistics hub, transporter base and, eventually, home to the race team. Steiner, however, is adamant that hiring that race team won't become a priority until the end of the current season. "We are basing the race team in England because you can get the people there. My plan is to recruit at the end of 2015 when the season is over, because there really is not a lot to do now. You need some people, but not all of them.

"We will get talent that is there already because there is always talent around. We will feed a few new people in of course, but you cannot start off a race team with all-new people. That just doesn't work in F1. In fact, it doesn't work in any business. The main thing will be the experienced people we will take from [the current F1 paddock]."

Tee/LAT

ABOVE Team principal Günther Steiner in conversation with Maurizio Arrivabene, his opposite number at tech partner Ferrari

Haas F1 has, however, been accumulating senior personnel over the last few months. Rob Taylor, former Jaguar/Red Bull Racing chief designer, has been recruited to fulfil the same role at Haas, while Ben Agathangelou is the new team's chief aerodynamicist, likewise renewing a working partnership with Steiner from their time in Milton Keynes. Making a shorter journey is former Jordan team manager Dave O'Neill, who recently held the same position at Marussia and will continue to do so for Haas.

Haas F1 began work on its debut car in the autumn of 2014, with aerodynamic work commencing in January this. According to a statement from the team, Agathangelou and Taylor have already designed a 60 per cent scale model of the car, which has been tested in Ferrari's wind tunnel, and chassis construction began shortly before the 2015 F1 season commenced.

"Like everyone else, the manufacturing will begin in July/August," says Steiner. "However, we want to be a little bit earlier starting to put the car together than the established teams because we are new. It will take us a few weeks longer. We want to have our car ready at the beginning of January, not the end of January.

> *"Haas is a racer. He's not just a business man who likes F1 and thinks he can do better"*

ABOVE The last proposed US entrant, US F1, made the mistake of going it alone as a constructor

EXCEPTIONAL PACE

"While there is still a lot of work to do, a lot has already been accomplished for Haas F1 Team to be competitive when we join the F1 grid in 2016. Our technical partnership with Ferrari has allowed us to develop our car and our people at an exceptional pace. The way we're going about our F1 team is new and different, but it's working. We're committed to our plan, we're committed to F1 and, most importantly, we're on schedule."

Inevitably, there is speculation about how much interaction there will be between Haas F1 and the Stewart-Haas Racing NASCAR team. Locating the headquarters of the open-wheel outfit in Kannapolis, next door to the NASCAR factory, suggests potential for quite a lot. Steiner, however, argues that in reality they will share very little.

"Marketing-wise, for sure, you can feed off each other. It will be very good. But we get to that point later. If we can share, fine, if not, we are still good – but for technical matters, it's not the plan," he says. "We have a complete new building beside their facility but we won't be using any of their staff – because they have to go racing. They have a full schedule: there is not an overflow of people there we can borrow. We need to learn from each other of course, but we need to start first before we do that. At the moment, they do it, we don't, so they cannot learn anything from us because we aren't producing much – but as we go along, we'll try to see if we can apply systems and share information. It goes both ways."

Listening to Steiner outline the roadmap for Haas, everything seems as it should be: a solid start-up with sound planning and realistic goals. But, of course, talk is cheap – and many teams have announced an F1 programme with what appears to be sound planning and realistic goals, only to be forced out by paralysing costs and unbridgeable performance deficits. So, why should Haas be any different?

It's a blunt question but one Steiner accepts with good grace – the current climate means it's not the first time he's been asked. The answer, he insists, lies in having a team owner who knows what he's getting into. "Don't forget Mr Haas is a racer," he says. "He's not just a business man who likes F1 and thinks he can do better. He's not listening to two or three people whispering that they can do it with half the money – or in half the time – and twice as good. He knows about racing and he knows what he's doing and he's under no illusions. Even the way we're doing it, F1 is a hard deal. It's going to be tough, but he knows that."

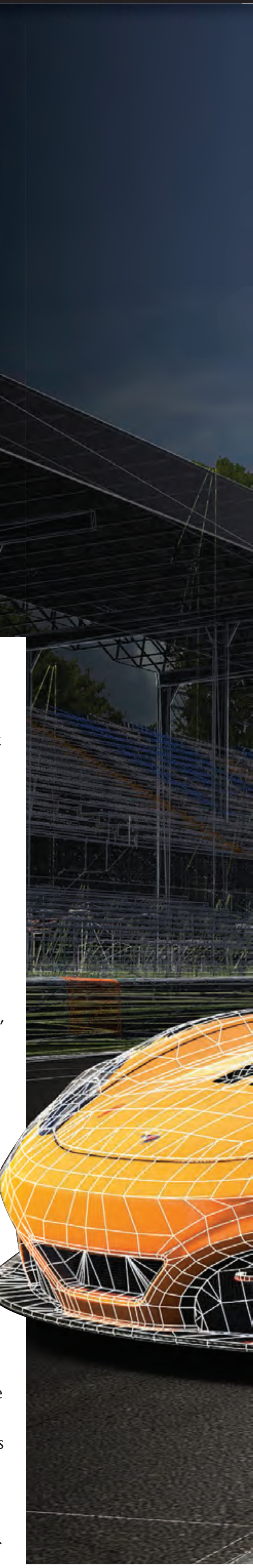
And perhaps herein lies an answer. Money builds Formula 1 teams but faith and resolution keep them going. Hopefully Haas F1 has enough of both. RT

ABOVE Haas F1 will be the first American team to compete since the unrelated Haas Lola outfit raced in the 1985 and 1986 seasons

Tee/LAT

GAME OVER

The days of dismissing sims as mere racing games are long gone. As **David Phillips** finds out when he talks to two vehicle dynamicists who have traded careers in the likes of F1 and NASCAR to do the same job in the virtual world



IT SEEMS ages since Jacques Villeneuve set tongues wagging by mentioning he used racing video games to learn unfamiliar circuits whilst transitioning from Indy cars to Formula 1. Some 20 years on, motorsports simulation has become integral to manufacturer and race team programmes at all levels of the sport. Only the most senior of old-school drivers does not hone his or her skills "in the sim", be it the multimillion-dollar, full-motion machines found at every Formula 1 team base or a steering wheel/pedals set mated to their home computer.

Of course, the impact of motorsports simulation extends beyond drivers adjusting their lines through Eau Rouge and The Corkscrew. Faced with the stratospheric cost of – and draconian limitations on – track time, teams and manufacturers increasingly rely on simulation for testing and development. And as their sims have become increasingly sophisticated, the pace of development in consumer motorsport simulations has accelerated to the point that the term "racing video games" is a misnomer.

Sure they're still loads of fun. But as the sophistication of titles like *Forza* and *Gran Turismo* blur the line between virtual and reality, so thinking of them only as "games" does them a disservice. Nowhere is this more evident than with iRacing.com, founded in 2004 by John Henry (owner of the Boston Red Sox, Liverpool FC and the "Fenway" in NASCAR's Roush Fenway Racing) and Dave Kaemmer (co-founder of Papyrus Design Group, developers of award-winning race simulations including *Grand Prix Legends* and *NASCAR Racing: 2003 Season*).

One measure of iRacing's commitment to authenticity is the fact that each of its nearly 70 virtual racetracks is laser-scanned and accurate to within 2 mm of the real thing. Another is the fact that Messrs Henry and Kaemmer employ two vehicle dynamicists with bona-fide credentials as "real world" race engineers to help build and develop iRacing's digital race cars: Eric Hudec and Chris Lerch. Bona fide? Consider that Hudec provided trackside engineering support for Dodge's NASCAR programme and, later, worked as race engineer for Petty Enterprises; Lerch's resume includes race and championship-winning stints as both a race engineer and vehicle dynamicist in F1 (Jaguar Racing), IndyCar (Precision Preparation Inc., RuSport and Pacific Coast Motorsports) and Formula Atlantic, along with several sports car teams in the Grand-Am and American Le Mans Series.

SYSTEMS APPROACH

To the layman, building racecars out of nothing more tangible than computer code would seem worlds apart from extracting the maximum performance from corporeal Formula 1, Indy, GT, stock cars and prototypes. Real or virtual, however, any vehicle can essentially be reduced to numbers. In the case of iRacing, those numbers are supplied by manufacturers and teams in the form of CAD files, blueprints and setup sheets – and supplemented by photographs and laser scans taken by iRacing staffers.

Dallara DW 12, Silver Crown car or Mazda MX5, however, Hudec and Lerch apply that data to the same proprietary framework, then fill in the details that make each car unique.

"We take a systems approach," Lerch explains. "We break the car into its major systems – masses and inertia, powertrain, aerodynamics, suspension, steering, braking, tyres, torque and power delivery. With each of those systems we further break them down into their component elements, prioritize and gather as much information as we can to create the mathematical inputs the model requires.

"So for the masses and inertias, when we (laser) scan the cars we also take a whole lot of photographs which I use, along with the art models, to place the masses at the appropriate locations on the drawings. From those drawings I do a first principles calculation to determine the centre of gravity, the ▶

RIGHT iRacing.com has partnered with McLaren Electronics to incorporate the ATLAS Express data analysis software into its system. Now members wishing to delve into engineering details to improve their car's handling (tyre data from a McLaren 12C is shown here) can do so using the same tool as F1 and NASCAR teams

> *"Real or virtual, any vehicle can essentially be reduced to numbers"*

ABOVE iRacing's commitment to authenticity extends not only to nearly 70 virtual racetracks, accurate to within 2 mm, but also two top vehicle dynamicists to model the cars that race on them total mass and the inertias which will go into the model; they have a first order influence on the cars' behaviour.

"For example, the mass/inertia properties of the McLaren MP4-12C are completely different from those of the BMW Z4. And *that* is the biggest difference between those two GT3 cars: how the masses and inertias are distributed influences the way the car moves under the application of forces and moments."

In many respects, iRacing's vehicle dynamicists' jobs vary little from their former duties in real world racing.

"At iRacing we have partners who supply us with information," Hudec says, "and we build our models to conform to the data they provide. For example, we make sure our load cases correspond with the load cases on the real data and any additional information we might receive, whether that be from a shaker rig, the wind tunnel or real track data.

"In the real world, my team-mates and I would collect the data ourselves and I would use my experience to match it with the software I was using to try to find speed. So the process is very similar."

Although Hudec (Carleton University) and Lerch (MIT) each have strong academic credentials, their contacts within the world of racing are priceless. Not just anyone can dial-up Rahal Letterman Lanigan Racing for an in-depth discussion on the BMW Z4 GT3, or Penske Racing and the NASCAR Sprint Cup Ford Fusion.

THE REAL DEAL

And developing those cars is not just a matter of creating a digital BMW or Ford that matches its real world counterpart's lap times at Watkins Glen. It must do so in a manner that emulates the real thing.

"Lap time is not my top priority," Hudec explains. "I can make a Formula 1 car do the same lap time as a Camping World Truck… and vice-versa. I can make a car do whatever I want in the sim. What matters is how the car responds to inputs. Does it behave in the same way as the real machine? That comes down to masses and inertias being correct; aerodynamics being accurate; suspensions, springs, dampers and anti-roll bars being in the correct proportion; power delivery matching the real torque curves. Then you'll have something that drives with a high correlation to the real thing.

"At the end of the day, we're looking to create a model that represents the real car with a high degree of fidelity. We'll never be perfect, but we keep getting better at making our cars directionally correct. We may not have the correct magnitude – but what our tools are telling us match the types of things teams would do to tune the real car. We may over or under predict what we need to do, but it's directionally correct."

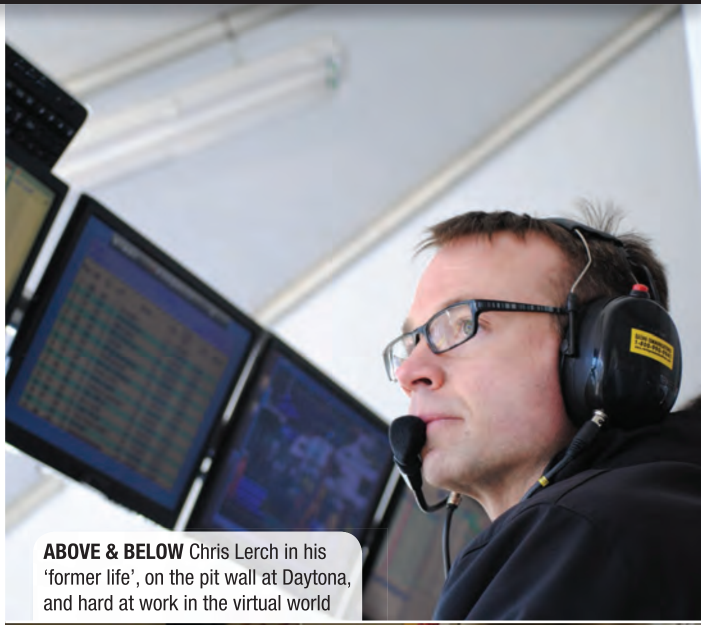
The engineers' hands-on experience comes into play in developing that correlation. After all, Hudec knows the ranges of spring perch, ride height and 'wedge' commonly found on a variety of NASCAR stock cars and trucks; likewise Lerch is familiar with the setups run on Indy cars, sports cars and prototypes.

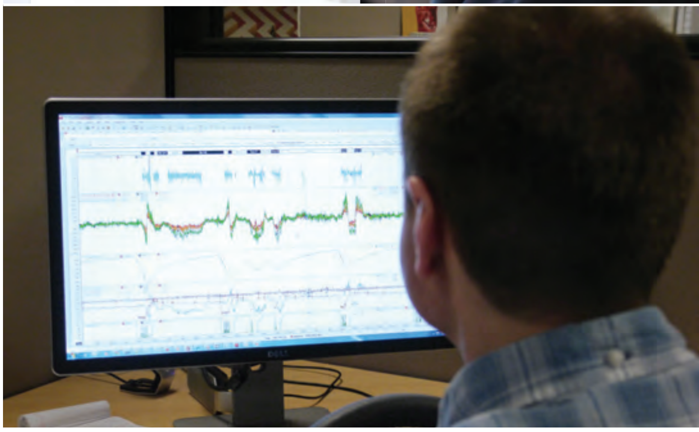
"I know the rough spring ranges Indy cars run," he says. "I know the damping; I know how they set-up their aero… and why."

Just as in the "real" world, driver input is crucial. Who better to gauge the correlation between virtual and real than race drivers with genuine experience with a given car? Here again, the engineers' experience comes into play, as they call upon the likes of Justin Wilson and Will Power, Dale Earnhardt, Jr. and Bobby Labonte, John Edwards, Andy Priaulx and Shane van Gisbergen to test the digital cars' authenticity.

"More and more these days, most drivers at a high level use a sim, so they're comfortable in that environment," Lerch explains. "It doesn't take a lot of time and effort to find a real racing driver who has experience with a given car who is also an iRacing member, put it that way. It *can* be hard to get enough of their time to get the feedback that you need. But whenever possible I like to use the guys who actually drive them."

After the real drivers give a thumbs-up to a new car, development continues with a cadre of veteran sim racers to ensure parameters like fuel mileage, ▶





ABOVE & BELOW Chris Lerch in his 'former life', on the pit wall at Daytona, and hard at work in the virtual world

ABOVE & BELOW One of the Sprint Cup cars (above) that Eric Hudec engineered before jumping to the virtual side of the fence (below). The real-world contacts are vital to the accurate development of the cars

The future of fire suppression is here

NEW Zero 36₂0 MEETS THE CHALLENGE

Designed and built to conform to the FIA's new regulations covering World Rally Championship and off-road events, Lifeline's new Zero36₂0 system will be a game-changer in fire suppression, as it not only eliminates the source of any fire immediately but also prevents re-ignition simultaneously.

For more details and installation requirements, call our technical team on +44 (0)24 7621 2999

FIRE SUPPRESSION SYSTEMS

Zero 360

The latest range of Zero 360 systems has been developed so that they are now even lighter and more compact. Available in three formats:

- Mechanical stored pressure
- Electric stored pressure
- Remote charge

Zero 2000

Lifeline Zero 2000 systems are constructed using only the finest materials and fully comply with the requirements of FIA MSA and SCCA. Also available as Rally Packages, comprising a plumbed in system and a handheld.

Zero 0

Specially for the single seat and prototype sports car market, Zero ZERO extends the boundaries of motorsport fire suppression.

BELT MOUNTED & HANDHELDS

A comprehensive range for fire marshals and pit crew protection, to deal with small fires or the largest conflagration.

ANCILLARY SAFETY PRODUCTS

RAINLIGHTS

Manufactured from aluminium with sealed-in high intensity, low energy LEDs, our new rain light is suitable for ALL racecars.

- Flashing facility
- Greater viewing angle
- Brighter
- More compact.

QUICK RELEASE STEERING BOSSES

For Formula, Touring and Rally cars.
Available with pre-wired 8-way electrical connector.

RACE MIRRORS

Formula, Touring, Sports and GT.
Conform to FIA and MSA requirements.

ROLLCAGE PADDING

Tested to exceed the lastest FIA standard. Available for 32, 38/40, 50 & 60mm diameters.

MOTORSPORT INDUSTRY ASSOCIATION

ASTON MARTIN RACING
OFFICIAL PARTNER

All products designed & made in the UK.

Champions of Safety

lifeline®

Lifeline Fire and Safety Systems Ltd **UK:** +44 (0)24 7671 2999 **USA:** Sube Sports +1-714-847-1501 **www.lifeline-fire.co.uk**

ABOVE Blast from the past: not just the Lotus 49, but the track! Oran Park in Australia was scanned a few weeks before it was bulldozed to make way for housing and a shopping mall. But the track lives on in iRacing

tyre and brake wear are within the window of their real world counterparts. Meanwhile, Hudec and Lerch work on chassis and aerodynamic set ups to give iRacing's some 60,000 members a predictable baseline when the car becomes available.

