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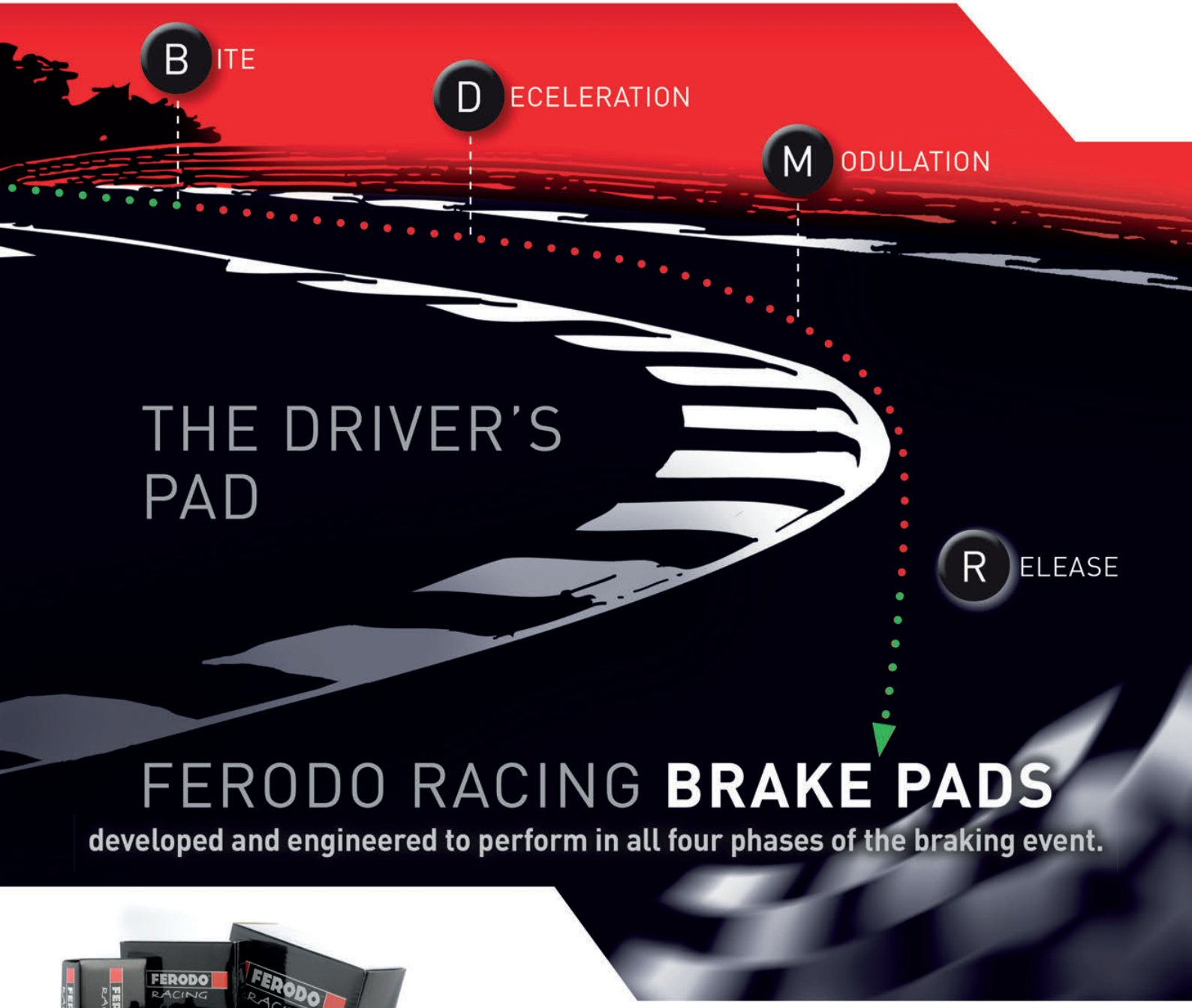

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Who needs a driver?

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COVER STORY PAGE 6 & 22

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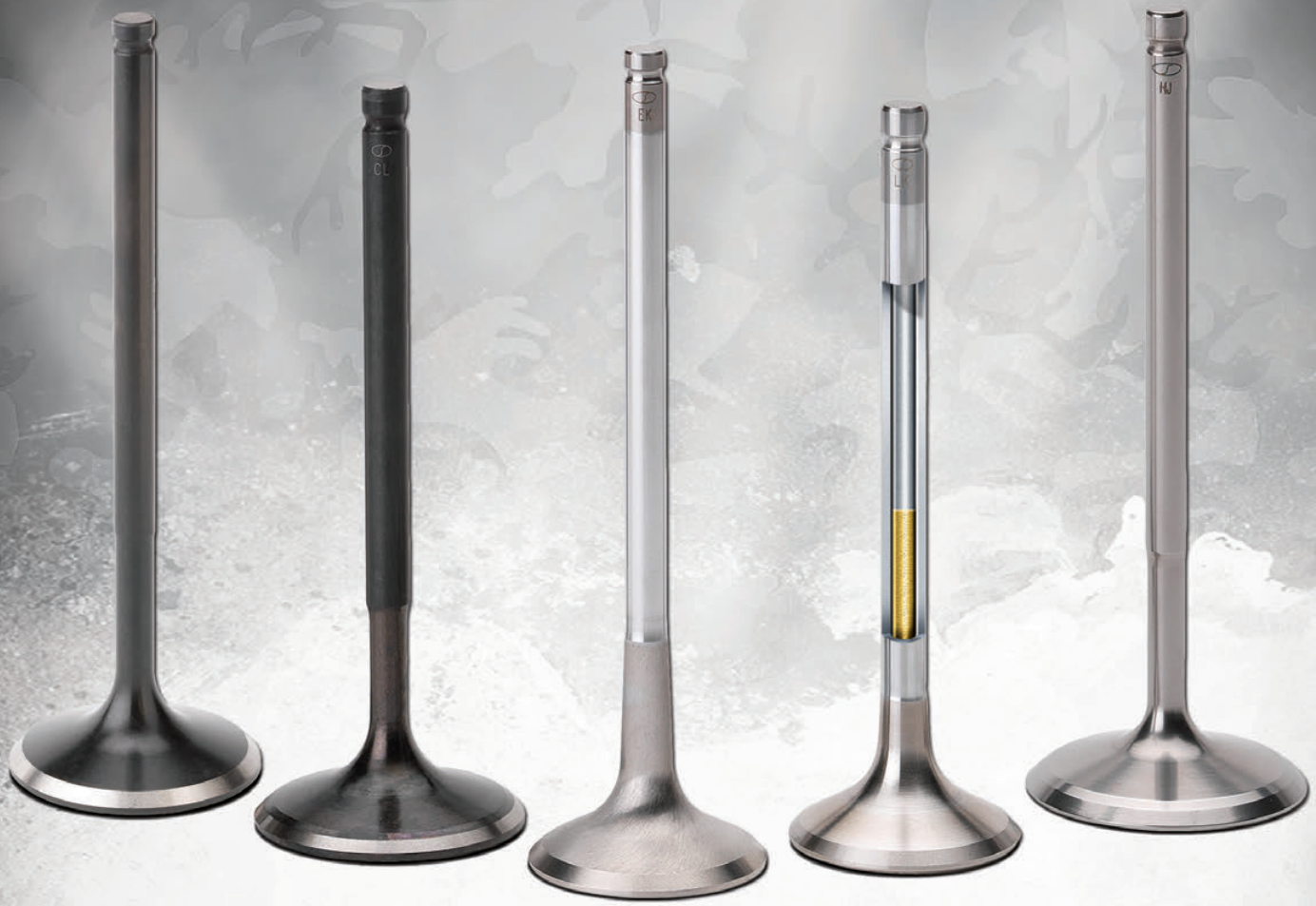

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ART EDITOR
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Maryam Lamond

MANAGING DIRECTOR
Adrian Goodsell

PUBLISHING DIRECTOR
Soheila Kimberley

RACE TECH Motorsport Engineering

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

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A DANGEROUS SIGN

THREE major events at Silverstone in three consecutive weeks is tiring but inspiring for all different sorts of reasons.

The Formula 1 race this year was quite magnificent. It needed the help of the safety car a couple of times, but the race was alive from the start when Lewis Hamilton had to fight his way back through the field. The crowd and atmosphere there was fantastic and it would be extremely foolhardy if Liberty Media was not able to agree terms with the British Racing Drivers Club to let it remain a fixture on the calendar after 2019. Hopefully the Bernie Ecclestone era, when only money and nothing else mattered, has now passed on so that other considerations can be taken into account.

The third event was Silverstone Classic. When you get 1,000 cars of all types and varieties and of different ages racing over the long weekend, you just cannot go wrong. Add into the mix the fact that you can go and see them up close and personal, along with all the car clubs that put on such a display, and two or three days is not enough to take it all in. Then there's the sound. I do understand why the modern Formula 1 car's sound is muted, but when you hear the roar of a DFV or the myriad other unmuffled engines reverberating around the circuit, then it really does make your hair stand up.

These two events are quite superb, but it's perhaps Formula Student, which nestles in between them, that is the most inspiring. Unfortunately it did clash with the Goodwood Festival of Speed, which has its own aura, although the crossover in terms of participants and spectators is virtually nil.

This year's competition was a little down on numbers, the Dutch, Swiss and Germans, with the exception of the TU Munich electric car team, all staying away to attend another Formula Student event due to a rather ridiculous clash of dates. When Formula Student started 20 years ago as an offspring of Formula SAE, it was the first to be held outside the US. Now they are springing up like daisies all over the place. The generally underfunded student teams have to cherry pick which ones to do.

Pretty well every team, and there were nearly 100, had their own story to tell. But the one thing that struck me, and is the cause of a great deal of concern, is that while the students themselves and their faculty advisers who attend are naturally enthusiastic in what they are doing, I was hearing quite a lot over the weekend about the lack of support and understanding from their respective universities. What's happening is that mechanical engineering, and certainly when it comes to motorsport, is now seen as a waste of resources, and not worth wholeheartedly pursuing. If their students wish to have a Formula Student team, then the university department heads are rather washing their hands of it. They give lip service but no real support.

No names, no pack drill, but some that have spent years building up a fine reputation for providing the motorsport industry with bright young engineers are now rather turning their backs on it as a discipline, and that's very sad.

The buzzwords now are computer science, artificial intelligence and neural networks. There's no question that these are part of the future, and congratulations to the Institution of Mechanical Engineers for introducing an autonomous category in the competition, but at the end of the day, nothing works without mechanical engineering. If we are to discourage the young from taking it as a degree, then we may as well wave the white flag and surrender.

Finally, I just want to say a few words about the Race Tech Spirit of Formula Student award we gave to Team AUJ from the National University of Sciences and Technology. There were many deserving teams, but we gave it to this all-female squad, not just because of their sex, which is pretty astonishing in itself, but for the message we wanted to send out. They have come from Pakistan of all countries to show the world that women engineers can do just as good a job as males, and yet, in the UK at least, women engineers account for just a paltry nine per cent. That's not good enough.

William Kimberley
EDITOR

ABOVE Roborace made history by being the first autonomous car to go up the famous Goodwood Hill at the Festival of Speed

Autonomous cars make their mark

William Kimberley

GOODWOOD and SILVERSTONE, UK: While Serena Williams was being denied the opportunity to equal Margaret Court's tennis grand slam singles record by being beaten by Angelique Kerber in the women's final at Wimbledon, history was being made 60 miles to the south at Goodwood when an autonomous car without a driver at the wheel went up the famous hill. However, it was not the only driverless car to make the ascent. Although a bit more haphazard in its route, a 1965 V8-powered Ford Mustang also achieved the goal.

They were not the only cars making history on that weekend because at Silverstone, which was hosting the 20th Formula Student event, an autonomous car completed one lap of the endurance event on a course mapped out with cones.

Roborace, the autonomous car that ascended the 1.16 mile Goodwood Hill faultlessly, was designed by Daniel Simon, the automotive futurist known for his work in Hollywood films such as Oblivion and Tron: Legacy. Weighing 1,350 kg, it is powered by four 135 kW electric motors used to drive each wheel for a combined 500-plus hp. An NVIDIA DRIVE PX2 computer processes the data, which includes inputs from the LiDar, radar, GPS, ultrasonic, and camera sensors. Its speed was limited to 120 kph to allow visitors to have a good look at the car on its way up the Hill. In a blog post, Nvidia described the race completion as "a significant milestone toward Roborace's ultimate goal: establishing a new racing platform without human drivers".

When not in action, it was part of the Festival of Speed's Future Lab that showcased fascinating technological developments in everything from motorsport to healthcare. Yamaha, for example, displayed its MOTOBOT, a humanoid robot motorcyclist that has already achieved a speed of 200 kph and aims to match Valentino Rossi's lap times around a circuit, the underlying ambition being to develop a robot capable of operating a machine originally designed for humans.

Siemens was also present showcasing how the virtual and real automotive production worlds came together by putting an Aston Martin Red Bull Racing Formula 1 car and its digital twin side by side to show how, from optimised design and testing, the virtual model becomes a reality with innovations in composite design and fluid and particle aerodynamics modelling.

A four-wheeled rover developed for ispace's anticipated Moon landing in 2021 was also being showcased, giving visitors an interactive glimpse into the future of space exploration. Able to capture 360-degree, high-resolution colour video and imagery from space and beam it back to earth, the rover has won admirers for its ingenious design.

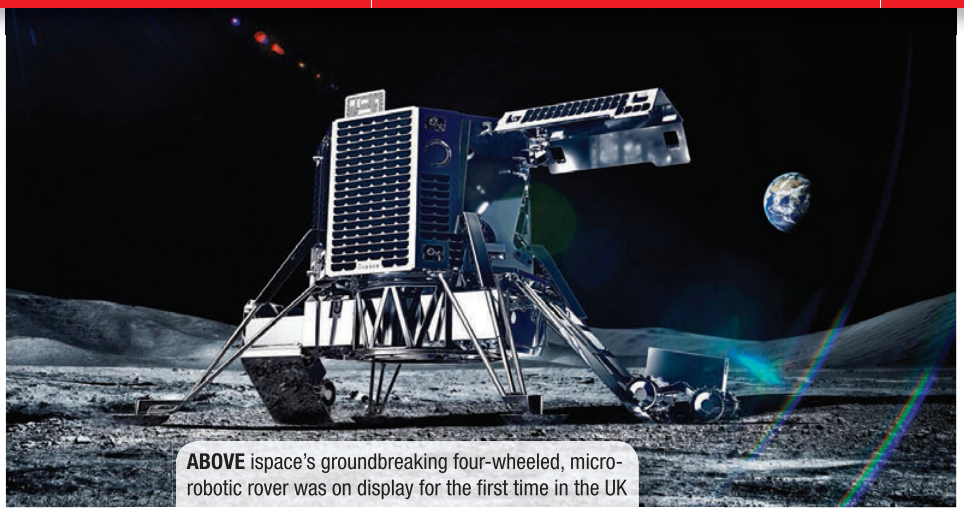
"The ispace rover is one of the most exciting new developments in making space exploration more accessible for researchers," said Lucy Johnston, curator of Future Lab. "A result of learning from automotive innovation as much as it is drawing on expertise from aerospace."

Although not motorsport related but using it to spark interest in STEM (Science, Technology, Engineering and Maths) among young people attending the festival, Fuel3D was debuting its cutting-edge technology 3D facial scan and personalisation platform where visitors were able to explore the unique three dimensions of their face, share their own 3D selfie and see how closely their face measured up to racing driver Johnny Mowlem.