Generally speaking though, once a car is "released" to iRacers, Hudec and Lerch move on to the next project. In that respect, their work is very different from their real world racing experience.

"Instead of constantly developing a single car, here I bring the cars to a given level and then move on to the next car," says Hudec. "When you think about it, racing teams are constantly trying to make their product on the racetrack better, faster, so I was responsible for finding performance gains. In iRacing I don't have to worry about that. That step is replaced by going on to the next car."

Which isn't to say development on a given car comes to a stop. Unlike 'console' games which issue major updates once every year or three, iRacing updates its online service on a quarterly basis. The most recent release features a new kinematic suspension stiffness model to more accurately reflect suspension performance. And, having introduced its Gen6 NASCAR Sprint Cup Chevrolet SS, Ford Fusion and Toyota Camry within weeks of their real world debuts in 2013, iRacing retooled the cars to come in line with NASCAR's 2015 rules package that reduced horsepower and downforce.

Perhaps the most formidable ongoing challenge Hudec and Lerch face is keeping pace with iRacing co-founder/owner – and chief technical officer – Kaemmer in his efforts to advance the art and science of tyre modelling beyond the Pacejka Curves that have long served as the industry standard.

"To the best of my knowledge, our tyre model is unique in the consumer sim industry in that it is a first principles model, not an empirical model," Lerch explains. "Dave has spent the better part of six years developing his first principles model and he's now at a point where all, or at least most, of the low-hanging fruit has been picked. And he's spending more and more time picking the high fruit. All of which improves the model, but it takes longer to make that progress.

"When it comes to developing the tyres for each car, Eric and I have a fairly limited set of parameters we can adjust. These include definitions of tyre construction (e.g. tread depth, number of belt plies, cord angles) and compound (e.g. glass transition temperature and parts per hundred of sulphur). So we will alter those parameters, we will go to the skid pad, we will do tyre tests from the code (independent of the skid pad or track) that will give us a pretty good idea of how the tyres are going to perform. We'll tune the available parameters to set mechanical behaviour – longitudinal, lateral, vertical and yaw stiffnesses – grip, and degradation, both thermal and wear-based. We're particularly concerned with accurately capturing tyre behaviour right around the ultimate grip limit. Drivers in the real world use subtle cues telegraphed by the tyres to determine whether they are operating under, at or over the limit, and we constantly strive to accurately replicate those cues in the sim."

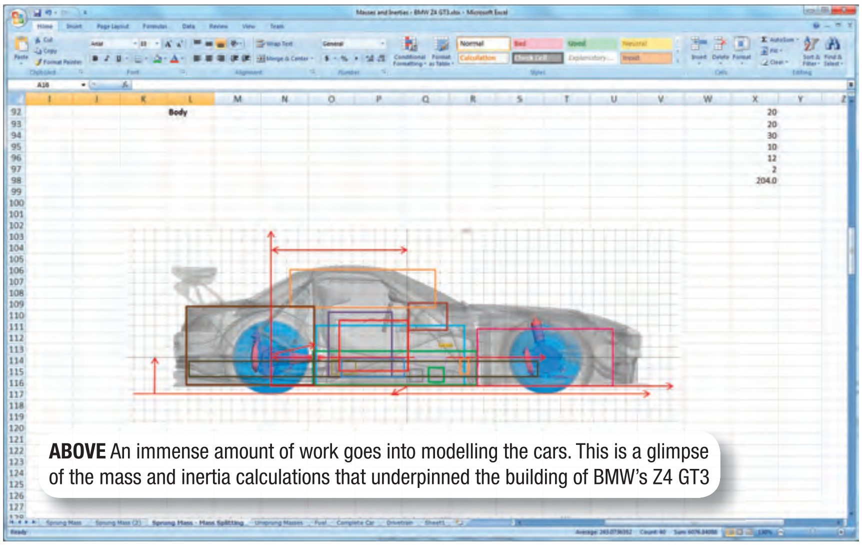
UNCHARTED REALMS

"The broader point is that a tyre is a tyre is a tyre," says Hudec. "They are all round, made mostly of rubber and similar cord materials and are all coloured black. It's the fine details that differentiate their behaviour and this is what makes Dave's model so great."

But tyres also exemplify where iRacing is venturing into uncharted realms. Case in point: apart from driver safety concerns, engineers at Ferrari, Porsche or Chevrolet don't much care how a car "performs" when it goes over the limit. Not so Lerch and Hudec ▶

ABOVE A NASCAR truck on the historic banking at Monza? Wherever you race, you can be sure that the experience has been faithfully modelled

> ***"Hit the wall in real racing and your day's over. We have to understand how a sim car's performance is compromised after it brushes the wall"***



ABOVE An immense amount of work goes into modelling the cars. This is a glimpse of the mass and inertia calculations that underpinned the building of BMW's Z4 GT3

who are breaking new ground in their efforts to make iRacers' spins, crashes and minor shunts as authentic as the racing itself.

"There's not a lot of information on the behaviour of tyres over the limit, but we need to understand that in a real time simulation," Hudec explains. "Most race engineers don't spend a lot of time worrying about how a car behaves over the limit. That's not how they find speed. They find speed *at* the limit; they really don't care what happens beyond the limit of the tyres. But we do, because we have people spinning-out and we want to accurately model what happens when they do.

"If you're overdriving a car in the sim, what happens has to be realistic. If you're an F1 driver and you overdrive in the sim, the engineer will say, 'You're over the limit of the tyres. Don't do that.'

"Accurately modelling damage is another thing real race teams don't care about. We do because we're a racing simulation, so not only do the cars have to handle right, they have to break correctly, fly through the air correctly, crash correctly and slide sideways correctly. In real racing they don't care about that sort of thing: hit the wall and your day is over. And if it's not over, the car is compromised. We have to understand how a sim car's performance is compromised after it brushes the wall. We have to care about everything."

BELOW Where engineers would normally pack up and leave after a wreck, iRacing has worked hard to model the damage incurred in such incidents to create an accurate online experience

Including drafting, but in different ways than their real racing colleagues. While designers and engineers in every form of racing look for ways to maximize their cars' performance while running ahead of or behind another car or cars, the iRacing vehicle dynamicists are taking that to the next level… and then some. Not only do they model how a NASCAR Sprint Cup Chevrolet SS behaves while tucked-up behind a Toyota Camry running through the tri-oval at Daytona, they're looking at what happens to the 20th car in a 30-car draft when the sixth car in line moves to the high side in Turn Three.

"I might be one of the few people who is trying to capture information on what's happening out there in the real world and putting it into a simulation where there are multiple racers on the track in real time," says Hudec. "Nobody else is doing that: doing real time racing on super speedways with over 40 cars on the track; just us and other video games. I'm drudging through the math trying to come up with good ways to develop a close fidelity between what we're seeing real cars doing and what our cars are doing.

"That's non-trivial! There's a lot of iterative work that goes into improving the product."

Hudec readily concedes improving the product is (and will always be) a work in progress. For example, recent updates to the drafting model have garnered mixed reviews from the iRacing community.

"I think I've made some steps forward," says Hudec, "but I also think I've taken some steps back… which is what happens when you try to advance."

In that respect, the world of sim racing precisely emulates that of real racing. RT

BACK IN THE GAME

Back where it should be in endurance racing, could Porsche's momentum be continued at Silverstone's WEC curtain-raiser? **William Kimberley** gets an update from Porsche LMP1 technical director Alex Hitzinger

ABOVE Hitzinger has overseen Porsche's return to the summit of sportscar racing

AUDI. Porsche. Toyota. Three manufacturers and the top three podium positions at Silverstone for the opening round of the World Endurance Championship with just 14.8 seconds covering them. It certainly sets the scene for the big one – the Le Mans 24 Hours.

For Alex Hitzinger, Porsche's LMP1 technical director, it was a satisfactory start to the season and one that means his cars are in the performance ballpark. But as any endurance racer knows, speed is one thing, reliability is another – and there's the question mark. While Romain Dumas, Marc Lieb and Neel Jani came to within five seconds of winning the race, the #17 car of Mark Webber, Timo Bernhard and Brendan Hartley retired in the second hour while in the lead with unspecified gearbox problems. So there's work to be done.

Up to that point, it had been a good weekend for the Porsche team, its two cars dominating the front row of the grid and then making that a one-two for the first hour and a half of the race.

"The first two races are really more or less preparation for Le Mans so we need to be as reliable as possible – reliability means avoiding change and change is risk," says Hitzinger. "However, we continually develop the whole car and introduce changes at the opportune time."

The cars that triumphed at Sao Paolo in the final race of the WEC season last year have been transformed during the off season to those that turned a wheel at Silverstone. The ambitious goals for the next evolutionary stage were to make the vehicle more efficient, more rigid, easier to handle, lighter and yet more robust. Thanks to a clever design from the monocoque to the power train, the 2015 car is lighter and more robust at the same time. In 2014 the car was about 30 kg heavier than the minimum weight of 870 kg. It now matches that limit despite the improved hybrid systems.

At its heart is still a 2.0-litre V4 engine but over the winter months it has been transformed. "The engine has changed a great deal from last year," says Hitzinger, "and we have even added a few cubic centimetres to it although it's still a 2.0-litre engine. However, the crankcase and crankshaft have changed as have the conrods, pistons and cylinder head. It's the usual scenario that there's a knock-on effect when something's changed. For example, we might improve the combustion efficiency

All photos: Porsche AG

but that then leads to increased in-cylinder pressures which lead to a stronger piston being required."

The car's also equipped with two different energy recovery systems. One converts kinetic braking energy from the front axle into electricity, the other does the same by a turbine in the exhaust – the latter makes it the only prototype in the World Championship which also produces electricity when accelerating.

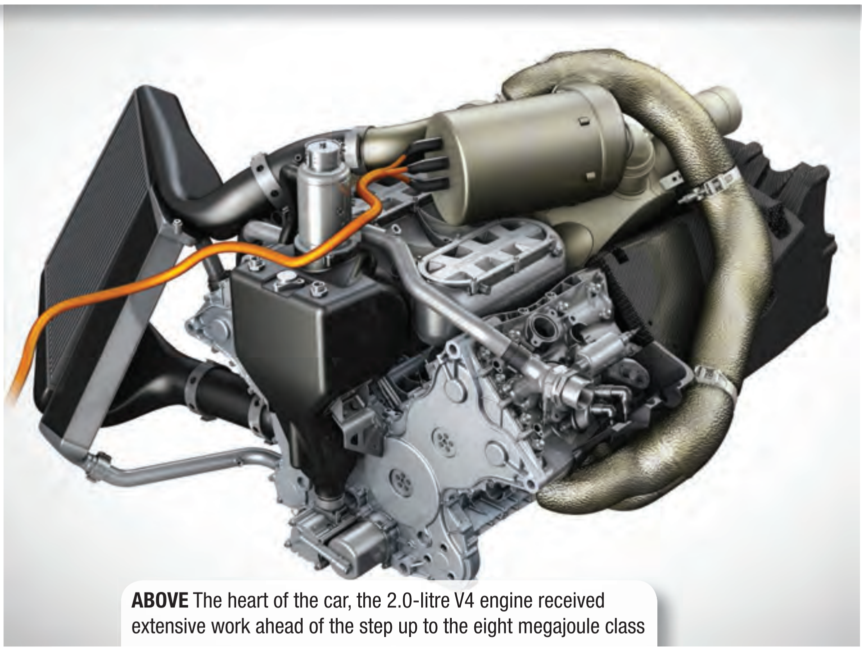
A liquid-cooled lithium-ion battery temporarily stores converted braking energy from the front axle as well as converted exhaust-gas energy, so the reworked drive system is more powerful and more efficient than before. Intense development work on the three-part powertrain has allowed Porsche to enter the highest energy recovery eight megajoule class for the first time.

"The switch from the six to the eight megajoule class must be beneficial," says Hitzinger. "To find out if this is the case, you have to take many factors into account and you have to overcompensate disadvantages, otherwise it doesn't make sense. This means that firstly, although the lower fuel amount costs combustion engine power, secondly, ▶

ABOVE The #18 car pushed Audi all the way in a thrilling race

BELOW Mirror image: the new 919 Hybrid looks much the same as its predecessor but has been transformed beneath the skin although the potential for the energy recovery on seven circuits is smaller than in Le Mans and, thirdly, although some components are heavier, still the lap times must be better because of the additional energy.

"So we've worked hard on the hybrid system and have made it lighter and more powerful than last year – but not by adding extra heavy batteries. We were overweight last year and wanted to make a big push in terms of weight reduction and this meant shaving a few grams off everything."



ABOVE The heart of the car, the 2.0-litre V4 engine received extensive work ahead of the step up to the eight megajoule class

CROSSOVER IS NO MYTH

The theme of reduced weight and increased efficiency chimes well with Hitzinger, who points to the large crossover with his production car colleagues. "The road car side from a technology point of view is gaining an advantage from our programme – it's not all about marketing and is one of the major reasons why Porsche is racing. This has happened many times in the past where motorsport technologies find their way into Porsche road cars.

"Our technology on the 919 is also very road relevant as we have the same key performance indicators, and it's all about efficiency and weight for both the racecar and the road car. Of course, the technologies we develop are somehow different because we have different constraints in terms of cost and so on, but the methodologies we've developed are applicable as are the tools we use, so it's a two-way co-operation.

"We use tools they develop and in fact, people from the road car side to do certain calculations, such as combustion calculations, which means that we don't have to employ such people. They can use our methodologies to speed up the development process because we work at a much faster rate. Then they can take ideas from new technologies we've developed and adopt them for the mass market, mass market being more than five cars a year.

"This is thanks to the regulations which I think are very good, especially when you look at how close the racing is and how attractive the cars are using technology that can be very well communicated. I think spectators don't need to understand all the fine details of the regulations, but it's important that we have close racing without, let's say, technical gimmicks so that the public can understand that the fastest car on the track really is the fastest. I think it's good for the spectators and good for the manufacturers to demonstrate their capabilities, using this as a showcase. It's also good for engineers because it's great fun." RT

BELOW Quick work in the pits. In every respect the first two races of the season act as a dress rehearsal for the main event at Le Mans


cruden
Open architecture simulators that put you in control
With open architecture for hardware and software, a standard Cruden DIL/HIL simulator is both a ready-to-run tool and an engineering blank slate.
- Easy integration of vehicle modeling packages (IPG, CarSim, VI-Grade, VeDYNA, SIMPACK, dSPACE etc.) or our fully open Simulink Vehicle Model (CVSM)
- Apply your own motion-cueing algorithms
- Incorporate your own hardware
Find out more – www.cruden.com/motorsport/


OBR
Control Systems
WHY FOLLOW WHEN YOU CAN........ LEAD
OBR / EFI TECHNOLOGY
TCR ELECTRONICS
WestCoast Racing's JAS Civic TCR features:
• EFI Technology Euro5 direct injection ECU
• OBR Power Control Module 2
• OBR Civic TCR Switch Panel
EFI TECHNOLOGY
JAS MOTORSPORT
WestCoast Racing
Specialising in engine / power management systems and a complete range of data logging, displays, sensors, actuators and wiring
Ole Buhl Racing (UK) Ltd is a world leader in the supply of motorsport electronics. Our range of innovative products are used in the world's most demanding environments ensuring performance and reliability.
WWW.OBR.UK.COM

The fastest Ford rally car ever

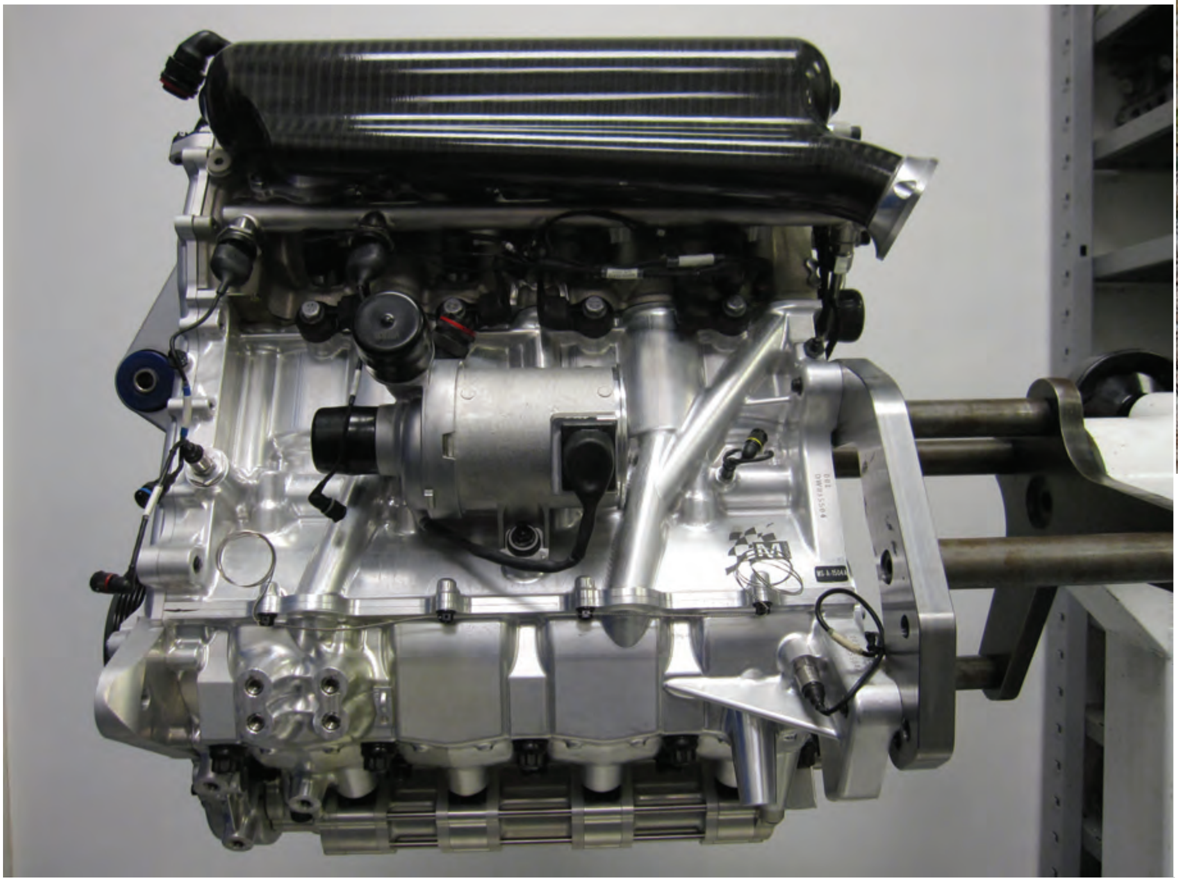
The evolution Fiesta World Rally Car makes its debut in Portugal this month after the most radical overhaul in the car's history. **Anthony Peacock** talks to the technical brains behind the revamp

IF THERE'S been one constant through the rally world, it's been Ford. In the same way that Formula 1 conjures up an instant mental picture of a red Ferrari, the word 'rally' is practically synonymous with a Mk II Escort going sideways: usually driven by a monosyllabic Finn featuring a surfeit of vowels in his surname and a high ratio of alcohol to blood.