"3D facial recognition technology has traditionally been used in security, but thanks to advancements in technology and machine learning algorithms it now has massive potential to disrupt the retail industry and set brands apart by redefining customer experience," said George Thaw, CEO of Fuel3D. "One of our aims with our installation was to help spark an interest and sport is a good way to attract people to STEM and Johnny is a great role model so we are extremely grateful to him for sharing his 3D facial scan with us for the festival."

The autonomous Ford Mustang that had been developed by Siemens and researchers from Cranfield's Advanced Vehicle Engineering Centre was the subject of some

ABOVE In collaboration with Cranfield's Advanced Vehicle Engineering Centre, Siemens had developed a V8-powered Ford Mustang that also drove up the hill without any driver input



ABOVE ispace's groundbreaking four-wheeled, micro-robotic rover was on display for the first time in the UK

derision for the way it went up the hill on its first run, someone describing it as looking as if it has come from the pub rather than a laboratory. However, it was revealed by *The Sunday Times* that it had been programmed to weave down the track to make it more dynamic for the television audience.

However, the car did have problems, which did not help. The power steering failed, and the system found it hard to compensate for the extra effort required, and while it had all the radar and LiDar sensors, it relied on GPS and a system of "accelerometers and gyroscopes" to cover times when the GPS had reception issues. Advanced location-scanning technology from Bentley Systems has allowed the engineering team to give the car an accurate 3D scan of the track, connected to an awareness of the car's own position. Finally, progamming, which was done by a Masters student rather than a professor, was achieved in just six weeks.

PREPARING FOR THE FUTURE

"Goodwood offered us a chance to reflect on why we have an emotional connection with cars and acts as a reminder that humans like to be engaged and part of the action," said Dr James Brighton, senior lecturer at Cranfield. "The Siemens Autonomous Hillclimb challenge project connects the classic spirit of automotive adventure with advanced technology."

Meanwhile, at Silverstone, Ross Brawn, who is the Patron of Formula Student and Formula One Management's director of motorsports, and chief judge Terry Spall, unveiled the purpose-designed autonomous car, codenamed the ADS-DV, at the opening Formula Student ceremony. It follows Formula Student Germany's lead which created a driverless car category last year.

The car, is the product of a collaboration between DJ Racecars for the chassis, suspension and bodywork design, manufacture and assembly, Hypermotive for powertrain and electrical systems design and integration and StreetDrone for the software systems design and integration of the AI computer, sensors and electronics. The aim of the organisers, the Institution of Mechanical Engineers, is for teams to develop a cost-effective software package to enable an Artificial Intelligence (AI) car to make its own decisions and evolve to improve its own performance. The new aspect of the competition ensures that FS continues to support industry by addressing the skills gap and providing mechanical engineering students with the opportunity for real-world experience of integrated electronics, software and systems engineering.

Founded by Mark Preston a Monash University alumni, who is well known in motorsport and has held senior management roles in Formula 1 teams along with his current position as team principal of the Techeetah Formula E team, StreetDrone is essentially building an autonomous car template for research facilities and universities to buy and improve. In that sense it is open-source and the technologies go to the deepest available reaches of artificial intelligence, virtual reality, augmented reality, sensors and coding. It aims to have the vehicles it is building in partnership with Renault not only on the road but also on the racetrack.

The design of the car was extremely important, Jon Hilton, a previous Formula Student chairman and also the IMechE's 131st president, making it clear that the autonomous car had to look good. As a result, there was a design competition open to teams participating in Formula Student which was won by a Monash University student.

"To design and build a competitive racing car in one year, whilst studying for a degree, is no mean feat," said Andrew Deakin, chairman of Formula Student. "The level of innovation, commitment and ambition that the teams display is incredible and it's very exciting to see their hard work pay off.

"The fact that we are introducing a new AI element this year is particularly exciting, as AI is already transforming so many industries, including the automotive sector. This new, exciting element to the competition aims to encourage enterprising students to look to the future by designing the software for a fully autonomous Formula 1-style vehicle in a safe environment." RT

ABOVE The Yamaha MOTOBOT, which has already achieved a speed of 200 kph, was also on display at Festival of Speed's Future Lab

See Who needs a driver? on page 22

All-female team from Pakistan win Race Tech Spirit of Formula Student award

William Kimberley

SILVERSTONE, UK: Team AUJ of the National University of Sciences and Technology (NUST) Islamabad, the first all-female team to take part in the Formula Student competition, was specially recognised at the event by being awarded the Race Tech Spirit of Formula Student award. In receiving it at the awards presentation, they received a standing ovation. It followed former Formula 1 World Champion Jenson Button's call for more women to get involved in engineering, made while he visited Formula Student.

He said female engineers are already making a big difference in motorsport, but that there is a need for a far higher percentage to address imbalances. "It is vital to push for more women working in mechanical engineering," he said. "Many Le Mans championships have been won by female engineers so there is obviously no reason why more females can't get involved, including the driving. I've worked with very competitive women at the highest levels of engineering, but we need many more to enter the field.

"I'm here today at Formula Student to help inspire the next generation of engineers and to highlight the importance of support provided by Santander Universities."

The Pakistani student team comprising 15 girls built the car without any mechanical engineer in the ensemble. The current members were from different disciplines including electrical engineers, industrial designers and members from business management. They had designed and built the car from scratch using local parts, including the engine, for the prototype, enabling them to keep costs down to $4,929. Taking up the challenge, the team trained in various fields such as design, modelling and prototyping while also attending various workshops on how to operate different types of machinery.

When asked about how it all happened technical team head Harim Akhtar said that it was coming across another team working on the chassis for their car early last year. "It was initially a mixed team of boys and girls but owing to immense workload and a hectic academic calendar, many members withdrew until it was reduced to an all-girls team of 15 students. This gave birth to the idea of creating Pakistan's first all-girls team to take part in the Formula Student competition.

"The unparalleled dedication and hard work convinced us to utilise the FSUK platform for the greater good, thus we began striving towards boosting women empowerment in Pakistan through our notable presence in a male-dominated field. Also, NUST enabled us to grow into the strong independent women who were able to step out of their comfort zone to experience something new."

ABOVE The all-female Team AUJ from Pakistan won the Race Tech award for the Spirit of Formula Student

Apart from the team attracting a number of sponsors, such as Automark, Wild Wings, Autocom, Syed Flour Mills and Ricardo, the team was also funded by the Pakistani Prime Minister's office, as the team was still lacking financial funds.

"It was a challenging job, but we completed our Formula car in just five months," said Akhtar. "We had to overcome so many obstacles, but by throwing ourselves into the project, which sometimes meant having to work through the night to get the car finished, we managed to get the car to England for Formula Student. Just to be here was something special and we learnt so much from so many other teams and getting the Race Tech Spirit of Formula Student award was the icing on the cake and something we can proudly take home to Pakistan to show what can done. It also helps us to create a platform for women to break stereotypes and to participate in male-dominated fields, thereby encouraging Pakistani women to enter the world of motorsport." RT

Engstler Motorsport will run two Hyundai i30 N TCR cars

William Kimberley

WIGGENSBACH, Germany: Hyundai will be represented in TCR Germany for the first time from the Nürburgring round of the series with Team Engstler running two i30 N TCRs under the Hyundai Team Engstler banner for the remainder of the season. The cars are then set to run a full campaign in the series in 2019.

Engstler Motorsport has had a long relationship with German car brands over the decades, but has also had associations with Alfa Romeo and SEAT in the past in the DTM and TCR International Series respectively.

"TCR Germany is the logical next step in our motorsport commitment for Hyundai Germany, and in the past few years we have set our sights on the series with our entries in the VLN and at the 24h races on the Nürburgring Nordschleife," said Markus Schrick, managing director of Hyundai Motor Deutschland GmbH. "We have a high-performance vehicle that appeals to customers emotionally with the Hyundai i30 N. We are very pleased that we have an experienced and successful partner at our side with Team Engstler."