But since the end of 2012, Ford in rallying hasn't quite been Ford – or not officially. Faced with increasingly challenging economic conditions, the manufacturer withdrew its full factory support to the World Rally Championship, but the brand stayed on in the guise of M-Sport: the company that has run Ford's WRC programme since 1997.

So outwardly, it appeared that very little had changed. The faces were the same, the cars were the same, and there was still a Blue Oval on the bonnet (as well as dotted around a few other places on the car).

But budgets were noticeably tightened, with Cumbrian firm M-Sport having to run the new Fiesta RS WRC – introduced in 2011 in response to the new 1.6-litre turbo rules, which required a smaller 'B' segment car – on its own. Despite that, the car has always been competitive: as recently as 2013 it finished second in the drivers' championship, while last year Mikko Hirvonen was best of the non-Volkswagen drivers.



LEFT Machining the block from solid for the first time has improved the engine's stiffness, weight, centre of gravity and cooling

ABOVE The new car looks outwardly similar to its predecessor but, beneath the skin, is very different

But in 2015, the Fiesta World Rally Car gets the most far-reaching and radical overhaul in its history yet. M-Sport is pulling out all the stops to try and decrease the gap to a dominant Volkswagen squad, which actually claimed all the rallies bar one last year (embarrassingly, that was Germany – and it would still have won that had both its lead cars not crashed).

In charge of the new car is M-Sport's brilliant technical director Christian Loriaux. The Belgian is well known as an outspoken maverick who goes his own way (Volkswagen's attempt to lure him to Wolfsburg a few years back fell on deaf ears). And he's gone through the new Ford Fiesta RS WRC15 – as it will probably be known, though no formal naming decision has been taken yet – with a fine toothcomb.

"I'd say the biggest change will be the engine, that's about 70 per cent new," he points out. "For the first time we've got a machined from solid engine block, whereas in the past we relied on a cast production engine block. This helps the stiffness of the engine and also the cooling jackets. It's not been ideal in terms of weight and centre of gravity when it comes to the engine, so this should help now. With the computational fluid dynamics we have now we can optimise water flow and see what's the best way to flow water around the block. As well as the new block we have a new cylinder head, a new dry sump, new exhaust, new exhaust manifolds – it's a pretty extensive overhaul. We're looking at lots of different ▶

ABOVE A new exhaust and manifolds form part of an extensive overhaul

improvements in every area. This is definitely the most work we've done on the car."

It's not just all that which is new. The cooling package has been completely revised and the electronics have been redesigned: there's now just one unit that controls the ECU and the car's direct injection, compared to the two that were there previously.

MAJOR WORK

The ECU is from Cosworth, as is the case in the Bentley Continental GT3, which is also created by M-Sport. "That rationalisation is a good step up and it saves weight," says Loriaux. "This is really a good example of what we've been doing with every single area of the car: looking at it closely and working out where we can make it better."

As well as the engine, the second major area of work has been the transmission of the new Fiesta. The differentials are new, designed to give better consistency of performance and more "tuneability" as Loriaux descriptively puts it.

"We've got the possibility to have negative preload now, which gives the option to delay the coming into play of the differential, whereas most have positive preloads. This is an advantage, but you need more testing and more input to get the most out of it." ▶

WRC opts for evolution, not revolution

THE 2015 Ford Fiesta will be the ultimate expression of a set of technical regulations introduced in 2011 and designed to be carried through until the end of 2016: 1.6-litre turbocharged cars that were designed to reduce costs and in many ways presaged the direction that Formula 1 would take.

For 2017 onwards, a number of new technical proposals for the WRC had previously been put on the table, ranging from a return to larger C-segment cars like the Subaru Impreza, to hybrid technology and spaceframe chassis. In the end, the consensus from the teams was for evolution: tweaks to the existing rules rather than a wholesale revolution. The only thing that's now likely to change from 2017 onwards is the addition of a bit more power and more aggressive bodywork – a bit like the latest raft of changes introduced to the World Touring Car Championship for 2014.

> *"It felt frustrating to lose the toys at first, but the simple truth is we probably don't need all that technology"*

Some have breathed a sigh of relief, while others bemoan it as an opportunity missed. Loriaux falls into the former category. "From our point of view, we can't see what good would come from a revolution in rallying's rules apart from more cost," he says. "It's true that technologically, we're probably at the lowest point we've been in the world championship for a number of years. Back in 2004, for example, we were working with active differentials and suspension – and spending a lot of money on it. Everything is mechanical now. But this doesn't mean that the sporting or engineering challenge is any less than it used to be. It felt frustrating to lose the toys at first, but the simple truth is we probably don't need all that technology."

Which, from a respected technical director, is a refreshingly honest viewpoint. RT

> **"We've got the possibility to have negative preload now, which gives the option to delay the coming into play of the differential"**

The 2015 season marks a return to paddle gearshifts (banned since 2010) with M-Sport introducing a "completely fresh" system. And that's all they will say for now. But a lot of tried and trusted suppliers remain. The gearbox itself is from Xtrac, which has been Ford's preferred supplier since the Fiesta RS WRC was introduced. Another favoured supplier is Reiger, which produces the dampers that form an essential part of the success or failure of any rally car. "We've been with Reiger for about 15 years, so basically forever in motorsport terms," says Loriaux. "We've been very happy with that relationship, and if we had time we could have developed the dampers for the new car more. But what we have is still good, even though it's not a dramatic change."

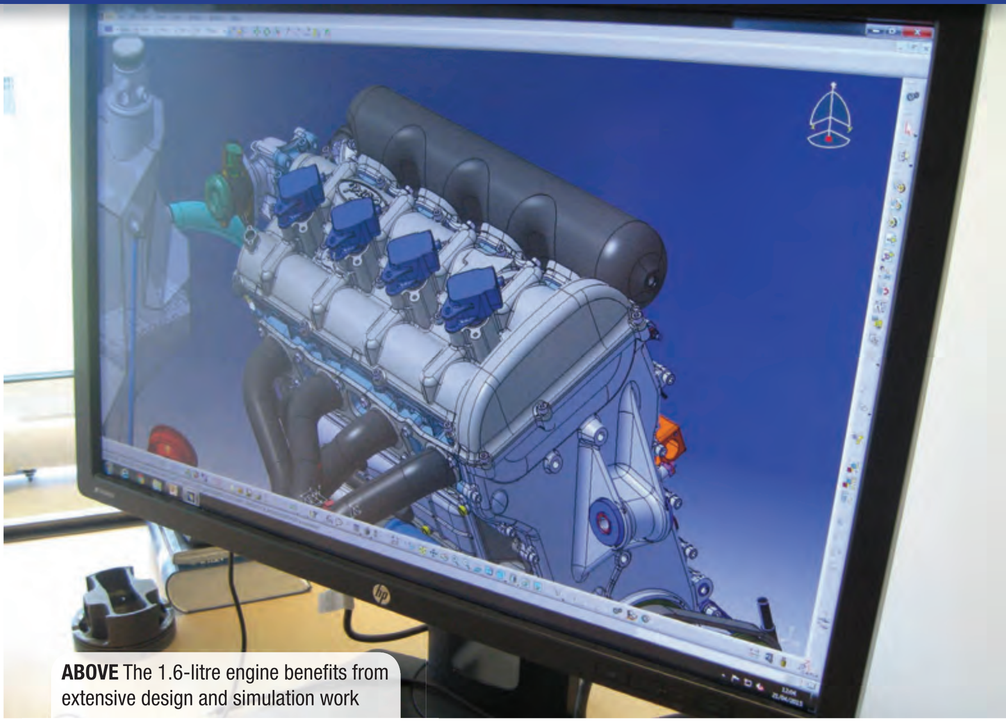
50 PER CENT DIFFERENT

Brembo supplies the brakes – again a carry-over from the previous car, which have worked well. "That's another historic relationship," says Loriaux. "We can rely on Brembo, so there was no reason to change."

Loriaux is also going to have "a play around with the weight distribution", meaning that while the new car (which is due to be introduced at the Rally of Portugal in May) will look outwardly very similar to its predecessor, under the skin it will be very different. At least 50 per cent different, once you total everything up.

So will that be enough to catch the seemingly omnipotent Volkswagens? "I don't know," is the surprising answer from Loriaux, a man who has trenchant opinions on most things. "The problem with Volkswagen is that you don't know how much is the car, how much is the driver or how much is the whole thing. I can't promise that we'll beat the Volkswagens. But I do think that our next car will certainly be a step forward."

As it is now, the Fiesta has still been able ▶



ABOVE The 1.6-litre engine benefits from extensive design and simulation work

New kids on the block

THE latest manufacturer to sign up for the World Rally Championship was Hyundai, which came into the sport at the beginning of 2014 and, much to everyone's astonishment, managed to secure a one-two finish just seven months later in Germany. Unusually, its debut i20 WRC was tabled to be used for just a season and a half, because midway through the 2015 season the all-new Hyundai i20 WRC was scheduled to make its debut – based on the coupe version of the next i20.

Or at least that was the plan. Owing to "homologation issues", the debut has now been shifted to the start of 2016 – and the new car will now be based on the five-door version of the i20 rather than the coupe.

It's a far-reaching change, comparatively late in the day. However, after a strong debut, team principal Michel Nandan is adamant that the new Hyundai will build on a solid platform of achievement rather than take a dramatic new technical direction. "In some ways what you will see is a refinement of the existing concept, just with some new ideas," says Nandan.

So no fundamental changes at Hyundai either; instead an enforced changed direction. Will fortune favour the brave at M-Sport? RT

ABOVE A five-door version of the new generation i20 WRC will join the fray at next season's Monte Carlo rally

to fight with the other factory cars (don't forget, as a privateer) from Citroen and Hyundai on more or less an equal footing. Hyundai will introduce a brand-new car based on the new i20 next year, while Citroen has no far-reaching changes planned to its DS3 WRC apart from the re-installation of Sebastien Loeb on selected events, which is probably about the most effective technical revision that any team can carry out. So M-Sport has a real chance of becoming at least best of the rest – but is the ambition in Cumbria, with the most radical revamp of the Fiesta yet, to aim even higher?

"It's all about putting yourself in contention," concludes Loriaux. "We need to make sure that we're right up there and in a position to take advantage of every single opportunity that comes our way. I'd like to think that we could win rallies with the 2015 car."


Chris Boyle

ABOVE The evolution Ford Fiesta RS WRC has covered 5,000 kilometres in testing, more than accrued before the Focus, Fiesta or Super 2000 machine were taken to their first rally

And with the recent eras of domination from Citroen and then Volkswagen, it perhaps doesn't come as a huge surprise to learn that Ford's last victory was on Rally GB 2012, courtesy of Jari-Matti Latvala – although there have been a few close calls since.

To be winning events again would be a major breakthrough for M-Sport, especially as the team has the youngest driver line-up of all its rivals, consisting of 26-year-old Elfyn Evans and 27-year-old Ott Tanak. Don't be fooled by the youthful looks and reticent interview technique though: both have won stages.

And with the driver line-up young and malleable, this allows the car's technical strengths to shine through. "We've got a strong driver line-up, that's for sure, but I tend not to get too distracted by the drivers," says Loriaux. "Our job is working with physics and technology: we make the best car available within the constraints we have got, then it's down to the driver to fine-tune it and get on and drive it. Obviously we can't go and stick them on the floor or anything like that, because they wouldn't be able to see out otherwise, but I've never seen too much need to think about the drivers much on the engineering side."

So if Tanak has any desire for a personalised drinks cup holder this year, or a group hug with the engineering department, he can forget it now. What he and his Welsh team-mate can expect for the rest of 2015 though is the fastest Ford rally car ever. RT

ABOVE & BELOW The existing Fiesta WRC has sunk from sight – at least it did in Mexico, where the crew were fortunate to escape this crash into a reservoir

BELOW Dampers are an essential part of any rally package, M-Sport continuing to benefit from a long-term relationship with Reiger


The Lightest, Most Flexible Hose and Fitting Combination Available!
USA North Carolina
704.793.4319
sales@bmrsusa.com
California NEW!
714.415.0080
socalsales@bmrsusa.com
UK Slough
01753.545554
sales@bmrsuk.com
www.bmrs.net
Brown & Miller Racing Solutions
BMRS
Professional Race Hose & Fittings


VAC MOTORSPORTS
World Leading Performance
MANLEY
Valve Train Upgrades
» VAC High Performance Valves & Springs
» Essential for High HP cars
» For BMW N54, S65, S54 and more
ATI
Harmonic Dampers
» VAC Exclusive for BMW M50, S54 and MORE!
» Unbridles Horsepower and unleashes torque
» Reduces engine wear from reduced vibration
Dailey Engineering
Billet Dry Sump Kits
» Increases HP and Reliability
» 4-cyl, 6 cyl, V8 & V10 applications
» Full Kits with Pumps also available
tilton
Clutch & Flywheel Kits
» Rally, Race, & Carbon Clutches
» Lightweight Flywheel included!
» Twin & Triple Disc Clutches in 5.5" & 7.25"
SCHRICK
ARP
ARROW
SAMSONAS MOTORSPORT TRANSMISSION
COMETIC
CARRILLO
+1.215.462.4666
www.vacmotorsports.com
2501 Snyder Ave, Philadelphia, PA 19145, USA
sales@vacmotorsports.com

FORMULA 1 RECOVERS

Chris Ellis completes his blueprint for F1 2017. Is this how the GP circus could recover braking energy and credibility at the same time?

FOR years, Formula 1 has been infected with a bad case of 'political correctness' in its engine regulations, eventually resulting in the nasty little turbocharged V6s in the current cars. However, the takeover by the new Strategy Group of the process of setting future regulations should result in Formula 1 recovering its pre-eminent position on the top step of motorsport. And F1 will recover in another (politically correct) sense in 2017, *if* the new regulations permit braking energy to be recovered as aggressively as the FIA already allows at Le Mans and in the World Endurance Championship.

My 'Regime Change!' article in May's edition focused on the ideal engine for F1, and concluded that a 3-litre naturally aspirated V12 would be perfect, for technical and 'sensational' reasons. But I omitted to mention the overriding reason why I expect the Strategy Group to choose this solution rather than adopt a lesser engine specification. Here's an extract from the draft script I'm working on for Jeremy Clarkson's new 'Overdrive' (joke!) TV show:

'James, of course F1's decision to move back to V12s makes sense. Most women know that four is sad, six is fine, but eight is even better. Twelve is rare, but very desirable. Allegedly.' Richard interjects, 'Jeremy, you do mean numbers of cylinders?' Clarkson: 'Of course, Dick! What did you *think* I meant?'

Pause for general laughter, then: 'At the top of most European manufacturers' road car ranges are their V12 models, starting with Aston Martin, Rolls-Royce, Mercedes, BMW and, of course, Ferrari and Lamborghini. Even Audi! If Formula 1 wants to make it clear it's the top racing formula, using V12 engines will definitely do the trick. Here's a clip which will let you hear what we have been missing, from way back in 1995.' [Run VT for: https://www.youtube.com/watch?v=5SoZiTxdQyw.]

Right now, the most technically advanced racing cars are the LMP1-Hs of the World Endurance Championship (WEC), graciously allowed by the FIA to have V8s and V12s of unlimited capacity, and with no limit on regenerative braking power, through all four wheels. If F1 is to recover its pre-eminence, it needs to catch up and overtake technically. That's why I think the commercial imperative to capture the hearts and minds (and credit cards!) of the next generation of motorsport fans will drive the Strategy Group to make V12s obligatory in the 2017 regulations.

Initial noises from within the group suggest a desire to cling to the V6s. My hope is that the manufacturer representatives are soon issued with new orders from above.

1,000 HP F1

It's rumoured that the twin-flywheel system fitted to the 2015 Nissan LMP1 is capable of over 500 kW, in and out, front and rear. It's more powerful than the engine! So Mr Ecclestone's target for F1 of over 1,000 hp for even more sensational acceleration can be achieved easily, with some 600 hp from the V12 and the rest from the ERS. Note that one advantage of this power split is that, because it will be engine power alone that determines

ABOVE F1 will reclaim the moral and technical high ground if its next set of regulations permit braking energy to be recovered as aggressively as is currently allowed in the WEC top speed, balanced by drag, speeds should not become excessive, given the need for drag-inducing downforce. Of course, over 300 kW into a battery could be challenging, to put it mildly, but the latest version of the single-flywheel system in the Audi LMP1 is already providing over 200 kW, in and out.