"We are very proud to be able to represent this successful and dynamic brand in the ADAC TCR Germany," said Team Principal Franz Engstler. "The entire team is extremely excited about the new challenge and great co-operation." RT

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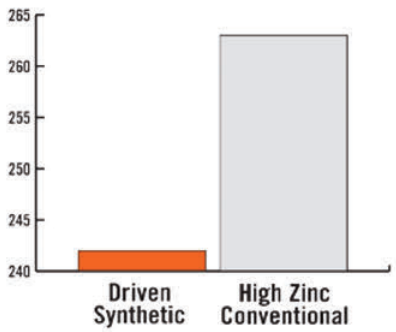

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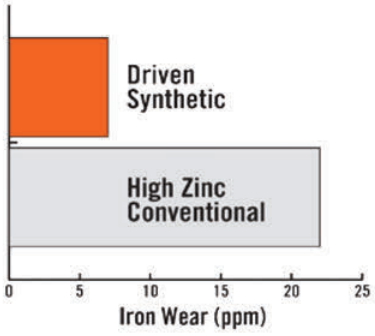

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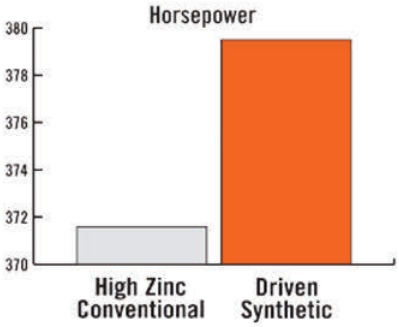

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VW I.D. R Pikes Peak sets new record for electric cars at the Goodwood Festival of Speed

GOODWOOD, UK: The I.D. R Pikes Peak has wrapped up another record. Romain Dumas set a new record for electric cars of 43.86 seconds in Volkswagen's first fully-electric racing car at the Goodwood Festival of Speed.

Following his record-breaking exploits at the Pikes Peak International Hill Climb, the French driver beat the previous fastest time for electric cars on the Goodwood Hillclimb, which has stood since 2013, by 3.48 seconds. The all-time record still belongs to Nick Heidfeld. The former Formula 1 driver completed the 1.86-kilometre route in 41.6 seconds at the wheel of a McLaren-Mercedes MP4/13 Formula 1 car in 1999.

"The I.D. R Pikes Peak has once again proven emphatically that it is a fantastic ambassador for our fully-electric I.D. family," said Dr Herbert Diess, the chairman of the Board of Management of Volkswagen AG and chairman of the Board of Management of the Volkswagen Passenger Cars brand. "I would like to thank the whole team. After the great success on Pikes Peak, at Goodwood we have shown once again how impressive the performance of an electric racing car can be. That is a very good preparation for our great electric car offensive which is starting next year."

Volkswagen driver Romain Dumas was delighted: "Goodwood is an absolutely fantastic event and I am more than happy that we won in front of such a great crowd of motorsport enthusiasts," said the 40-year-old after his latest record-breaking drive. "The hill climb track is short but often dirty and therefore you should definitely not underestimate it. In any case it is a great honour to drive here at Goodwood. You meet so many fantastic drivers, and the cars and motorcycles here span a century of motorsport. It is one of a kind."

Volkswagen Motorsport director Sven Smeets was also a happy man: "Although the route is not even two kilometres long, we once again showed what the I.D. R Pikes Peak is capable of. Volkswagen is committed to electromobility and we want to take every opportunity to show how emotional this topic can be, before Volkswagen launches its first fully-electric range as of 2020." RT

ABOVE Volkswagen brought the I.D. R Pikes Peak to Goodwood

McLaren launches the next phase of its pioneering esports programme

William Kimberley

WOKING, UK: Following the success of McLaren's esports programme last year, which saw Rudy van Buren become the team's official simulator driver, the British team has now launched McLaren Shadow Project, the next phase in its esports strategy. Its new esports programme will shadow its real-world racing equivalent.

As before, the programme is a champion of champions approach that can be entered via a variety of gaming formats including PC, Xbox One, and mobile (iOS and Android). This is via racing games that include Forza Motorsport, Real Racing 3, iRacing and rFactor 2.

The introduction of these new platforms and games opens the competition to all racing gamers and not just sim racers. The competition is structured to bring the most diverse pool of racers into the semi-finals, allowing McLaren to identify raw talent from anywhere in the world on any platform. The online heats are open worldwide to all racing gamers over the age of 18 with McLaren running on-the-ground events in China, Latin America and the Middle East with its partners.

The winner of the McLaren Shadow Project championship will get a seat in McLaren's new F1 esports team and join its esports development programme, to hone their skills and work with the McLaren F1 team. RT

ABOVE McLaren has launched the McLaren Shadow Project that follows up on its successful esports programme it launched last year

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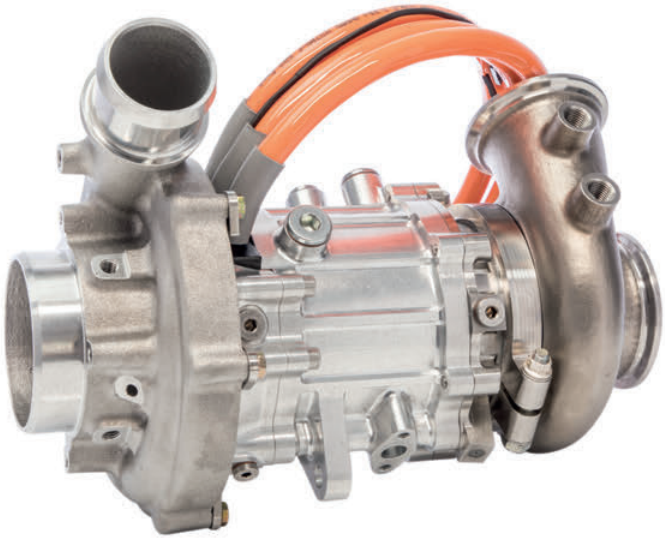

Pankl Systems Austria GmbH
Engine Systems

A-8600 Bruck/Mur, Kaltschmidstraße 2-6
Phone: +43(0)3862 51 250 0
Fax: +43(0)3862 51 250 290
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Forecasting the future

William Kimberley

MILTON KEYNES, UK: Aston Martin Red Bull Racing has announced an extension of its Innovation Partnership with IBM to include services from The Weather Company, an IBM Business. This builds upon its long-term partnership with IBM, which continues to accelerate its race scenario planning and design processes.

Weather is one of the key variables in car performance, with data on atmospheric pressure, likely temperatures, wind direction and rainfall being crucial across a range of strategic and tactical variables. For instance, accurate historical data is incredibly important in tyre selection, the allocations of which have to be made 14 weeks before a flyaway grand prix. Nearer the date, the combination of recent and historical weather trends for the event location is plugged into software models allowing the team to develop highly accurate baseline setups for the car's aerodynamic performance, ensuring it hits the ground running at the track.

The Weather Company uses one of the most sophisticated and powerful analytical engines ever seen, creating weather forecasts for 2.2 billion locations on the planet, responding to 50 billion requests for information every day and servicing the needs of 3,500 business clients that rely on The Weather Company to help make better, more informed decisions.

"We are really excited to have started working with The Weather Company as part of our IBM relationship, providing us with accurate worldwide weather insights," says Red Bull Racing's head of race engineering Guillaume Rocquelin. "With their advanced models and extensive range of weather stations, they are proven to be at the leading edge of global weather forecasting. Their easily accessible dashboard and customisable API (Application Programming Interface) information and database, will support Aston Martin Red Bull Racing operations with live and precise weather forecasting, tailored to our needs, in any location. This will improve planning and performance throughout our business, from pre-race event logistics to on-track activities."

"Weather is one of the most critical variables in performance improvement – whether that be on the race track or in business and commerce," says Craig West, managing director of The Weather Company, an IBM Business. "We are thrilled that dynamic organisations such as Aston Martin Red Bull Racing are turning to IBM and The Weather Company for insights that will drive improvements in performance."

New Peugeot 208 WRX introduced

Hal Ridge

ABOVE The new Peugeot 208 WRX Supercar

HÖLJES, Sweden: Peugeot's works World Rallycross Championship squad, Team Peugeot Total, introduced a new Peugeot 208 WRX Supercar for drivers Sebastien Loeb and Timmy Hansen for the sixth round of the series in Sweden. Peugeot boss Bruno Famin has steered away from calling the machine a 'new' car, but the latest 2018 has a new evolution of chassis, engine, suspension and transmission over its predecessor, in the first season of the French marque running the programme in house.

"The evolution we brought has been quite okay for the time being. Everything almost is brand new and we are already at the same level as without the evolution," said Famin at Höljes. "We have to learn the car in race conditions, we tested quite a lot but testing alone on a track and racing in Höljes is very different because of the high level of the competitors. It's the right way to go faster in the development of the car."

The Supercar engine has been built in-house by Peugeot Sport for the first time, using the basis of Citroën Racing's C3 WRC engine, increased to 2-litre capacity. "There are quite a lot of things in common with the C3 WRC engine, which makes life easier," said Famin.

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Revised rear cooling for Prodrive's Megane RX

Hal Ridge

BANBURY, UK: British firm Prodrive has been forced to revise the rear cooling package on the Renault Megane RS RX Supercar, built and run for the GC Kompetition team in the World Rallycross Championship. Featured in depth in RT211, the Megane features radically different technology than other machines on the grid, including inboard brakes.

Like many of the traditional Supercars on the grid, the Megane's water radiator is mounted in the rear of the car, but was designed to exit through the boot floor and underneath the car, rather than through the boot panel as with other machines, exploiting a grey area in the regulations.

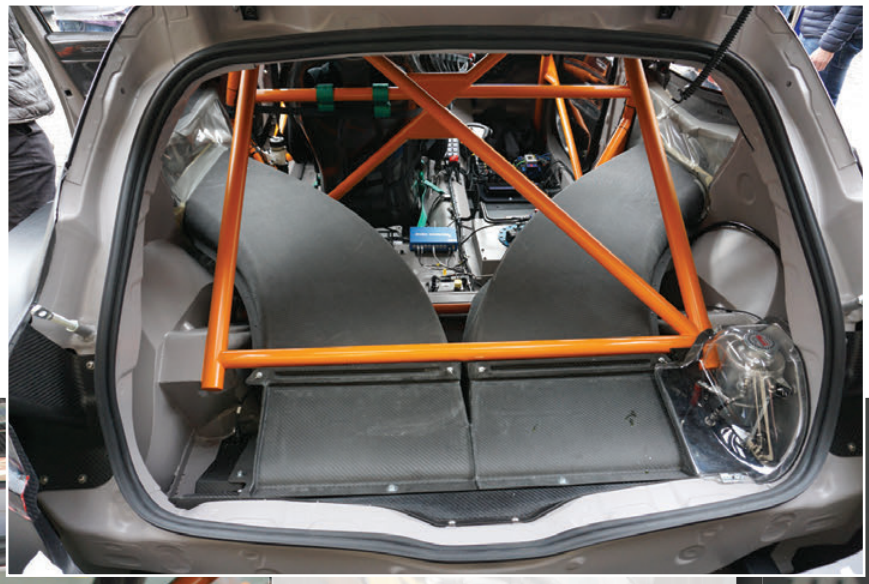
"You always interpret the regulations and you try to maximise them for your benefit. We saw our design as completely legal. Okay the FIA didn't agree with that and they have the final word, so we had to change," explained Prodrive's Richard Thompson.

While the steel boot floor in a Supercar cannot be removed, as the Megane RS has a plastic section of the floor as standard, the former World Rally title winning team had mounted the radiator as low as possible in its original specification. "We did not affect the static weight distribution with the change, which was important. With centre of gravity there was a small penalty to pay. Your car is made 95% fast on the drawing board and COG is one of the key gains.

"The rear cooling is a considerable amount of mass – the average capacity is 11 or 12 litres of water in the car, of which 60% of that is in the pipes and the radiator. The mass of the fans is also considerable.

"There was certain wording in the regulations that allowed you to remove trims and plastic parts, of which that (boot floor) section was. We weren't cutting a hole in the floor; the hole was already there. We interpreted it as being able to flow our cooling for the radiator through it."

The car scored its first podium at the Swedish round in the hands of Jerome Grosset-Janin. Prodrive said that it is working hard on engine calibration for its 2-litre turbo unit and hasn't experienced any heat build-up problems with its unique in-board braking system. RT



ABOVE & BELOW Prodrive has revised the rear cooling package on its Renault Megane RS RX Supercar

M-Sport introduces new aero package for Finland

Hal Ridge

COCKERMOUTH, UK: The M-Sport World Rally Team introduced a striking upgrade to the rear aerodynamics of its Ford Fiesta WRC ahead of Rally Finland at the end of July. Having extensively back-to-back tested a revised aerodynamics package, the Cumbrian squad ran a new rear bumper and diffuser on reigning champion Sébastien Ogier's car in Finland.

The biggest changes were made to the rear bumper, with a large, louvered exit for airflow behind the rear wheels, similar to that used on Toyota's Yaris. The sides of the new louvered exits taper at the lowest point, while the bottom the bumper rises up, tying the shape into a new diffuser. Four vertical stays are used on each side of the new diffuser, which doesn't appear to protrude as far behind the bumper as the previous version. With the Fiesta having initially been designed completely in CFD (Computational Fluid Dynamics), the latest developments have been made in conjunction with Ford Performance, following a visit for the Fiesta to the firm's wind tunnel in Concord, North Carolina after Rally Mexico earlier this year. It is the same facility that Ford's NASCAR AND IMSA GT programmes use, and includes a rolling road.

"It's been a long break but the hard work hasn't stopped and the team have been working around the clock to ensure that we had the new aero ready for Finland," said M-Sport boss Malcolm Wilson before the rally. "It's just on the one car for the moment, but we're confident that it will give Sébastien and Julien that little bit extra. Our goal for the second half of the season is to reduce the gap to our rivals in all three championships. We're certainly going to give it our best and I'm confident that we can deliver some strong results over the remaining events – starting in Finland."

New wing mirrors have also been added, which appear similar to those used by Toyota and Hyundai, with a slim support to the outside of the mirror body, allowing for better airflow to the rear wing while also helping to improve downforce.

ABOVE M-Sport's aero upgrade saw changes made to the rear bumper and diffuser of its Ford Fiesta rally car

New look Monte Carlo Rally

MONTE CARLO: Next season's Rallye Monte-Carlo (24-27 January) will adopt a more compact format than in previous years with added focus on its Alps base in Gap. There will be several new speed tests in a route that is 40 per cent different from this season's event, while Monaco's Thursday evening Casino Square start ceremony switches to the centre of Gap. There will be two late special stages, both running for 20 km in the Alpes-de-Haute-Provence and Hautes-Alpes regions. There will also be a number of stages that have not been tackled for many years but the finale on the Sunday will remain the same with two tests in the mountains above Monaco with no opportunity to service before the finish in the Principality. RT

BELOW From next year, the spectacular Monte Carlo Rally is set to adopt a more compact format

PERSONNEL

Sergio Marchionne, the former Ferrari and Fiat Chrysler Automobiles chief executive, has sadly passed away following complications which arose after he underwent surgery on his shoulder. Tributes from figures within the motorsport industry poured in for the man who less than a week earlier was replaced by Fiat Chrysler Automobiles (FCA) chairman **John Elkann** as Ferrari chairman and **Louis Camilleri** as CEO due to his deteriorating health. **Mike Manley**, the head of the corporation's Jeep division meanwhile, took over as FCA chairman.

Elkann expressed sorrow at Marchionne's passing and praised his "values of humanity, responsibility and open-mindedness". "The best way to honour his memory is to build on the legacy he left us," he added. "I will be forever grateful for what he has done."

Marchionne took a tough stance when it came to negotiations with Liberty Media, believing that Ferrari deserved special treatment and an enhanced financial return above all other teams, but McLaren team boss **Zak Brown**, who has praised Marchionne for his time as Ferrari boss, believes that the change in leadership might lead to a reset of the team's relations with the US owned company and Formula 1.