To retake the technical leadership from the LMP1-Hs, the Strategy Group will need to authorise the use of *unlimited* kinetic energy recovery, which implies full four-wheel drive and regeneration. Note that, led by Porsche with the 918, the top hybrid road cars have already adopted all-wheel regenerative braking. And Tesla has just caught up, with the new four-wheel drive P85D. BMW implemented 4WD in the i8 prototypes, but not in the production cars. At least, not yet…

The logic is compelling. To get the best possible NEDC figures, the use of a car's friction brakes during normal urban driving should be unnecessary, except in an emergency stop. And this logic also applies to battery-only and fuel cell cars. Which suggests a future common platform design, irrespective of power source, which will then allow global manufacturers to provide regional variants for different markets, determined mainly by government taxes and subsidies. Currently, four-wheel drive is an expensive extra, because it's implemented in a costly manner. Now, this can change, and motorsport could help demonstrate how to do it right.

FOUR-WHEEL DRIVE DEBATE

The sketch shows the safety cell of a 2017 Formula 1 car, with most of the key components attached. The V12 is set as far back as possible, with the gearbox behind the rear wheel centre line. Note that the position of the driver within the wheelbase will remain much the same as this year's cars, because of the longer engine. Note also the larger wheels and lower-profile tyres. I will outline the impact on braking of this particular change later, but the most significant change is the addition of drive to the front wheels.

Some older readers will remember Stirling Moss winning the 1961 International Gold Cup in a 4WD Ferguson P99. Later, in 1969, Colin Chapman and others attempted to reintroduce 4WD to Formula 1. Eventually, the FIA banned 4WD in 1982, probably because Ferrari didn't like it!

Originally, the case for driving all four wheels revolved around traction, particularly in the wet. The key negative factor was the weight increase, typically as much as 10%. However, the additional benefit of more efficient energy recovery, and the fact that much of the weight penalty of 4WD has already been allocated to the Energy Recovery System (ERS), now make a compelling argument for the use of 4WD.

In the sketch, an ERS using twin contra-rotating flywheels is shown. An ERS based on kinetic energy storage is 'legal' in endurance and GT racing, but isn't allowed in Formula 1. This must change if F1 is to recover its position as the pinnacle of motorsport. Two of the four global manufacturers competing at the LMP1-H level of Le Mans this year will use flywheels rather than batteries, for the very good reason that they help win races, as Porsche and then Audi have repeatedly demonstrated. A single manufacturer using flywheels could be dismissed as eccentric (a particularly undesirable characteristic in a flywheel!), but when the VW Group and Nissan/Renault do it in public, it begins to look like a trend. Now watch the other manufacturers wake up…

And it is not just some weird motorsport thing, like DRS! By the end of *this* year, there will be hundreds of big hybrid *buses* equipped with flywheel-based KERS providing normal bus services in several major English cities, cutting pollution and fuel costs, with over a thousand of these 'superbuses' in service before the 2017 F1 season begins. Right now, city buses are in the lead, technically. Formula 1 is not only behind road cars like the Porsche 918, but behind buses! Blame the usual suspects.

I have shown a flywheel-based ERS to alert my beloved readers to the potential this form of temporary energy storage offers across the full spectrum of vehicles, whether the primary energy source is a battery, a fuel cell, an engine or, eventually, a fusion drive. Talking of fusion, the research being carried out at the Culham Centre for Fusion Energy has relied for over two decades on two 775-ton flywheels to provide bursts of up to 400 megawatts each to fire up the fusion reactors. The rumour that the British government insists that the flywheels contra-rotate to avoid possible precession effects on the earth's orbit has been strongly denied. But they would say that, wouldn't they?!

Seriously though, in most vehicle applications, including most of motorsport, twin contra-rotating flywheels will be needed, and product liability concerns will probably force them into most road cars. The mild operating conditions of most urban buses and their high vehicle-to-ERS weight ratios means they can be the exceptions if their single rotors have a vertical axis. Certainly in the Netherlands! And on 'flat' race tracks with little pitch and roll… But elsewhere?

Of course, the Energy Store (ES) of the ERS *could* be a battery, but imagine what 500 kW in for a total braking time of 15 seconds every 90-second lap would do to a battery, particularly when almost the same amount of energy has to be returned during the same lap. You may think 500 kW is an exaggeration, given Mr Ecclestone's need for 'only' 300 kW. But do you think it will, or should, stop there? This is the opposite of profligacy. The higher the proportion of braking energy that can be recovered, the less fuel needs to be used per ▶

BELOW F1 2017? A 600 hp V12 with a 300 kW ERS using twin contra-rotating flywheels. Note also the larger wheels and lower-profile tyres. Could 4WD tempt some teams to move the front discs inboard, or will bigger discs be enough?

> *"The commercial imperative to capture the hearts and minds (and credit cards!) of the next generation of fans will make V12s obligatory"*

lap, assuming it's not allowed to be wasted on more downforce. So it's ethically wrong, *ethically wrong*, to limit the amount of energy that can be recovered and re-applied during a lap, and wrong to limit the regenerative braking power needed to achieve it.

The 4WD regenerative power requirements will start high and grow higher, but the minimum energy capacity required to be competitive will remain relatively modest, set (simplistically!) by a maximum braking time of four seconds times 300 kW (more by 2020?), i.e. some 1,200 kilojoules, or less than twice the energy available already in the single rotor of the GKN (ex-Williams) system used by Audi, and also by Porsche in GT racing. However, from comments by GKN already reported in this magazine, the thermal problems inherent in its design are already becoming challenging at the 200 kW level. It is essentially an all-electric solution, a 'flywheel-battery' if you will, complete with some of the functional weaknesses of batteries.

ABOVE The most technically advanced racing cars currently exist in the WEC

Adrenal Media/WEC

SUPER-CAPACITOR FLAWS

By now, some of you may be thinking, 'Ah, it will be super-capacitors then'. But, despite the name, low specific capacity is one of the key weaknesses of super-capacitors, requiring significant weight to achieve only modest energy capacity. Another weakness, rarely mentioned, is relatively low efficiency at high power levels, much like batteries.

'Ordinary' capacitors can deliver excellent in-out efficiency at all power levels, but so-called 'super-capacitors' generally cannot. High power is certainly available, but these two flaws make super-capacitors an unattractive choice in this application. The efficiency with which the majority of the kinetic energy recovered during braking is returned to the car as it accelerates out of a corner becomes increasingly important to lap times as ERS power levels rise. Last year, we had token hybrids, with only 60 kW of recovery power. This year, it's better, but F1 cars will only become 'true' hybrids in 2017.

Last year, when the peak power output allowed from the ERS was low and there was also a low limit imposed on the recovered energy that could be used per lap, the efficiency of kinetic energy recovery didn't matter very much. So these perverse regulations had the effect of masking the inherent inefficiency of the battery-based systems. I don't know whether this was yet another unintended consequence, or actually intended to avoid an expensive technical race to achieve greater efficiency. And I don't really care, because these limits are clearly unjustifiable if demonstrating energy efficiency is genuinely a key technical objective of Formula 1. If it is, these limits must be removed.

I have believed for years that a design which keeps the motor/generator separate from the rotor will prove essential for high energy-throughput applications. Using a magnetically-loaded composite in a 5 kW ultra-centrifuge probably works well, but 200 kW is another matter. Flybrid, now part of Torotrak, has adopted separation. It uses a toroidal IVT to provide a highly efficient, all-mechanical pathway to and from the wheels. But this then presents the historical challenge in a single-seater of how to connect the other axle. This is easily done with an electric cable if an all-electric system, i.e. a battery or 'flywheel-battery', is used.

However, there is another solution, combining most of the advantages of the all-electric and all-mechanical approaches while minimising their disadvantages. Essentially an electro-mechanical hybrid of the other two, it promises to achieve the power and efficiency of the all-mechanical approach with low-cost implementation of four-wheel drive and the capability to work equally well in battery-only and fuel cell cars. The latter may seem irrelevant in Formula 1 and WEC, but think outside 'Box 56' for a moment!

Pirelli

ABOVE F1 has already experimented with larger wheels and low profile tyres. Could this lead to moving the brakes inboard?

CONQUERING RANGE ANXIETY

Imagine a 2017 Formula 1 car, complete with an energy recovery system delivering over 300 kW, in and out, via all four wheels. Now ▶

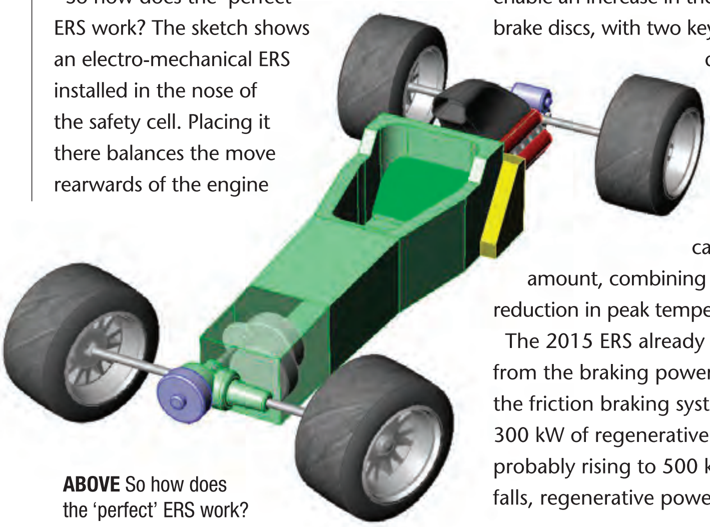
ABOVE Led by Porsche's 918, the top hybrid road cars have already adopted all-wheel regenerative braking

remove the engine and gearbox, increase the power of the rear MGU from 150 kW to 300 kW, and drop in a standard, 150 kW, Formula E battery pack (28 kWh, 320 kg!), to give a total of 450 kW for acceleration. This will make the current generation of FE cars look distinctly short of volts! And 'our' car will go a lot further on a single battery charge, assuming top speed remains limited, potentially removing the current embarrassment of each driver needing two cars to finish a race. That is *not* the way to dispel range anxiety!

And what if 'powerful forces', such as Toyota, Honda, GM and the burgeoning renewables industry, want to demonstrate the advantages of fuel cell vehicles, with renewably-sourced hydrogen as their fuel? Instead of a Formula E battery pack, install a fuel cell system, and you have Formula H, with two-hour races and the return of refuelling. Any slight fuel leakage won't pollute the environment, and the refuelling system will be inherently safer than the crude, error-prone, gear used for petrol. No need for tyres that wear out ultra-quickly to produce drama in the pits. How much greener is hydrogen from renewables, rather than electricity predominantly from fossil fuels for at least the next 20 years? Is Formula H going to overtake Formula E, once the 'perfect' platform is available?

So how does the 'perfect' ERS work? The sketch shows an electro-mechanical ERS installed in the nose of the safety cell. Placing it there balances the move rearwards of the engine and gearbox, and the extra weight at the front helps traction out of slow corners with roughly half the total ERS output being fed to the front wheels. This weight distribution will increase the polar moment of inertia, but the combination of the lower profile tyres and the front wheels being able to 'pull' the front of the car into each corner should mask the increase.

The flywheels are connected mechanically to the front differential via an electro-mechanical IVT which also connects electrically to the second Motor/Generator Unit (MGU) integrated with the gearbox. Because the flywheels are directly geared to the front differential, efficiency to and from the front wheels is about as good as it can get, at over 96% in each direction, more efficient than the Torotrak drive. The efficiency to and from the rear wheels is lower, being all-electrical, but should still average over 90%, about the same as the GKN system. The IVT comprises a single planetary gear set with the first MGU connected to its ring gear, and the flywheels to the sun gear. So, light and relatively inexpensive. And it's being developed for road vehicles in Changzhou, China, right now…



ABOVE So how does the 'perfect' ERS work?

FOOTBALLERS' BRAKES!

The increase in wheel size to at least 18" will enable an increase in the diameter of the brake discs, with two key advantages. The disc surfaces can be as much as 50% larger in area, improving cooling considerably, and the thermal capacity can increase by a similar amount, combining to produce a marked reduction in peak temperatures.

The 2015 ERS already takes 120 kW away from the braking power required from the friction braking system. Now imagine 300 kW of regenerative braking in 2017, probably rising to 500 kW by 2020. As speed falls, regenerative power can remain almost constant, while the total braking power required will reduce, and disproportionately because the downforce will be reducing. Into slow corners, regenerative braking will recover an increasing proportion of total braking energy, year on year, as regenerative power is increased.

All this promises that safety will be enhanced because the thermal stresses on the brake discs and callipers will be much lower. And front driveshafts open up the possibility of inboard front brakes; much easier to cool. The spectacle of carbon-carbon literally turning into glowing particulates will be just another memory, like smoky diesel engines! And someone is bound to try oxygen-diffused titanium discs, mainly because the brakes will still be expensive, but less so than the current absurdly expensive carbon discs. Then watch the supercar manufacturers offer them, because titanium sounds more expensive than carbon, and looks more impressive. 'Wow! Look, footballers' brakes'!

WHO PAYS?

Last but not least, who will pay for all this? Let's consider four-wheel-regenerative-braking first. It doesn't require any novel hardware (assuming the hydraulic brakes remain carbon-carbon and just need re-sizing), except for new front uprights, and these are new anyway, most seasons.

Of course, the big extra cost is in developing the Brake-By-Wire (BBW) software. But notice this: even though the brakes and MGUs of the Porsche 918 and Tesla P85D are very different from the equivalent hardware needed in Formula 1 the software that co-ordinates friction and regenerative braking will turn out to be almost identical, apart from some specific parameters. So Mercedes, Ferrari/Fiat/Chrysler and others should be able, if top management is comfortable with the idea, to spread the development costs of this core software across the whole population of their car, bus and truck offerings that will eventually use Four-Wheel-Recovery (FWR). And sell it to everyone else?

Now I am worried that I may be about to commit heresy. Or is it just a necessary part of the 'Reformation' of F1? If so, Ferrari may naturally feel compelled to resist it, even though they know I am a 'true believer' in V12s! So what is this heresy? Rather than persist with a (reducing?) maximum fuel flow limit, I am beginning to believe the peak power of the new 3-litre V12s should be directly limited to, say, 450 kW, or 600 hp.

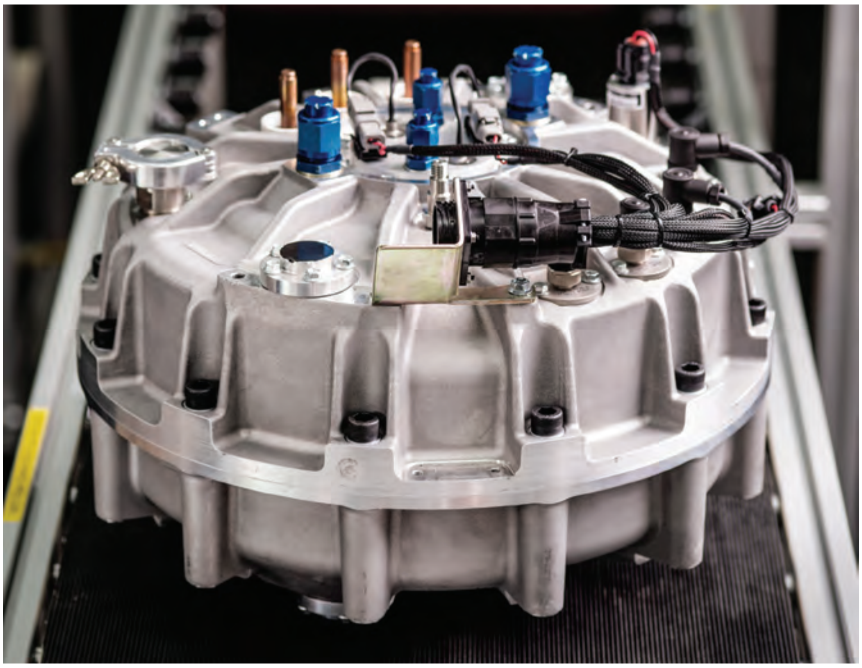
At a stroke (almost certainly a longer stroke!), engine development costs would plummet, and you really could get F1 engines genuinely suitable for powerful road cars, large and small, radically cutting production costs through volume, and by allocating much of the development costs to the V12 road cars. The idea of politicians and billionaires riding around in limos with price tags that help to pay for the development of Formula 1 engines and ERSs is particularly appealing. Genuinely applying the principle of 'road relevance', not just talking about it, will help to pay for motorsport.

> ***"It was daft to believe forcing F1 engines down to the same capacity as the average family car would produce innovations relevant to general road vehicles"***

Seriously though (but it *was* a serious suggestion), fixing peak power would stop the massive waste of the finest engine development talent currently focused on getting peak efficiency out of an engine averaging 12,000 rpm. This is a radically different task from getting peak efficiency out of a superficially similar combustion chamber in an engine needing to produce only some 40 kW to cruise at around 2,000 rpm down a crowded autobahn. It was a daft idea to believe that forcing Formula 1 engines down to the same capacity as the average family car would produce any innovations relevant to the general population of road vehicles.

Fortunately, Formula E has now arrived to take up the position of 'blocker' (see definition in American football), to intercept the attempts of the 'politically correct' to interfere with general play. FE may be boring, but we should all support it because it could do a great service to motorsport in general by running interference.

And I haven't written anything yet about downforce and drag; sadly, there's a word count limit here. It's the literary equivalent of a fuel capacity limit. And I haven't run out of words, just hit the limit! Apologies. RT



ABOVE & BELOW With GKN's flywheel-based KERS (above) soon to feature on hundreds of bus routes in the UK, F1 finds itself trailing, in technical terms, not only road cars but buses!