Following the resignation of **Eric Boullier** as racing director of McLaren Racing just days before the British Grand Prix, chief executive **Zak Brown** has announced a simplified technical leadership team. **Simon Roberts**, COO of McLaren Racing, will oversee production, engineering and logistics, **Andrea Stella** is appointed performance director, responsible for trackside operations and **Gil de Ferran** takes up the new role of sporting director to maximise the effectiveness of the team's racing package.

Mercedes-AMG Petronas Motorsport has announced a planned transition of its senior technical leadership that will see the baton handed on to the next generation of leaders within the team for 2019 and beyond. **Aldo Costa** has chosen to move into the role of technical advisor to the team from the beginning of 2019 to spend more time with his family in Italy. He joined Mercedes in 2011, following a highly successful Formula 1 career with Ferrari and Minardi, and played a central role in structuring the team's technical organisation and leading it to championship success.

As part of the transition to the future, the Engineering Group led by Costa has evolved in recent months and in the future will take an even sharper focus on car design activities. Chief designer **John Owen**, who has been with the team since 2007, will become the senior member of this group, under the leadership of technical director **James Allison**.

Performance director **Mark Ellis** has decided to retire from his current position and to take a sabbatical beginning mid-2019. He returned to Brackley in 2014 following six years with Red Bull Racing that included multiple world championship wins and continued that run of success with Mercedes. He previously worked with BAR and Jaguar Racing in Formula One. He will be replaced by chief vehicle dynamicist **Loic Serra**, who has worked for Mercedes since 2010, at the end of the year.

Australian Supercars is carrying out a worldwide search for a new sporting and technical director after incumbent **David Stuart** announced he will leave the company. Stuart, who has been in the key Supercars role since midway through 2014, is set to move to CAMS as division manager – safety and race operations. He joined Supercars following lengthy stints at Dick Johnson Racing and Stone Brothers Racing/Erebus Motorsport, leading the latter through its transition from Ford to Mercedes. He will continue as Supercars' sporting and technical director until the end of the year, overseeing the homologation of the Ford Mustang, which will enter the championship in 2019. His time in the job included an overhaul of the category's aerodynamic testing procedures, which are again being refined for the latest testing, and its operations manual. In his new role at CAMS, he will play a critical role in ensuring the continued safety standards of Supercars circuits in Australia and New Zealand. In addition to safety matters, his role will also include holding the position of Race Director at selected events. RT

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AWARDS DINNER at the Millennium Gloucester Hotel London on the evening of Tuesday 27th November

A portent for the future?

IN June we saw what could well be classified as a game changer. While not widely reported in the mainstream media, it nonetheless was a momentous result – Volkswagen's all-electric car, the I.D R smashing not just the all-electric car record at Pikes Peak, but the outright record as well by as much as 16 seconds.

There will be those who say that this isn't a racing car, but a prototype that's been specifically developed for this event, and they would be right, but does it herald the future? Can we expect more spectacular cars like this take to the race track and compete against each other.

There is a sense that the tide is turning. Formula E is going from strength to strength, the FIA has confirmed that the main class in rallycross will be all electric while the new Tesla one-make series is gathering momentum as well. It is easy to take things out of proportion, but just what should we expect in the future?

The World Motorsport Symposium has developed a reputation for been an influential Think Tank where important issues like these are openly discussed by the most senior engineers and executives in the industry. Formula E, for example, was first discussed at the Symposium when it was no more than a twinkle in the eye of one or two visionaries.

Don't miss out on what is a unique event and be part of it and play a part in shaping the future. So put 27 and 28 November in your diary and come and join us at the Institution of Mechanical Engineers in central London for what will be two thought-provoking days.

For further information please contact Maryam Lamond at maryam.lamond@kimberleymediagroup.com

"Although I could only make the Thursday, I was very impressed with the format – its rare to have an opportunity to openly discuss important matters affecting the future of our sport, from club racing to F1. The mix of industry experts and the next generation of engineers and designers brought a healthy balance to the debates. A very informative and thought-provoking event – keep it up!"

JASON SOMERVILLE, Head of Aerodynamics, Formula One Management

"To shape the future of motorsport – the World Motorsport Symposium is a must for all key people in that business."

THOMAS KRAEMER, Manager Engine Design LMP1, Porsche Motorsport LMP Team

"The WMS offers a fantastic forum to gain opinions from some of the most influential people in the world of motorsport."

JOHN MANCHESTER, Operations Director, Gibson Technology Ltd

'ASSISTED DRIVING' IN FORMULA E?

Autonomous technology made its bow at Goodwood's Festival of Speed, but where do we go now? **Chris Ellis**, a Fellow of the British Computer Society, has a few suggestions for how to harness these autonomous capabilities

MOTOR racing is all about competition: competition between the cars, and competition between the drivers, especially within each team! So replacing the drivers with clever software will result in a much less interesting series, once the novelty of autonomy has worn off.

Of course, full autonomy will remain of considerable interest to those many readers of Race Tech magazine directly involved in the development of road cars. But I can't see tens of thousands of spectators paying big money in 2025 to gather round circuits like Silverstone or Monaco just to watch a bunch of driverless cars demonstrate their latest software!

But what if 'driver-assistance' is allowed in Formula E from, say, 2022? That could be a much more interesting and important story…. details next month!

Full or part-time autonomy for road cars is already being funded lavishly by some of the world's richest companies, for two good reasons. They know already it will help reduce road accidents and save lives, and it will also cut the cost of running taxis and limos, and may radically reduce the need for urban buses. And there is an additional reason, which has only just emerged. It could make practical the use of active downforce to enable road cars to brake harder, further reducing collisions.

Because this idea is so new, there is still much work to be done to prove its cost-effectiveness. However, if it can be shown to work effectively in Formula E, this should motivate the FIA, with its global responsibility for road safety, to encourage the major manufacturers to make it work in

FIA/Formula E

ABOVE Formula E would make a powerful marketing tool with which to promote the active aero philosophy

ABOVE The Robocar's appearance at Goodwood opened a whole new avenue of debate

road cars. If this is successful, motorsport will have made another major contribution to road safety which will mirror what happened with disc brakes, years ago.

Active downforce is currently banned across motorsport, perhaps because the powerful 'aerodynamics lobby' fears the demise of passive downforce once active downforce has demonstrated how much more efficient and safer cars using it could be.

So, how to prove this? To drive the powerful fans needed to deliver a strong partial vacuum under the car, the ideal form of energy will be electrical. So, in theory, the latest generation of hybrid Formula 1 cars are an obvious fit, but the politics of F1 will probably make this impossible in any useful timescale. And, above all, anything that makes F1 even faster, and consequently more dangerous, has to be avoided, which would happen if all those wings and things disappeared. On the other hand, almost everyone in Formula E would like its cars to be faster and more efficient, from the drivers through the manufacturers to the spectators.

So, as a thought experiment, consider the following: A 200 kW motor-generator is added, connected to the front wheels, resulting in a total of 400 kW of regenerative braking and acceleration, through all four wheels.

Consequently, during braking there will be *potentially* up to 600 kW to drive the fans, comprised of 200 kW from each generator plus 200 kW(?) from the battery, if required. This should prove more than enough to build a partial vacuum very rapidly under the car, assisted by automatic flaps at the vacuum boundary, with the flaps learning when to deploy optimally. This may result in braking at up to 4g – probably a sensible and necessary limit without g-suits.

The bodywork would be optimised aerodynamically to provide the least possible drag, consistent with enough passive downforce to keep the nose of the car safely on the track at high speed without any help from the Active Downforce System (ADS). The basic aerodynamic objective is to make the cars use as little energy as possible when active downforce is *not* required, which is probably at least 70% of most lap times.