3T RPD

BELOW The metal additive manufacturing process taking place. Some 40-60 parts on an F1 car are reputed to be made from printed metal

PRINT AND BE DAMNED?

A lot is made of 3D printing being the future of Formula 1 but, as **Craig Scarborough** points out, the future is already here: a surprising amount of printed parts are already utilised on a modern F1 car every race weekend

3D PRINTING is a well known term but often misapplied, as much as simply saying something is 'CNC-machined'. We've known of printed parts being used in F1 for some 20 years. Most of the talk of their application has revolved around rapid prototyping, making scale or full-size parts for testing or mock-ups. But as much as 3D printing has revolutionised work back at the teams' factories, over the last 10 years printed parts have been appearing and racing on the actual cars.

Less has been made of this progress, but there's a surprising amount and range of applications of printed parts on the modern F1 racecar. From a front wing part to the trim around the switch panel on the steering wheel, bits of the floor and even the roll hoop, many parts are now produced digitally in 3D printers.

This article looks into where these techniques are being exploited, what materials are harnessed and where the technology may go in the future. We've spoken to an F1 digital manufacturing manager (who is to remain nameless for obvious reasons of confidentiality) and several suppliers in this field.

There are many terms that can be applied to this field of production: 3D printing; rapid prototyping; additive layer manufacturing... we'll call it 3D printing for simplicity through this article and point out the specific technologies as we go along.

MATERIALS AND METHODS

3D printing has come a long way from the amber-coloured resins used in the mid-nineties for wind tunnel models. Where by Stereolithography (SLA) a vat of liquid resin was selectively hardened by the laser, now with SLS (Selective Laser Sintering) a laser scans a powder bed, with a variety of materials that can be selectively melted. Materials are largely split between plastics and metals, with each taking similar properties to their more conventionally-produced counterparts. In the plastic form, the powder can have fillers incorporated to improve its material properties, whereas with the metal parts, post-manufacturing processing can produce properties akin to machined or cast components made from the same base material.

The current trend in commercial 3D printing is a move towards cheaper filament-fed FDM (Fused Deposition Modelling) printers. These are attractive for the domestic market but currently the end products do not have the strength for F1 in either prototyping or race use. This is due to their tendency to pull apart when subjected to tensile stress along the Z-axis, the filament literally unwinding like the wool being pulled from a cartoon character's jumper.

In a similar process to FDM, carbon filaments can be bonded together to form a 3D object – somewhat akin to the continuously wound filament process for making propshafts – creating a shaped 3D component. As with FDM, at this stage in the solution's maturity the problem of the component being pulled apart is an issue.

The wide range of materials with different properties makes SLS attractive. From the early 2000s this process has been exploited in F1, initially for rapid prototyping back at the factory, but by the mid-2000s there were parts made from nylon evident on the racecars themselves. It was then just a short step for metal parts to be produced in full size to be run on the cars. Although this is an immature technology, progress is being made rapidly, with new printers, materials, processes and post-manufacturing treatments. Our F1 contact suggested there are currently some 40-60 parts on the car made from printed metal alone!

Every F1 team currently has some form of 3D printing resource, be it split between SLA and SLS, although it appears no team has its own in-house hardware for producing metal parts. This work therefore is outsourced to third parties, either small specialists or bureau services provided by the printer manufacturers themselves. This at first might seem to be a drawback for the normally agile self-sufficient F1 teams, especially with the increasing volume of metal parts being produced. However, the current state of the available hardware and investment required to scale up for large scale production in-house means this is not a viable means to base production on.

Moreover, the current hardware for laser melting metals is split between a few machines, each with their own particular specialism. "There are machines with great metallurgy but a bad surface finish, then there are ones offering a better surface finish at the cost of metallurgy," explains our F1 contact. "Thus you choose the machine to suit your application." This is the key benefit for metal printing currently being an outsourced service.

There is also the tantalising prospect of teams having 3D printing capability out on the road, with small units installed in the race trucks. No printer manufacturer or team has admitted to having such a resource, although I have been told by a guest in a top F1 operation's race truck that two such devices were seen working flat out producing brake duct parts at a race weekend. The potential is there to produce new parts either to replace damaged or out-of-life components.

More interestingly, perhaps with cooperation from the race engineers and design office, parts tailored specifically for that weekend's conditions could be produced, such as a brake cooling duct sized between two existing stocked parts. There are, however, currently drawbacks to this potential method. The first is the requirement for sufficiently rugged and mobile printers, able to withstand the constant travel, although there are versions like this on the horizon.

Secondly, production time is an issue: a complex brake duct currently takes some 30 systems-hours of machine time to produce. There is not simply the print time to consider but, given the heat from the melting process, also the cooling down time required afterwards. Embedded in a tank of hot powder, the component is well insulated. It therefore takes time before the thermoplastic is both cool enough to retain its shape and to be handled by the technician. Yet with some limitations a 3D printer with a carbon-filled nylon powder could be as useful at the track as the lathe and drill press in the back of the trucks.

DESIGN BENEFITS

For an F1 team 3D printing offers many potential benefits. Such is the development rate that parts may be produced for testing and only run a few laps before being retired; even race components may change specification on a circuit-by-circuit basis. Thus production runs are short, as are timescales between design and end use, with little time for paths being programmed for CNC production and complex jigs. The more design time a team has, the better the end product can be. ▶

BELOW Every team on the grid uses a variety of 3D printing techniques but some are known to actually be producing printed parts at the track during a GP weekend

Staley/LAT

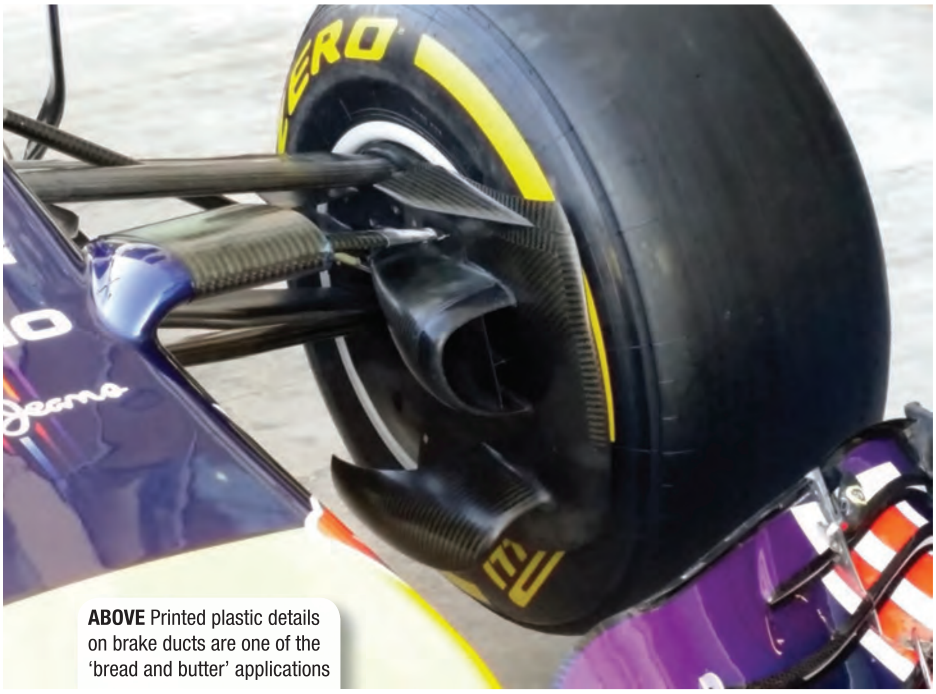
For the design office the flexibility 3D printing offers is beyond that of many conventional manufacturing techniques. It enables the formation of hollow galleries, for example, so long as the unmelted powder can be removed from within the object. Experienced designers, used to creating parts for production via CNC machining or casting, spend their career battling the problems of tool access and moulding allowances. With a 3D part, though, these problems do not apply, for there is almost complete freedom with the final shape of the part.

Our F1 contact points out that younger designers, unencumbered by the negative experiences of their more traditional counterparts, tend to design better with 3D production in mind. "They're not corrupted by conventional manufacturing," he says. "They don't worry about, 'How do I hold it down?', 'Can I make a hole in that shape?' or 'What tool do I need to make that?'"

While the designer has more freedom in the part's geometry, the choice of material still needs careful consideration. Clearly the plastic parts will not be as strong, nor as heat-resistant as metal parts, but the in-house production capability and low cost compared to moulding carbon fibre makes it a common choice for complex shapes on the car. With various fillers that can be added to the basic nylon powder, there are a wide range of materials available within this segment. Now there is even a short filament carbon fibre option in development: one leading company is known to be working on a process whereby not only are the filaments embedded into the melted material, but they are aligned to create a sort of unidirectional composite material, a stepping stone between printing plastic parts and full carbon fibre parts.


ABOVE Printed parts lack strength? Not when produced for an F1 roll hoop, they don't!

Another process in common use is metalizing printed plastic parts, whereby a thin layer of copper is applied to the surface of the part, greatly increasing its strength and heat resistance. The myriad of specialists supporting the sport provide this service, whereby finished parts will go for treatment, rather than the team have the capability in-house. Such is the step forwards in strength and thermal properties offered by this process that metalized plastic parts are being used in far more arduous situations than one would expect non-metallic parts to be exposed to.


ABOVE Printed plastic details on brake ducts are one of the 'bread and butter' applications

Moving onto the metal powders, all the commonly used metals and alloys are available, from aluminium to titanium, Inconel and even cobalt steel. The process of producing the metal parts is fundamentally the same as for plastic ones, though a common misconception exists that the metal powder is sintered, rather than actually melted. One prominent supplier explains: "It's a misunderstanding that is picked up from the plastics side; all systems developed since the mid-2000s are laser melting solutions."

Thus the finished items are a homogenous metal part, with metallurgy similar to that of parts produced by other means with the same base metal. It's not a case of the printed part having better material properties, as the expert explains: "It just ▶

has *different* properties."

"Metals can be of higher strength than machined components," he adds, "but that might require additional processing after printing – such as machining, polishing or heat treatment to increase hardness – to find the specific properties the designer is after."

Comparisons are frequently made with casting but where casting risks porosity in the finished item, this isn't the case in a printed metal part. Micro defects can be created where the laser fails to melt the powder completely, but these faults are in the tens of microns in size and not on the scale of the porosity that can be involved in casting. Once again, post-printing heat treatment can resolve these issues.

Any part produced is unlikely to be used in isolation or purely mechanically fastened to an assembly, thus the bonding of parts to components of other material or production is required. Luckily, the matt and slightly grainy surface finish is ideal for accepting adhesives and indeed paint. Many printed parts are incorporated seamlessly, then covered with paint, such that it is difficult to detect if a part is made from printing or other processes.

Applications

PLASTICS

Plastic printed parts in the trademark dull grey finish have appeared on F1 racecars since the mid-2000s, first being detected in the small ductwork around the front brakes. Often the complex scoops and flicks mounted to the inboard face of the carbon fibre 'cake tin' brake ducts are now printed parts. Being far from the heat of the brake discs and always greeted in the pit lane by cooling fans, this was an easy application of the technology. In the subsequent decade more and more of the complex ductwork and aerodynamic flicks on the brake ducts have been produced with printing, better materials and metalizing allowing the parts to be used ever closer to the heat from the brakes and on more heavily aero-loaded parts.

Indeed cooling ductwork has become the 'bread and butter' of 3D printed plastic parts. Throughout the car small ducts now grab cooling air and direct it towards the driver's feet, electronics and power unit components. Other low-temperature, low-stress parts are printed small brackets for electronic boxes, switch panels on the steering wheel and, using material like PEEK (Polyether ether ketone, a high-strength plastic), insulated mounting for electronic parts.

Application of the race-ready aerodynamic parts is less common, for the aero loading on an F1 car at over 200 mph negates plastics being used for some bodywork applications. However, in some lower stressed areas it is used in many ways. Complex shaped parts such as slots and louvres that form part of a larger assembly, such as a wing endplate, are often printed then bonded into the assembly, this being far simpler than creating a tool that will allow carbon fibre to be laid up into it. Often the drag-reducing louvres in the F1 rear wing endplate are produced this way (see image). Equally, small aero details, such as flicks and vanes on the front wing and around the cockpit, are printed and bonded on. Their small size means they are not highly stressed and again are simpler to produce with printing.

It's in the more highly-loaded parts, such as wings, that printing has yet to be popularised, although as pictured smaller sections of front wing are clearly printed in carbon-filled nylon materials. The cascade winglets on the Force India were seen two years ago and clearly these are loaded aero parts. So teams can still find scenarios where the process can be applied.

Force India

ABOVE The cascade winglets on the Force India two years ago were printed parts that were subjected to aero load

METAL PARTS

With their greater strength and thermal properties, metal printed parts have a wide range of applications too, aided greatly by the wide variety of base metals and alloy derivatives available.

One application of printing in metals is to reduce the laborious hand fabrication of parts and equally to decrease the machining required on difficult materials such as Inconel. Thus exhausts are a perfect solution for printed parts, with the flanges and collectors and other complex sections produced in titanium and Inconel. The advent of turbo engines in F1 in 2014 also means the exhaust service life is far shorter than with the old V8s. Thus these parts are routinely printed in order to be welded to the interconnecting pipework sections. For the exhaust port flange, being printed means the part can be lighter with tighter radiuses and thinner wall sections. A lot of weight has been taken out of F1 exhaust systems simply from the lighter printed flange sections, compared to cast or machined parts. Additionally the part's geometries are ▶

accurate and repeatable, such that the front left cylinder's exhaust flange can be exactly the same as the one on the rear right-hand cylinder. Or a specific geometry per cylinder can be adopted if the designer so wishes.

Exhaust parts have been made printed from Inconel alloys, titanium and even cobalt chrome for particularly high-temperature applications. It is even possible to produce an entire exhaust system from printed parts. This has certainly been done for rig or dyno testing, but it's not believed this is a race application as yet.

When the pre-2014 technique of blowing the exhaust towards the floor of the car was used, it meant that the exhausts exited through the sidepod bodywork and blew along their surfaces using the Coanda effect and then on down to the floor below. This naturally meant that normal carbon composite couldn't cope with the temperature along the floor and diffuser, nor the exhaust tailpipe at some 800-900 degrees C. High-temperature carbon composites exist, such as glass ceramic composites, but these are very expensive and in short supply, thus printed metal parts are attractive. So the curved channel sections within the sidepod, that directed the exhaust plume downwards, were printed.

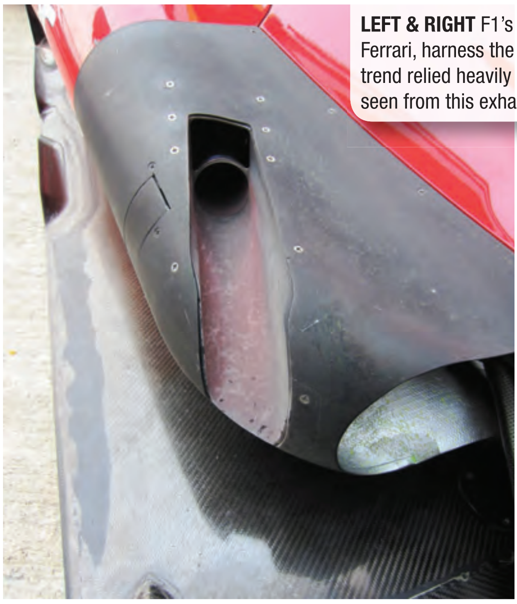
Lotus, for example, polished its to a high shine while many other teams left the metal natural but with a further black heat-resistant coating applied. Floor and diffuser sections subject to the greatest heat were also produced by printing and then bonded into the larger floor assembly.

Back in 2010, when teams first tried to really exploit blown diffusers, McLaren made a late change from its so-called 'octopus' exhaust and reverted to a more conventional exhaust blowing over the diffuser. The need to produce a complete diffuser in heat-resistant materials forced the team down the rapid prototyping route. The entire diffuser at the tail of the floor was produced in titanium in record time. Quite how such a large item (1,000 mm x 350 mm x 125 mm WxHxD) was produced has never been made clear.

ABOVE 3D printing is an ideal solution for the flanges and collectors (pictured) on exhaust systems

As with exhaust sections, the pitot tubes used for measuring the car's airspeed are short service life items. Their necessarily hollow cross section and curved shape makes them surprisingly suited to this application. Inner surface finish is more critical with these parts, compared to the strength required. Pitot tubes therefore form a large part of the output from laser melting 3D printers. Continuing on from this application are the large arrays of Kiel probes used in a rake-like setup for aero testing. So again the 3D printing route is taken for producing the probes, although the supporting structure remains machined aluminium.

As well as external instrumentation, aerodynamic parts are also produced with internal structures for instrumentation, for example metal wing sections complete with ports for pressure taps. These sort of wings wouldn't be raced, but would replace a conventional carbon wing to gather data when used during a free practice session. As well as producing printed parts for internal structures for data gathering, teams also produced wing sections in 2014 with internal ribs for cooling. This was applied to the small winglet aft of the exhaust pipe, known as the monkey seat. With the exhaust plume playing directly on the wing, the internal vanes help



LEFT & RIGHT F1's arms race saw many teams, such as Ferrari, harness the Coanda effect successfully (left). The trend relied heavily on the use of printed parts, as can be seen from this exhaust outlet used by Marussia (right)

ABOVE Complex shaped parts, such as slots and louvres on a wing endplate, are often printed then bonded into the assembly

> ***"One common use blows away any misconception that printed parts lack strength: the car's main roll hoop"***

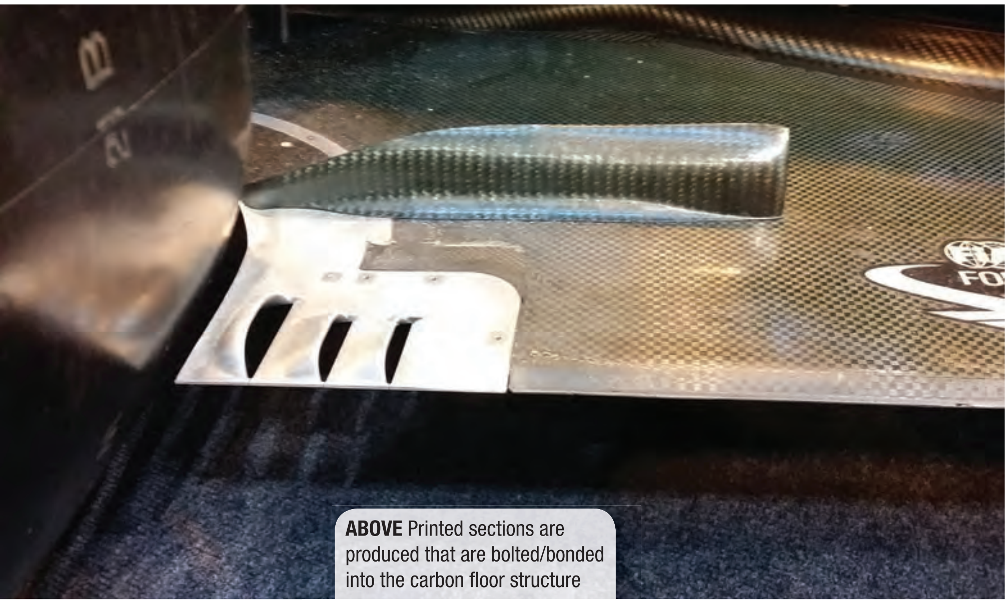
to keep the part a realistic temperature.

Then of course more conventional parts can be printed in metal, either where there's greater heat or loading, preventing even metalized plastic parts being used, but also where complex geometry of weight saving voids inside the part suits the printing technique. Common applications are the lower leading edges of the sidepods and the rear tyre decks. Much of the floor of an F1 car is made up from carbon fibre, though some exposed sections require greater strength, complex geometries and sharp edges. Also, being aerodynamic parts, their design life is short as new shapes are introduced on a regular basis. Thus printed sections are produced that are bolted/bonded into the carbon floor structure.

Beyond purely aerodynamic components, the associated mechanical parts such as front flap hinges and adjusters are printed. This produces a lighter part, without the complexity of creating jigs to machine such a small and heavily shaped component.

All of these are relatively small and lightly-loaded parts. But there is one common use of this production technique that blows away any misconception that printed parts lack strength: their use for the car's main roll hoop. It's been a long time since F1 roll hoops were steel tubular fabrications. Nowadays their shape is heavily dominated by aerodynamics, so complex aluminium or titanium inner structures are created, then bonded to the top of the monocoque and enclosed in a carbon fibre outer skin. Machining from a large solid billet of material is one production method, but printing is also used by teams. The parts can be more complex, with inner hollow sections inaccessible to machine tools, yet still have the strength to withstand the FIA load tests.

Printed roll hoops have been in existence for over four years. It's not clear which teams pioneered this application, but several are known to be racing, or have raced, with printed roll structures. Making such a large part which has to withstand such loadings was thought beyond the scope of the available technology. "There was a myth in the technical world that you couldn't manufacture titanium parts if they were taller than a few tens of millimetres high, because of stresses that are involved when you build them," explains a leading supplier. "Our expertise is very much about how you do build large structural components." Conventional machined roll structures are produced in both aluminium and titanium. In the printed form titanium is used, although it's understood aluminium ones have been tested but not yet applied to the actual race car.



ABOVE Printed sections are produced that are bolted/bonded into the carbon floor structure

FUTURE DEVELOPMENTS

Plastic printed parts are still some way from having the physical properties of carbon fibre, which they are naturally predisposed to replace. But materials, filler and post-processing will continue to allow greater loads and heat to be applied to the finished part. With still so few restrictions on the pace of aerodynamic development or on geometry, the ever more complex wings, vanes and details on the F1 car will increasingly be formed by printing and potentially produced at the track too!

There are so few metal parts remaining on an F1 car, the potential applications for metal printed parts are also limited. Suspension parts and even uprights are attractive, being short run productions with very complex geometries, attention even extending to brake calipers. Again research has been done in this area but it's not thought to have reached a race-ready end product.

With cooling of the complex new generation power units a major issue for the team, 3D printing of oil and water coolers is a distinct possibility. Formula Student teams have already proven their application. For F1, the likely scenario would be initially in forming the side tanks and pipework, before being used for the actual cooler's core itself. Such a part may have to be made in sub-assemblies as the limits on size are a restriction with the current printers.

Logically the gearbox would be a sure target for printing, as a technical tour de force. As gearbox service lives are now extended to six races, there's little scope for the huge R&D investment to provide a payback for the few gear cases required for the race team each year. RT

Need for speed driving 3D printer development

William Kimberley finds out from 3D printing expert Stratasys how motorsport is making unprecedented demands of the industry

STRATASYS is the formation of two different companies that came together at the end of 2012 when Stratasys, that was then the world's largest 3D printer company, merged with Objet, the privately held but substantial 3D printer manufacturer based in Israel.

Then in June 2013 the newly enlarged company bought MakerBot, the manufacturer of entry-level desktop-type 3D printers, to complete an extensive range. The portfolio of 3D printers now runs from a $1,000 printer to one costing more than half a million for idea development, prototyping and direct digital manufacturing.

ABOVE Race day grabs the column inches but behind the scenes Strakka's printing of production-grade thermoplastic components has drastically reduced lead times

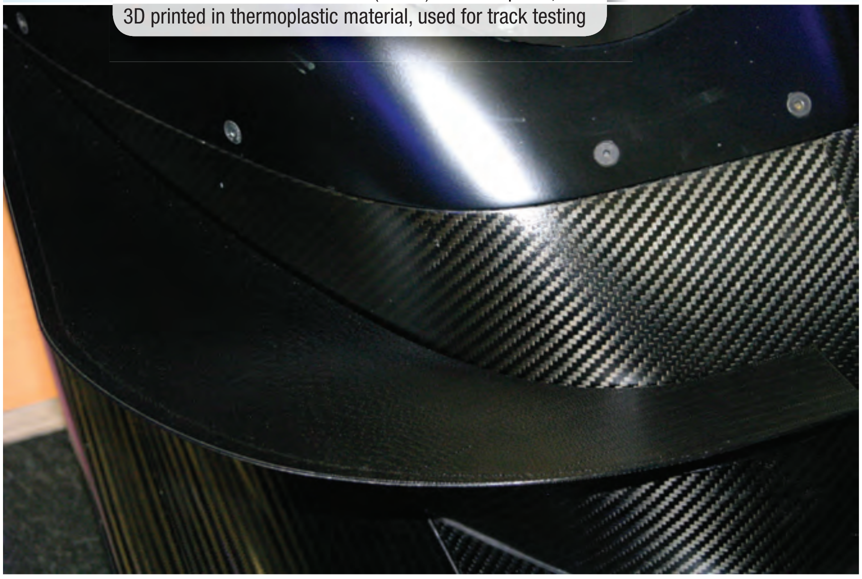
FDM TECHNOLOGY

The company claims that its range of specially engineered 3D printing materials is the most comprehensive in the industry. Its patented FDM technology, known for its reliability and durable parts, extrudes fine lines of molten thermoplastic, which solidify as they are deposited. Its PolyJet technology, known for its smooth, detailed surfaces and ability to combine multiple materials in one part, is relevant for prototypes or manufactured goods directly from 3D CAD files or other 3D content. Its WDM technology (wax deposition modelling), meanwhile, produces finely-detailed wax-ups for investment casting, particularly in dental applications.

At the time of the merger, the Stratasys CEO said that high-end 3D printers were advancing most in two areas: speed and material. He said that to make their rapid prototypes more viable, printers have to create products out of material that is stronger and more like the material used in final products, and they have to do it faster ▶

ABOVE The 3D printed camera module was mounted on the roof

> *"3D printing technology isn't just available to F1 and manufacturer teams, but also to privately-run teams that don't have a massive budget. It's a game changer"*



ABOVE & BELOW A brake duct (above) and dive plane, both 3D printed in thermoplastic material, used for track testing

and that is what the new company was going to focus on.

"3D printing is now used in most industries but it's the automotive industry that has widely adopted it," says Chris Baker, Stratasys' Northern European territory manager. The Bentley design studio, for example, uses Stratasys 3D printers for the assessment and testing of car parts prior to actual production. With the high-precision capabilities of Stratasys 3D printers, any designed part can be fabricated and prototyped at a smaller scale size, from the tyres, headlights and door mirrors right down to the crystal decanter.

Meanwhile, from a production point of view, Volvo Trucks has dramatically decreased turnaround times of assembly line manufacturing tools by more than 94% since incorporating Stratasys additive manufacturing technology at its engine production facility in Lyon, France.

"So whether you're talking about the style studio where they'll be printing many different parts to get the right designs," says Baker, "or engineering departments that are printing parts to test different designs accurately before they go to manufacture, or even final parts made, mainly for the interior, 3D printing is widely used."

However, for all this, motorsport companies are ahead in what is being achieved and pushing the boundaries, says Baker. "I think it's to do with the tremendous pressure on optimising the car to meet the track conditions. For example, we saw Strakka, the team we sponsor, using its FDM-based StratasysuPrint 3D printer in the garage to optimise parts during the World Endurance Championship event at Silverstone."

As an example of how quickly the team could react, he cites how it was presented with a camera that had to be fixed to the car. But rather than just attach it to the bodywork, a cowl was designed for it that was then printed in its garage and attached to the car.

TWO-WAY STREET

Away from the track, Strakka is using 3D printing with production-grade thermoplastics for all areas of its part production process that reduces part lead time from two to six weeks to just one day. This includes the wind tunnel testing of scale model parts, fully functional prototypes and track test parts.

"While we are sponsoring Strakka and we are providing them with equipment, it's a two-way street as it's coming to us with ideas and suggestions, applications and material requirements," stresses Baker. "What's important to take on board is the fact that 3D printing technology isn't just available to F1 and manufacturer teams, but also to privately-run teams that don't have a massive budget. It's a game changer in the motorsport world." RT

ABOVE Strakka's FDM-based StratasysuPrint 3D printer in the garage at Silverstone's WEC round

THE RIGHT ATTITUDE KEY TO SUCCESS

Chris Pickering highlights some of the latest developments in motorsport suspension technology

IT'S hard to overstate the importance of suspension. The ability to maintain the right level of contact between the tyre and the surface is key, whether you're in search of traction, braking stability or cornering force. If that wasn't enough, the suspension also has a major role to play in aerodynamic stability, controlling the car's attitude and ride height across a vast range of load conditions.

For this month's special report, we've spoken to a selection of companies working in this area of the industry, from spring and damper manufacturers to those working on bushes and fluids.

ZF RACE ENGINEERING

Automotive giant ZF has a competition history that stretches back to at least 1914 when the Sachs company (now part of the ZF Group) began supplying ball bearings to the Mercedes grand prix team. A couple of decades later, when the Silver Arrows of Mercedes and Auto Union swept all before them, they did so with Sachs dampers. Since then, the brand – now represented in motorsport by its ZF Race Engineering subsidiary – has picked up titles in everything from Formula 1 to the Dakar Rally.

With that in mind, we were curious to find out what the ZF Group's head of chassis technology, Rainer Kirchner, considered to be the company's biggest technical achievement of recent years. "Definitely our rally dampers," he responds. "A few years ago we weren't that heavily involved in rallying, but now they're our most complex dampers."

Perhaps surprisingly, this comparison even extends to the company's Formula 1 dampers. "The rally dampers are more sophisticated than any Formula 1 damper," says Kirchner. "They're quite complicated from an oil flow perspective. You need to understand what the oil is doing in each part of the damper under all circumstances. What is the flow through the adjuster? What is the pressure doing? How does it react to changes in temperature? Getting those features right in the first place is complicated enough, but you have to understand how they work in combination with the stiffness of the chassis, the weight distribution and so on."

It all adds up to a major performance differentiator: "In Formula 1 people sometimes question whether you even need dampers

ABOVE Rally dampers are more sophisticated than even their F1 counterparts

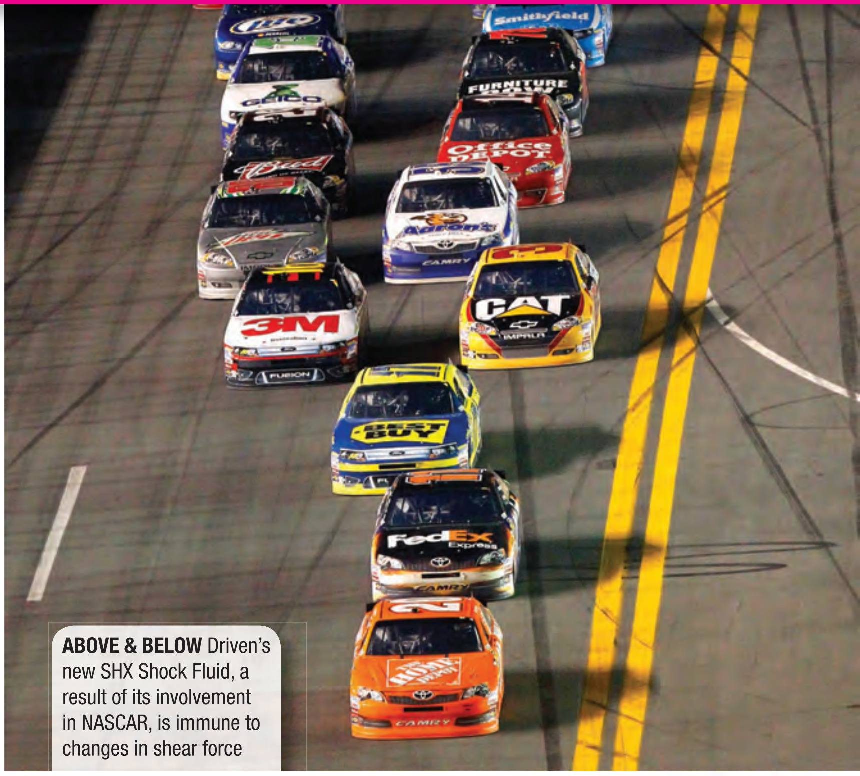
VW Motorsport

or whether the tyre itself is enough, but in rallying I'd say 50 per cent of the performance comes from having the proper suspension."

One of the most fundamental differences is the range of adjustment. Following customer demand, ZF has done away with external adjustment altogether on its Formula 1 dampers. Budgets, simulation techniques and the level of knowledge are such that the teams can assemble the dampers to the correct spec in advance without the need for the additional size and weight that comes with external adjusters. These dampers do offer a huge range of adjustment if you're prepared to strip them, but that's not common practice at the track; even sudden changes in weather tend to be compensated for with wing or tyre adjustments.

The WRC dampers, however, typically come with rebound, and high- and low-speed bump adjustments, plus adjustable hydraulic bump stops. Even during a single event the range of adjustment on every single one of these parameters can be considerable. And then you have the sheer forces involved in rallying, the wheel travel required and the harsh environmental conditions.

This is borne out by the weight. Formula 1 dampers range between 180g and 350g, but a WRC damper developed to a comparable extent is likely to weigh at least 10 times as much.



ABOVE & BELOW Driven's new SHX Shock Fluid, a result of its involvement in NASCAR, is immune to changes in shear force

DRIVEN RACING OIL

At their heart, all modern dampers are hydraulic components. And while huge sums of money (and no small amount of column inches) are devoted to the physical design of the valves, pistons and reservoirs, the fluid within them is often overlooked.

In reality, the behaviour of the damper is absolutely dependent on the characteristics of this fluid. Changes in viscosity due to heat or chemical breakdown can have both instantaneous and long-term effects. And not all damper fluids are created equal.

Most hydraulic fluids are made up of naphthenic base oils developed for low temperature operation in the aviation industry. As such they require viscosity index (VI) modifiers to improve their high temperature performance. (Viscosity index is an arbitrary measure of how a fluid's viscosity changes with temperature; the higher the VI, the better the fluid resists these changes.)

At high shaft speeds, the piston can physically shear the polymer chains that make up these VI modifiers as it travels through the damper fluid. This causes them to break down, changing the fluid's viscosity index. In theory – all other things being equal – the damping force should be directly proportional to shaft velocity, but this effect means it tails off at higher speeds. Initially these changes to the fluid's viscosity index are temporary, but over time they can become permanent.

Driven Racing Oil has come up with an ingeniously simple solution. Instead of using low VI base oils, it has taken advantage of recently developed high VI synthetic base oils and cut out the viscosity index modifiers altogether. This, the company claims, means its new SHX Shock Fluid is immune to changes in shear force.

"Having a high viscosity index that's achieved without VI improvers gives the shock engineer a different tuning tool," explains Lake Speed Jr, certified lubrication specialist at Driven Racing Oil. "They no longer have to compensate for shear force, so it lets you do things with valving that weren't possible before."

The idea first came about a few years ago when Joe Gibbs Racing identified that there was a technical benefit to be had from running a very light viscosity oil in its NASCAR dampers. "We wanted a low viscosity oil with a high VI. Initially we tried doing it with traditional base oils but you could actually see the fluid changing over time," recalls Speed. "At the time the benefits still outweighed the drawbacks, but it got us thinking about other ways of doing it."