A car with active downforce will use much less energy from the battery most of the time than one relying on passive downforce. Even during braking, the driver will be able to choose that only 200 kW of braking energy goes to the fans, and the battery still receives its usual 200 kW of regeneration, as now. So the driver will probably hold down the 'max g' button only when this could give a competitive advantage, and keep it held down for the fastest possible time round the corner. This should mean quicker and potentially more exciting cornering than F1 at almost all FE speeds on most FE circuits.

Note also that faster cornering implies less energy needed to reach any target speed during acceleration. No simulations have been run yet, but a guess is that, if a driver controls active downforce optimally, he will be able to lap significantly faster while using less energy. This is a clear case of 'having your energy and using it'!

So why would one of the manufacturers already involved in FE choose to invest in the development of this 'outside the regs' solution if it is far from clear, initially, that it would ever be allowed to race? Simply put, because it will produce far more 'brand enhancement' than the basic involvement in FE, particularly if there is sustained resistance from the rule-makers and other, less innovative, teams. Why? Because fundamentally this is about developing and demonstrating what could prove to be as big a contribution to road safety as disc brakes.

Imagine what a clever marketing department could do with that idea, along the lines of: "We are the good guys! We have already convinced the FIA that we should be allowed to demonstrate a prototype before each race next season…. But some of the other manufacturers are resisting…" RT

WHO NEEDS A DRIVER?

Jenson Button mingled with the teams at Formula Student, but the former F1 world champion shared the headlines with a car that could one day render drivers obsolete. **William Kimberley** and **Alan Stoddart** report

IMAGINE a future motorsport team that is spread out across the world, its members in far flung locations communicating and cooperating remotely. Perhaps they have never actually met each other face to face. This race team might not include a single engineer, but instead be made up of a collection of geographically isolated programmers.

When it is time to race at the 24 Hours of Daytona, for example, instead of travelling all the way to Florida, this race team may just be able to remotely upload the bundle of algorithms which it hopes is going to win it the race, to a sensor-festooned car of a fixed specification from the lounge of one of its members. The software governing its autonomous sports car could do the rest.

This futuristic vision is already being approached by none other than students set to compete in the brand new Autonomous element of Formula Student.

On show at this year's event was a demonstration autonomous car which is set to be made available to students who want to compete in the new category. Although the details of the competition are yet to be confirmed, the racer, the ADS-DV as it is named, will help student teams looking to get into autonomous motorsport by offering them the chance to purchase or lease an autonomous platform, or enable them to compete using a pooled car, which they can simply install their own software on when it is their turn to run.

It has been funded by the UK Government's Centre for Connected and Autonomous Vehicles (CCAV) that has provided support to the FS-AI due to its great potential for accelerating the skills agenda in autonomous vehicles. Engineers, technologists and programmers will be required to make the potentially transformational benefits of the technology a reality.

The car presented at the official opening of the event by Ross Brawn, Formula Student's patron and Formula One managing

ABOVE The launch of the ADS-DV ushered in a new era for Formula Student

Photos: Formula Student/IMechE

director of motorsports, was designed and developed by DJ Racecars in collaboration with Hypermotive, and StreetDrone. DJ Racecars builds the 'Firehawk' and 'Firestorm' single-seaters that have record-holding pedigree in the MSA British Sprint and MSA British Hillclimb Championships, as well as developing a V8 IndyCar engine that produces more than 800 bhp. DJ Racecars also has a composites components side to its business. This supplies a large range of competition use aerofoils, and custom aerodynamics solutions for all levels of motorsport, from sprint racing to Historic F1 and international-level GT racing.

"The thinking behind the Formula Student autonomous car project was that all the big car manufacturers now are trying to go autonomous and any computer science student who has a background in programming autonomous cars with real-world experience is obviously a very attractive recruitment candidate," said Del Quigley, founder of DJ Racecars. "While computer science students generally don't have any mechanical skills or interest to ▶

ABOVE Could fans one day be competing for the coveted signature of software engineers instead?

ABOVE The inaugural demonstration of the autonomous car mirrors the developments happening in the automotive industry

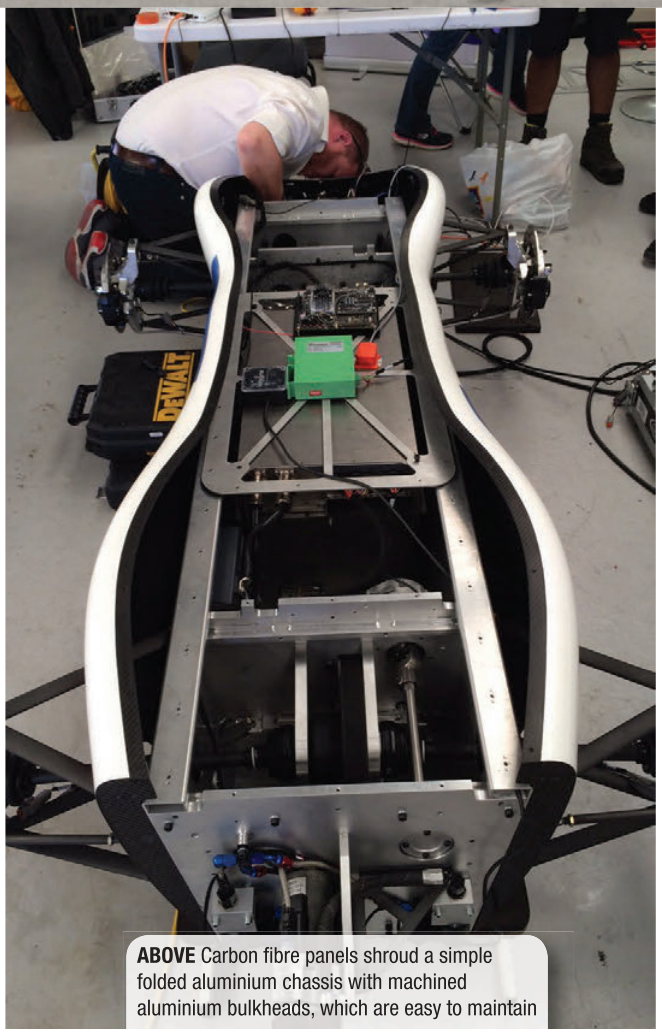
design and build a car, the IMechE decided that it wanted to have designed and built a single-make car that could be sold or rented to various universities as a complete rolling car, complete with batteries, motors, LiDaRs and cameras. It can then be used by the computer science students to write all the algorithms and the software in order for it to be able to navigate and drive autonomously.

"We were approached by Jon Hilton of the IMechE last October and commissioned to be the main contractor for the proposed electric autonomous car project ahead of anyone else being appointed and so we started work on designing a chassis and bodywork on 17 December," continues Quigley. "We got some very vague dimensions to work on, such as an approximate wheelbase and width, and then started on the mechanical design of the car. In Jon's words, they wanted something that was a little bit futuristic, a little bit quirky and had sexy corners.

"We are very good at mechanical design, but we aren't the best stylists so a competition was set up with the IMechE where any student could submit a proposal for the peripheral shape of the bodywork. It was just a concept sketch, the best one being used on the car. Oman Barty from Monash University was the winner, the sketch then being turned into a CAD model.

"Work then continued with the physical mechanical design of the chassis while the IMechE was deciding on which company would provide the drivetrain. We had to make assumptions at this point about which motors would be used and it was last February that I was asked by Jon to accompany him to a company in Lutterworth called Hypermotive. It was only 18 months old when they put forward some ideas on what batteries and motors they would like to use along with the control systems, but both Jon and I agreed that it was the right company to go with on this project.

"They were then signed up to provide the electric powertrain for ▶



ABOVE Carbon fibre panels shroud a simple folded aluminium chassis with machined aluminium bulkheads, which are easy to maintain

ABOVE Formula Student patron Ross Brawn was among those on hand to launch the FS-AI Autonomous class

the car and sent us drawings or physical parts, which we then reverse engineered and incorporated into the model as we were responsible for all the installation and deciding where things would go and how we would manage the heat. We worked closely with them from that day on until we came to Silverstone for Formula Student.