It appears to be a win-win situation for damper engineers. The only real drawback, he says, is compatibility with some of the older seal materials: "Low viscosity base oils with a high VI can react with some seal materials. If this happens it can cause the seals to swell, which increases drag on the damper. It's not a problem with Viton seals, but you have to be aware of that if you're using traditional materials."

The valving may also need to be changed to take advantage of the new fluid, but it raises some intriguing possibilities. ▶

Owens/IndyCar

ABOVE & BELOW Penske's 8781 AF Series damper has enjoyed encouraging results

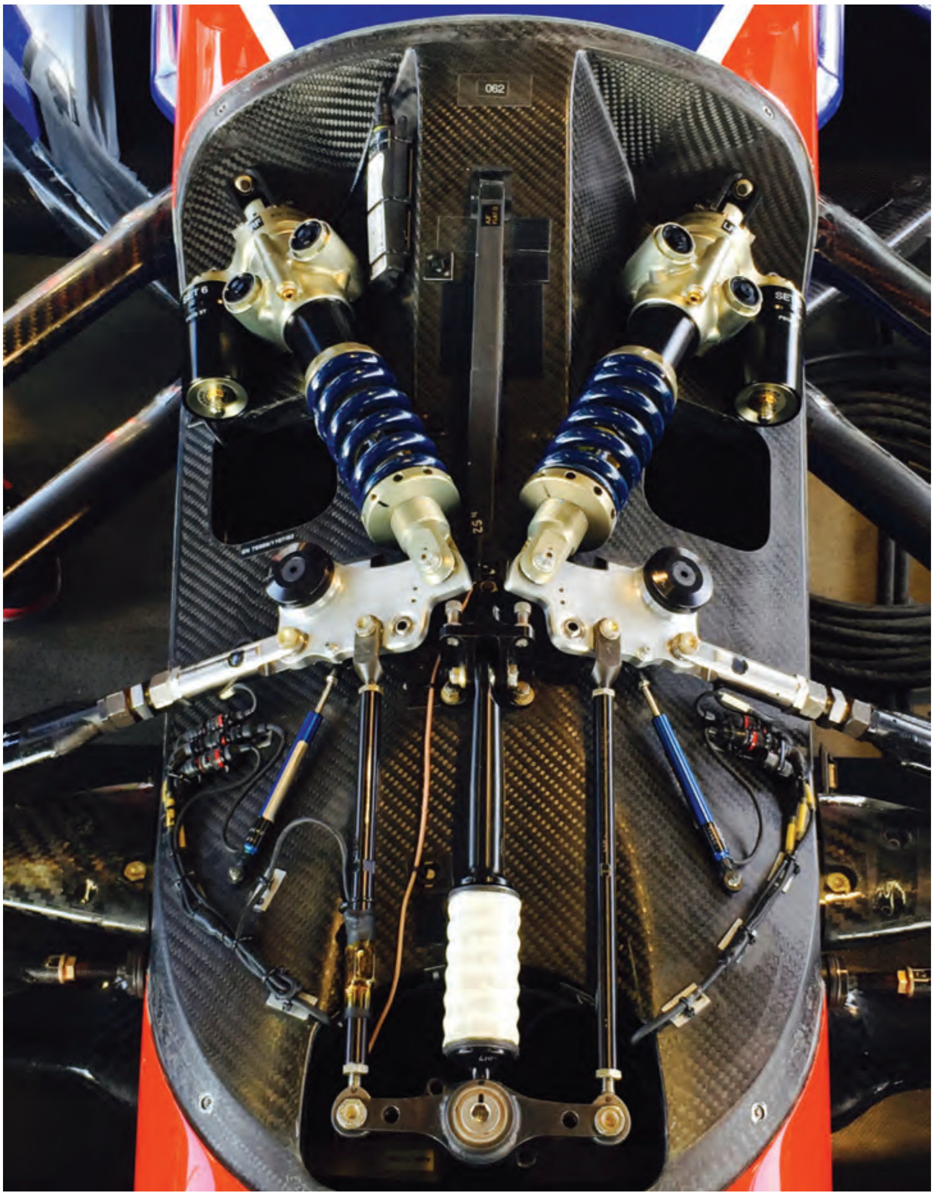
PENSKE

Penske Racing Shocks has been a constant force in high-end motorsport since the late eighties, having been formed to cater to the needs of Penske's IndyCar team. Since then it has diversified into just about every conceivable branch of motorsport, but America's premier open-wheel series remains a major influence.

In 2011 Penske introduced the 8780 Series damper for the new DW-12 IndyCar chassis. It came with a number of different manifolds that could be 'bolted' onto the side of the damper, allowing functions like blow-off, regressive, G-sensitive, and semi-active damping to be added.

Now Penske has taken this philosophy a step further with the 8780's successor, the 8781 AF Series damper, which is pitched at a wider variety of markets, including those using coilover suspension.

The 'AF' tag – short for annular flow – is a reference to the twin-tube fluid path within the damper, which Penske says is essential for allowing longer springs to be fitted in coilover applications. It's just part of a clever design that features some unique technology. Damping is still created through adjustable pistons and shims, but the damping assemblies have been repackaged outside of the main damper bore for greater ease with tuning and when using integrated inerter technology. The new adjuster designs also allow incorporation of Penske regressive technology, which turns the IndyCar damper into an 8-way adjustable unit.



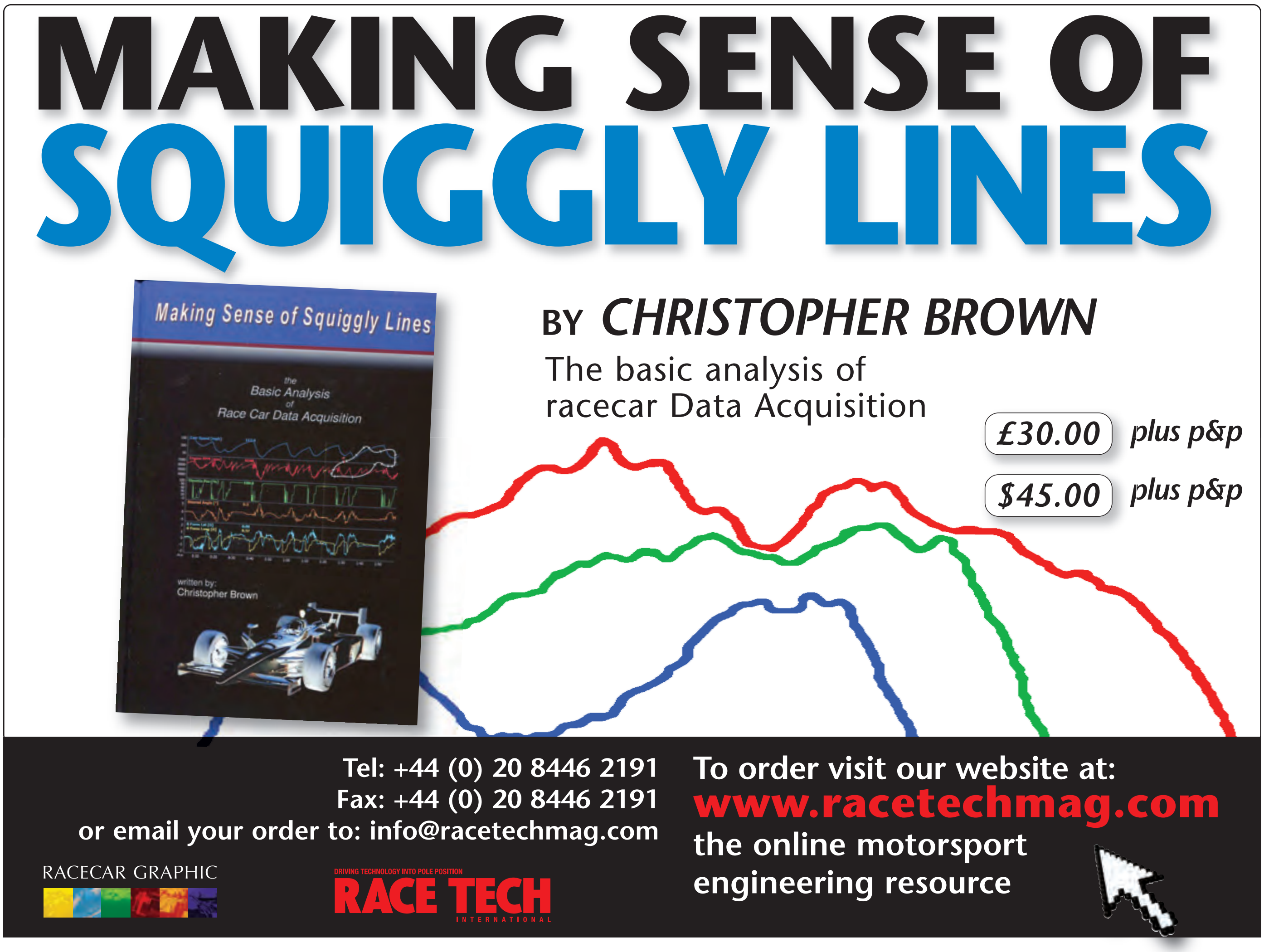
This opens up a seemingly bewildering array of adjustments: high-speed compression head valve; low-speed compression head valve; high-speed compression main; low-speed compression bleed; low-speed rebound bleed; compression regressive blow off; and rebound regressive blow off. This may seem excessive, but Penske promises us each has its own effect on various parts of the dyno curve and allows more extensive manipulation of characteristics.

"The 8781 damper was developed in direct response to what our customers have been asking for in terms of adjustment range, ease of use, and packaging," comments Penske Racing Shocks technical director, Jim Arentz. "Additionally, the ever-changing requirements in racing also make the case for a more user-friendly, externally-adjustable damper. The 8781 accomplishes these things and allows us to explore new areas of motorsport with some unique technology."

In IndyCar form, the 8781 AF damper can be configured in multiple formats including monotube, through-rod, and hybrid inerter. It is already in use with promising results and by the time this issue of Race Tech hits the shelves it should be available to the full IndyCar field.

Elsewhere, the 8781 adjuster allows implementation of large external adjustment to such things like Formula 1 7-post dampers as the response of the units very closely mimic that of non-adjustable race dampers. It's also expected to appeal to GT racing teams and other formulae. ▶


8e Edition
International Business Days LE MANS 2015
Race for Business
8th International Business Days
Le Mans
With the patronage of
DANISI ENGINEERING
Technoparc of Le Mans 24 Hours - June 10-11, 2015
Win the race for business !!!
Meet the buyers !!!
Don't miss the start of a unique business meeting which combines effectively business, motorsports and gastronomy
All our services and our offers. All information at:
www.ibdlemans.com
Special fare conditions on Air France KLM flights identification code : 23865AF
Major Media Partner
RACE TECH
DUNLOP MOTORSPORT
GRAND PRIX ESSEC
PROSPEED COMPETITION
REBELLION
ALPINE
Sarthe Développement
PRODUCTION
TRAMETAL
LE MANS


MAKING SENSE OF
SQUIGGLY LINES
Making Sense of Squiggly Lines
the Basic Analysis of Race Car Data Acquisition
written by: Christopher Brown
BY CHRISTOPHER BROWN
The basic analysis of racecar Data Acquisition
£30.00 plus p&p
$45.00 plus p&p
Tel: +44 (0) 20 8446 2191
Fax: +44 (0) 20 8446 2191
or email your order to: info@racetechmag.com
To order visit our website at:
www.racetechmag.com
the online motorsport engineering resource
RACECAR GRAPHIC
RACE TECH INTERNATIONAL

REIGER

Dutch rally and off-road specialist Reiger Suspension has also been working on a new damper fluid. Until recently, it had used three formulations to cater for conditions ranging from -25 deg C on the Arctic Rally to more than 40 deg C in the Atacama Desert on the Dakar. For the damper itself, that represents an internal temperature range of about -40 deg C to 180 deg C.

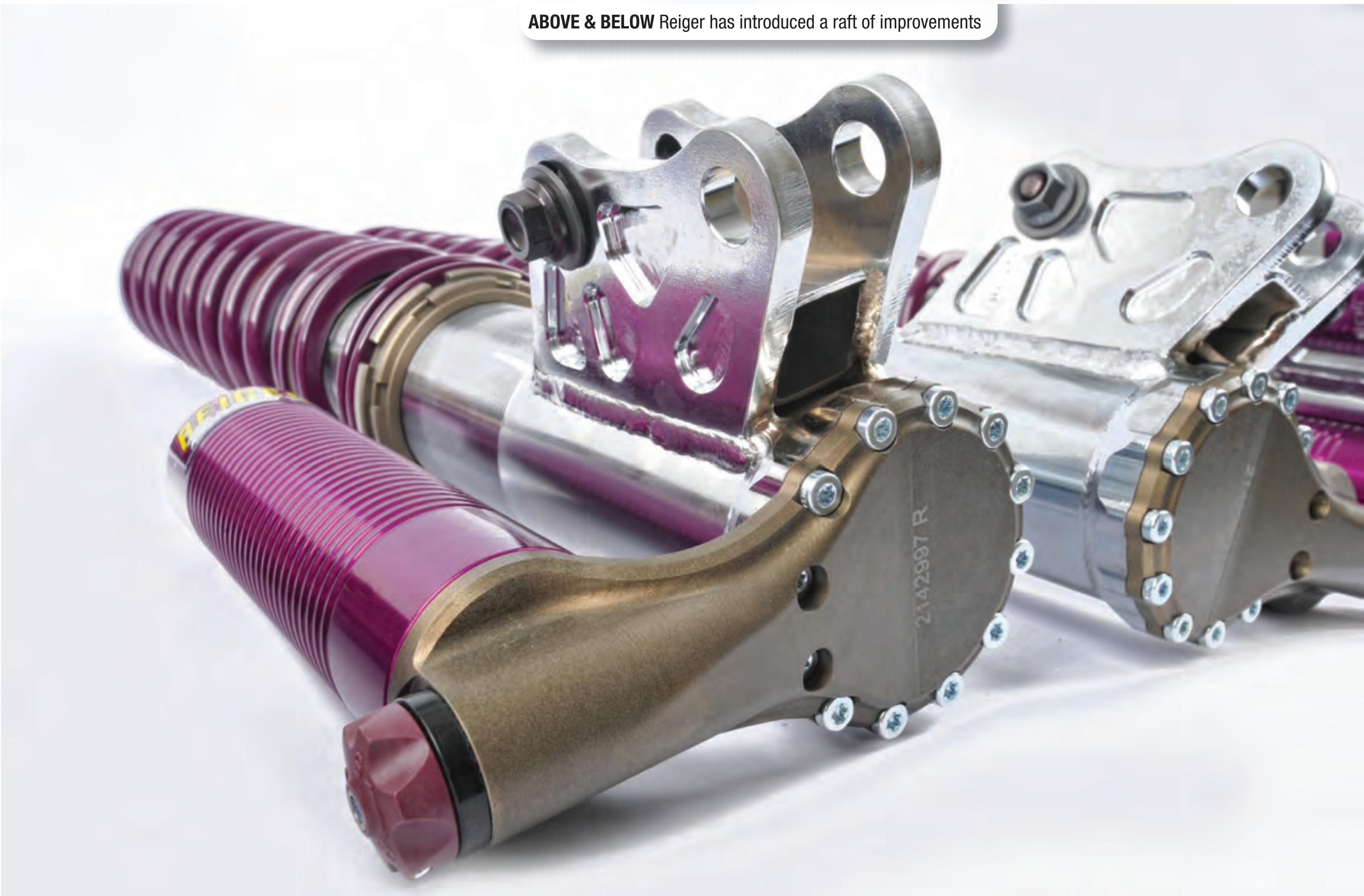
The engineers wanted to find a single oil that would cover this entire range. After several tests, however, they decided to formulate their own blend in partnership with their oil supplier. The prototype oil was used in one of the X-Raid MINIs for the 2014 Dakar Rally. It completed the 8,500 km marathon without a single fluid change and no discernible loss of performance.

With a few minor modifications this went on to become Reiger's damper fluid blend. An additive package is still used for very low temperatures, but apart from that the company can claim to have achieved its goal of creating a single damper fluid that provides greater performance than the three previous blends.

The company has also been developing its mechanical hardware. In particular, it has been targeting friction reduction with a new seal design that uses an improved rubber compound. According to Reiger, feedback on the new seals has been excellent and they have since been rolled out on the company's entire range of shaft diameters.

The engineers have also been looking at valving, with a number of clever systems such as the patented Corner Control Valve (CCV) which firms up the low-speed damping when it detects that the vehicle is cornering, and the Intelligent Compression System (ICS) which helps to differentiate between small wheel movements and major impacts from bumps and obstacles.

Another interesting idea is the company's speed-dependent damping system known as HDP (or Hydraulic Double Piston). This results in a damper curve that is dependent on both shaft speed and displacement, allowing teams to find a better balance between traction and comfort – the latter being a major concern if you're facing a 900 km Dakar stage littered with rocks the size of house bricks. ▶



ABOVE & BELOW Reiger has introduced a raft of improvements


SECRETS OF THE SANDS
The innovations that lit up rallying's ultimate challenge
RACE TECH
Driving Technology Into Pole Position
MARCH 2015 No. 172 UK £5.95 USA $11.99
INTERNATIONAL
www.racetechmag.com
Bernoulli
DTM
Dominic Harlow
EXCLUSIVE
Engineering the world's most spectacular touring cars
Plus Quaife's radical new gearboxes
Revealed: the 1-litre engine that could change rallying


F1 TECH GRABS GOLD!
RACE TECH
Season Preview
F1 2014
+ THE BEST LE MANS CAR NEVER BUILT?

ABOVE & BELOW Family affair: You can see the resemblance between the dampers from AST (above and left) and Moton (right)

AST/MOTON

Our next two companies are also located in The Netherlands' Damper Valley – a relatively small area that's responsible for a disproportionately large number of the world's high-end suspension manufacturers.

Moton, now owned by AST Suspension, developed a reputation during the early years of the 21st century for supplying high-end GT and touring car dampers. Back in 2000, nearly a third of the Le Mans grid was using the company's products, while later that decade Moton dampers helped Andy Priaulx on his way to three consecutive World Touring Car Championship titles with BMW.

In 2011 the firm ran into financial difficulties, and that's when AST stepped in. "Taking on the Moton brand was an easy decision for us," recalls Curtis Woodman of AST Suspension UK. "We already had close links with the company, supplying various parts, so all the drawings were available. After a year we moved Moton into our facility in Holland and continued servicing and building the dampers from there."

Since then, the Moton range has been given an overhaul. As well as improvements to the damping performance, the AST/Moton engineers have been focusing on making the dampers easier to build and service. Revisions have included a new system for mounting the pistons on the damper shafts, which makes the Moton dampers much easier to assemble.

AST has been broadening its own product range too, with new additions in the rally and off-road markets. Like Moton, however, it's best known in touring car circles – particularly in mid-level series like the Kumho BMW Championship and the VW Cup.

Both brands produce virtually everything in-house. Shafts, pistons and casings all start life in the same 8,000 square metre workshop near Eindhoven. Even the heat treatment is carried out on site and AST/Moton continues to supply parts like top mounts to other manufacturers.

Producing the shafts is a deceptively involved process. The steel rods are first cut to length, before they're ground to a precise finish: too rough and the bushes will wear out, causing the oil to leak; too smooth and it can cause problems with the coatings process. Next they're line bored, using a special machine to create the bleed path through the shaft. Finally, they're sent for coating, using either a standard chroming process or a very low-friction dilithium DLC finish. The latter adds a substantial cost and is typically only used for motorcycle applications. ▶

Image: Jakob Ebrey Photography

KONI

It's nearly a decade since the mysterious J-damper became the centre of Formula 1's Spygate saga. It quickly emerged that these enigmatic devices were in fact tuned mass dampers, otherwise known as inerters.

In a nutshell, the inerter reacts to the acceleration rather than the velocity of suspension movement. Consequently, it can smooth out oscillations in the tyre carcass that would be outside the range of a conventional damper. At least that's the theory. While some F1 teams continue to use inerters, Force India is using Koni's patented Frequency Selective Damping (FSD) system for much the same purpose.

The FSD system uses two different flow routes through the damper. As the frequency of the motion changes, it opens and closes a mechanical valve that controls the oil flow through an additional circuit. This means the damper can be tuned to exhibit different behaviour at different shaft frequencies, controlling both high frequency tyre oscillations and lower frequency body movements.

"The FSD device acts like a hydraulic amplifier," explains Koni's sales manager for OE cars and racing, Frits Altorf. "It increases the pressure in a chamber, which cuts down certain bleed holes."

The technology was actually developed for road car use. One of its early applications was the Mercedes-Benz SLR McLaren supercar. This caught the attention of the McLaren Formula 1 team, which was based in the same building at the time, and it prompted a technology transfer into F1.

"We used to see a lot of technology developed for F1 applied elsewhere, but nowadays it's principally a means of promotion," explains Altorf. "We're a small company and it's basically a business card; it allows us to showcase our technology."

Formula 1 remains the most extreme test of the technology, due to the miniaturisation required and the high temperatures it has to sustain. Since then, however, the basic concept has spread into other areas of Koni's motorsport range.

ABOVE & BELOW Force India is using Koni's FSD technology

Sahara Force India

POLYBUSH

Polybush produces polyurethane bushes for fast road, track day and race machinery. When it comes to competition, the company is well represented in both historic racing and modern production-based series like the Production GTi Championship.

Polyurethane has a comparatively high tensile strength, which reduces unwanted deflection in suspension components compared to standard rubber bushes. It's still a very resilient material, springing back into shape to prevent the ingress of dirt, plus it doesn't perish or age.

Polybush's products are cast by hand, although a machine is used to prepare the polyurethane, which is mixed from a combination of isocyanates and polyols, with a third chemical used to control the rate at which it cures. Before being set, the finished blend resembles liquid paint, and by varying the ratio of the various constituents it's possible to tune its physical properties.

"Polyurethanes get their hardness at a molecular level. They're basically a mixture of soft, long chain polymers and hard, short chain polymers," explains Polybush design engineer Mike Paris. "The soft chains give the material its resilience, while the hard chains give it the wear resistance and Young's modulus. The more of those hard, short chain polymers you put in, the stiffer the finished product will be."

The polyurethane mixture is poured into a mould and then left to cure for around 12 hours in an oven. After that, all that remains is to trim off any excess material. ▶

BELOW Polybush's polyurethane bushes feature in both historic and modern production-based series

DELIVERED DIRECTLY TO YOUR DOOR!

40% Off SUBSCRIPTIONS

...or find digitally on

Available on the App Store

Samsung Apps

available on kindle fire

By subscribing online
www.racetechmag.com

ONLY

£40.00 12 Issues, UK
€71.00 12 Issues, Europe
$112.00 12 Issues, USA
£72.00 12 Issues, Rest of the world

RACE TECH is the only technology led motorsport engineering magazine that focuses on every aspect of the racing car, from the drawing board to the race track. News reactive and highly topical in its content, it covers everything from the design and manufacturing processes to the cutting edge products that are constantly being developed for racing. To be kept up to date on the hottest technology in the motorsport world, subscribe to **RACE TECH**.

ONE YEAR/ 12 ISSUES	FULL PRICE	YOU PAY
UK	~~£66.00~~ Free P&P	£40.00 Free P&P
EUROPE	~~€120.00~~ Incl P&P	€71.00 Incl P&P
USA	~~$185.00~~ Incl P&P	$112.00 Incl P&P
ROW	~~£120.00~~ Incl P&P	£72.00 Incl P&P

Subscribe online at www.racetechmag.com

HYPERCO

It's not often that something fundamentally different comes along in suspension technology, but Hyperco's innovative Carbon Composite Bellows Spring system could lay claim to being just such an idea.

The concept has been well documented in these pages in the past; in place of a traditional coil spring it uses a stack of composite discs arranged in either series or parallel orientation, placed concentrically over the damper. Using this arrangement, Hyperco says it's possible to make a spring that's around a third of the weight of a steel coil and half the weight of an equivalent titanium unit.

The Carbon Composite Bellows Spring's trump card, however, is configurability. By varying the quantity and orientation of the various base rate discs it's possible to build up a vast range of different spring rates.

Hyperco general manager Kelly Falls explains just how adaptable the system is: "You could set the car up to race on any circuit in the world using a collection of washers that would fit into something the size of a laptop case. If you wanted to carry around enough traditional coil springs to do that you'd be looking at an air freight container."

Ultimately, Falls argues, this helps to reduce costs too. Viewed in isolation, the Carbon Composite Bellows Springs aren't cheap, but a single stack can replace multiple coil springs. Whereas titanium coils can cost $800 per rate, Hyperco says the composite system can work out at as little as $150 per rate.

ABOVE & BELOW Hyperco continues to refine its full range

In these straitened times it hasn't always been easy to convince series organisers to adopt new technology. Falls is hopeful that the system will be seen in IndyCar and endurance sports car racing before too long, but in the meantime it has found homes in other categories of racing, not to mention aerospace and high-end mountain bikes.

Behind the scenes, the company has also been busy refining its coil springs. "Compared to a spring of just a few years ago you'd see that they are now substantially lighter, with more space between the adjacent coils and probably smaller for the same rate and displacement," he notes.

It all comes down to the continued development of ultra-high tensile steel wire. The material that Hyperco uses is a comparable quality to that used for valve springs; it undergoes multiple inspections for pits, seams or inclusions, and it's subject to a carefully developed shot-peening process.

"Shot-peening is a critical part of producing a spring and ensuring that its performance is consistent over time," says Falls. "We've experimented a lot with different sizes of shot and different velocities to get the best results."

There are also some important details in the design. Grinding the two ends of the spring square and parallel is essential to reducing unwanted side force, but the relative orientation of the two tips was found to have a huge impact too. The engineers fine tune this effect using a 'body bulge' – where the diameter of the coils varies in between two fixed diameter ends. This also helps to control the stresses within the spring, and Falls points out there's more to it than a traditional barrel spring, which has a consistent diameter in the middle: "If you took 10 springs out of our range for a given free length and rolled them across your desk, you'd see that no two are the same. Each one has a different degree of 'bulge'." RT

A solution to flying cars?

AAMGARD Motorsport has developed an ingeniously simple concept to combat the phenomenon of racecars taking flight. In the wake of the tragic incident involving a GT3 car at the Nürburgring Nordschleife earlier this year, the German company has adapted its DX ground clearance control system to act as a safety device.

Initially developed for test and development purposes on dragsters, where the front end is prone to lifting during acceleration, the DX system contains a set of three or four laser ride height sensors from KA Sensors, coupled to an intelligent control unit. It measurers the ground clearance a hundred times a second to an accuracy of 0.1 mm, immediately sending out an alarm signal if a preset threshold is exceeded. This can be used to trigger an ignition cut or activate the vehicle's traction control (where used), as well as an audible warning in the cockpit.

The ride height threshold can be programmed using Aamgard's SmartProgrammer SU95 module or preset by the factory to the customer's requirements. The system has the potential to detect aerodynamic oscillations and rates of ride height change (dx/dt). It can also monitor additional physical values like suspension forces, lateral and vertical accelerations and underfloor pressure. For future models, Aamgard is looking into the possibility of adding a pitot to measure underbody air flow, with the ability to compare front and rear values.

Scalmalloy

AIRBUS Group subsidiary AP Works is promising big things for its new Scalmalloy material. Intended for use in additive layer manufacturing (ALM) processes, this unique second-generation aluminium-magnesium-scandium alloy is said to combine the specific strength of titanium with the density of aluminium and a high level of ductility.

AP Works says that high cooling rates and rapid solidification create a unique microstructure which rivals the performance of the highest grade aluminium foundry products, while ALM offers greater flexibility in design.

Go-Race Quick Release

MANY cars have quick release steering wheels, but they can be far from quick to reattach. The new Self-Aligning Quick Release Steering Hub from Go-Race Engineering aims to solve that, with a clever mechanism that eliminates the need to line up splines.

Using the Go-Race system you simply pull back on the locking collar, slide the hub onto the steering column boss and spin the wheel until the quick release unit automatically locks in the correct position. Conforming to FIA specifications, the new hub is available in a range of sizes in both weld-on and bolt-on fitments. Despite its added functionality, the Self-Aligning Quick Release Steering Hub is still very light, with the weld-on Formula 3 model tipping the scales at just 215g.

Ride height control

WHILE it was developed primarily for the street performance market, we couldn't help noticing JRi's new Hydraulic Ride Height System. It uses an hydraulic weight jacker in the top of each damper unit to vary the vehicle's ride height by as much as 3" without affecting spring or damper rates.

Unlike airbag-based systems it's virtually immune to environmental affects like air temperature and altitude and it's suitable for any chassis that uses eyelet mounted coilovers. Despite a modest weight increase, the concept has proved a popular fitment on Pro Touring autocross machines, such as Bob Bertelsen's Chevy C10 pick up, pictured here.

B-G Racing Turn Plates

B-G Racing's new Turn Plates are designed to be placed directly on top of scale pads to measure castor, camber and kingpin inclination angles. They are constructed from lightweight aluminium and feature steel ball bearings to ensure they are free floating and do not bind. Up to 25 degrees of steering angle can be accommodated and they come with a laser etched dial that can be zeroed once the vehicle is in position.

BOOKS FOR SALE

www.racetechmag.com

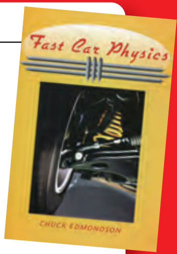
BUY NOW

(AND BE PREPARED FOR THE NEW SEASON)

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

FAST CAR PHYSICS

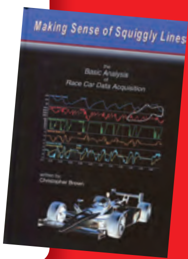
by Chuck Edmondson
Softback 229 pages
£20.00



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

MAKING SENSE OF SQUIGGLY LINES

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



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

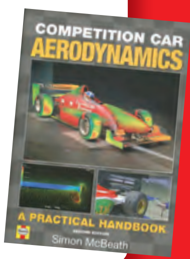
RACE CAR AERODYNAMICS

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

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

COMPETITION CAR AERODYNAMICS

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



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

THE COMPETITION CAR DATA LOGGING MANUAL

By Graham Templeman
Softback 128 pages
£19.99

SOLD OUT

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

ENGINEER TO WIN

By Carroll Smith
Softback 280 pages
£19.99

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

HOW TO BUILD MOTORCYCLE-ENGINED RACING CARS

By Tony Pashley
Softback 128 pages
£24.99

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

COMPETITION CAR ELECTRICS

By Jon Lawes
Hardback 160 pages
Hardback: £25.00

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

DRIVING TECHNOLOGY INTO POLE POSITION
RACE TECH
INTERNATIONAL

RACECAR GRAPHIC

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

Are the Fab Four really that fab?

The proposed future for LMP2 sees the constructor count pinned at four. But is this a wise decision?

SOMETHING of a revolution is brewing in LMP2. It's no secret that the FIA and the ACO are working on a radical shake up of the category, which will include switching to a single 'spec' engine and limiting the number of chassis suppliers to just four companies.

Reaction in the LMP2 paddock seems to vary from guarded optimism to outright bemusement. In Europe at least, the class is doing well with no less than 19 cars registered for this year's Le Mans. That makes it the single biggest field at the French classic if you count GTE Am and GTE Pro as two separate entities.

So why change things if everything is going well? One argument would be to rejuvenate the class on the other side of the Atlantic, where the situation is far from rosy. Under the new proposals, at least one of the four manufacturers would have to come from North America. Whether or not this would provide the necessary shot in the arm remains to be seen, but some sort of shake up is definitely in order.

Back on this side of the Atlantic, the ACO has made it very clear that it sees LMP2 as a category for teams and drivers rather than manufacturers. With that in mind, it seems like a curious decision to pin the number of chassis manufacturers at four; this is still enough to allow a dominant chassis to emerge as 'the one to have' and yet it would appear to miss out on the cost savings you might be able to achieve with a true single-make series.

Of course, that's assuming that cutting down the number of manufacturers will actually reduce budgets. LMP2 is already a cost-capped formula with no less than eight constructors in operation. The argument presumably is that, with a greater share of the market, those four manufacturers would be able to reduce their profit margins on each car, delivering more bang for the teams' bucks. Good for the teams, but not so good for the manufacturers.

It's very possible that this is also an attempt to divert some of the chassis and engine constructors back into LMP1. While the hybrid-powered factory teams are treating us to the most competitive LMP1 season in years, the unofficial privateer class in the World Endurance Championship numbers just two teams, only one of which actually made it to the opening round at Silverstone.

Another crucial group to consider are the fans. One of the best things about endurance racing is a visible, audible distinction between the various cars. Plus, recognisable brands like Nissan, Morgan and Alpine hold their own appeal to casual fans who may not be able to name the individual drivers behind the wheel. Perhaps the view is that spectator appeal – like technical development – belongs with the big factory teams in LMP1?

Finally, we come back to the engine. Rumour has it that the new 'spec' unit will be a naturally aspirated V8 of around four litres. The feeling is it would have to be a purpose-built racing engine to satisfy targets for increased longevity and extra power. This would rule out the current crop of powerplants, all of which are based on heavily re-engineered production units. A clean-sheet design is, of course, a possibility but there are other suggestions. It's been mooted that the new V8 could be based on two four-cylinder Global Race Engines grafted together, but this could turn out to be an extremely expensive way of developing an engine. A more likely option seems to be an existing V8 competition engine.

The specification has also raised a few eyebrows. Direct injection is understood to be high on the priorities list, but you have to ask what the point is in a category that excludes any sort of technical competition? One specialist we spoke to estimated that direct injection and the associated high-pressure fuel system would add around £10,000 to the cost of an endurance racing engine. That's worth every penny if it buys you an extra lap per stint over your less efficient competitors, but it just adds extra cost otherwise. We understand there have also been suggestions of running a kinetic energy recovery system, which sounds like little more than wishful thinking.

To be fair, much of this is based on hearsay and the final specifications have yet to be announced. But the logic behind turning LMP2 on its head just after it announced a bumper 19-car grid for Le Mans remains far from obvious. RT

ABOVE The LMP2 shake up has provoked a mixed reaction

ELMS


PAGID RACING
Brake control
from green light
to chequered flag.
EKSTRÖM
NEED FOR SPEED
COOPER TIRES
PAGID RST
Double DTM Champion Mattias Ekström has clinched his first-ever FIA World Rallycross Championship victory after a flawless drive in the Audi S1 EKS RX in Holjes, Sweden. In his RX campaign, Mattias relies on the supreme stopping power of PAGID RST racing brake pads – high initial bite, constantly high friction over temperature with excellent modulation over the whole temperature range. With the highest degree of braking performance, PAGID RST racing brake pads deliver the competitive edge that successful drivers demand.
bt Bremsen Technik
www.pagidracing.com · info@bremsentechnik.de
+ 49 6172 59 76 60
Pagid is a registered trademark of TMD Friction
TMDFRICTION
A NISSHINBO GROUP COMPANY

What's the
secret
about the new 911 GT3 Cup's
new brakes?
It's Quicker.™
PFC
PORSCHE
OFFICIAL PARTNER
PORSCHE
MOTORSPORT
PFC
BREMSE
www.pfcbrakes.com
*44(0) 1295 221 020