"The IMechE had been looking around for who would do the software to drive the vehicle and originally had assumed that Roborace was going to assist as it has been in talks, but it then pulled out and showed no interest. So it was only five or six weeks before the competition that we found StreetDrone, who were asked if they could help.

"StreetDrone specialises in creating a development platform that allows its customers to focus on the programming side, rather than having to spend time building a car and equipping it with actuators, cameras, LiDaR and all the other necessary paraphernalia that an autonomous vehicle requires. However, they don't yet have the means of fully autonomously driving the car, so were put in contact with a group of incredibly bright students from the University of Edinburgh who really helped.

"I met them for the first time at Silverstone, as did Hypermotive. At that point we had Ian Murphy from StreetDrone in the pits along with half the guys from Hypermotive, along with two or three of my guys there as well, all working together fitting cameras and LiDaRs where required. We routed circuit boards and changed wiring, so it was a bit full on for a few days.

"We worked through numerous electrical issues and problems and integrating software, but in the last 30 minutes of the track being open, the car did do one fully autonomous lap, touching just one cone. We went to do a second lap but the battery had flattened and that was it."

A COMPLETE SYSTEM

"This project has provided a great opportunity for our engineering team to showcase our wide capability to develop electrical systems and integrate these alongside other powertrain components to provide an autonomous development platform to support university teams competing to develop the best artificial control code," said Jeremy Bowman, engineering director of Hypermotive. "Our team has developed a bespoke 48V traction battery, battery management system (BMS), electrical safety systems and a new electronic controller with a loosely coupled dual CPU architecture providing autonomous control CAN gateways, battery safety systems and overall vehicle electrical system management and control.

"In addition, we have integrated dual high-performance air-cooled motors from Saietta with the precision control of the Sevcon Gen4 DC motor controller, which allows fast speed and torque control. Steering is made possible by the use of the Shiftec steer-by-wire motor and controller. Other components include a data logger with WiFi capability provided by CSS Electronics of Sweden and remote E-stop (RES) from GrossFunk of Germany.

"Hypermotive has also provided a unique emergency braking system which allows the vehicle to stop rapidly using disc brakes by the use of pre-accumulated hydraulic pressure. So any development AI code that doesn't go to plan can be rapidly stopped from a safe distance using the RES."

StreetDrone, meanwhile, is a relatively new British company founded by Mark Preston, who is well known for his many senior roles in various Formula 1 teams as well as being the current team principal of the Techeetah Formula E squad. It is essentially building an autonomous car template for research facilities and universities to buy and improve. In that

> *"The best autonomous cars won't be an expression of the developers themselves, but the software and how well it can teach itself to run the car"*

sense it is open-source, and can be used for technologies that go to the deepest available reaches of artificial intelligence, virtual reality, augmented reality, sensors and coding. The philosophy of the StreetDrone and Formula Student's autonomous racer is similar; both offer a platform which allows the programming and software side of driverless technology to come to the fore. This philosophy has also informed the design of the ADS-DV.

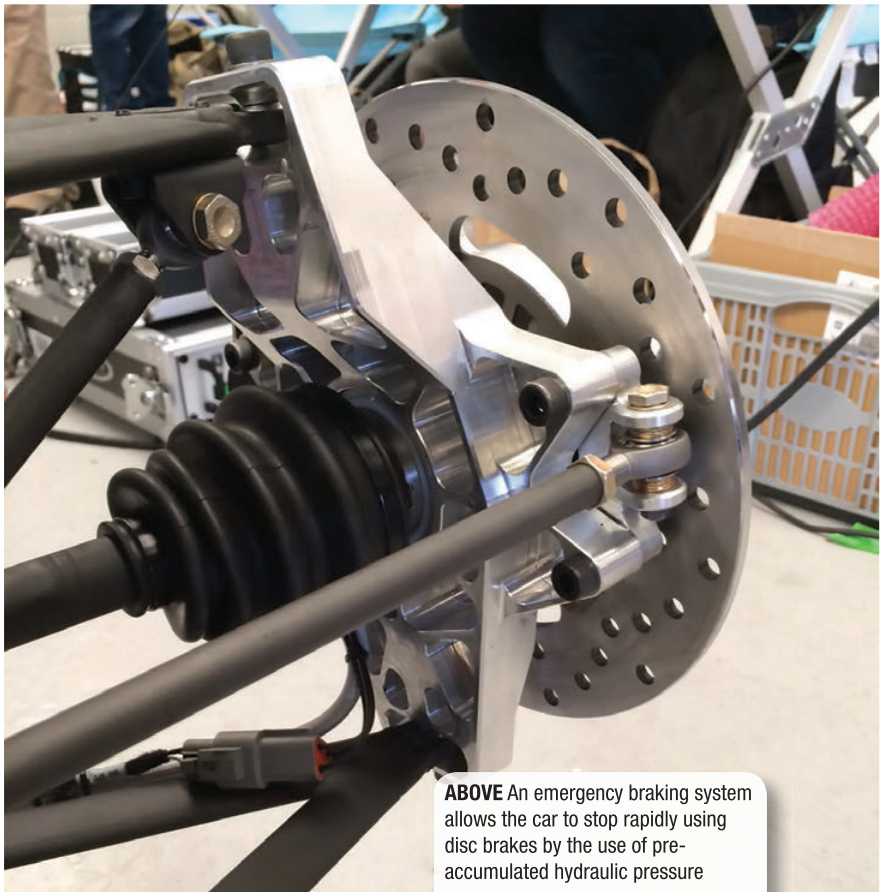
Given that many of the students competing in FS-AI will come from a computing rather than engineering background, simplicity and usability are very important to the ADS-DV, which has been reflected in its construction. It uses non-load-bearing carbon fibre panels that shroud a simple folded aluminium chassis with machined aluminium bulkheads, which are easy to maintain. It has completely interchangeable suspension due to its use of wishbones that are identical and can be fitted to any corner. This, along with the ability to fit an identical steering rack at either end, also makes the inclusion of four-wheel steering in the future a simple addition.

It is four-wheel drive thanks to the use of two selective motors driving the differentials through a tooth belt. These are powered by a relatively low voltage system of around 60 volts, courtesy of 16 prismatic lithium-iron phosphate cells, which are relatively cheap, very simple and have been designed to be easy to access. The battery itself sits in a crate as low down in the car as possible, in the centre where a driver would otherwise be.

It was demonstrated at Formula Student by a team from Edinburgh University, who had come from a computing, rather than a motorsport engineering-based degree as is more usual of the competition's entrants. Teams writing the code, therefore, are the ones who define what the autonomous car does in terms of throttle position, braking and steering.

This brings up the intriguing reality of programmers expressing themselves through their algorithms, with the car ultimately behaving differently depending on the skill of those programmers. Adrian Bedford, head of software at StreetDrone, says this means that ultimately the difference between driverless cars with the same hardware will be akin to the difference between different drivers in a spec series.

"So a better algorithm will be just like a better driver, one which can get the vehicle to the limit," he suggests. "The difference between a professional driver and an amateur one is that the professional will get the tyres on to their maximum grip and achieve maximum turning force in the hardest corners, and get much closer to the optimum of what's possible, whereas an amateur driver will be wondering about the optimum and not getting close to it."



ABOVE An emergency braking system allows the car to stop rapidly using disc brakes by the use of pre-accumulated hydraulic pressure

SELF-IMPROVING ALGORITHMS

Ignat Georgiev, the founder and team manager of Edinburgh University's Autonomous Formula Student team, however goes further. He contends that the better algorithm will be the one that is the most efficient at improving its own performance.

"In my opinion, in the future, the best running autonomous cars won't be an expression of the developers themselves, but will instead be an expression of the software itself and how well it can teach itself to run the car," he explains.

"For example, for one of our planning algorithms, we use a machine learning algorithm, which is more or less teaching itself how to control the car all the time... We are currently at the stage where none of us [on the team] understands how the algorithm works, only the algorithm itself and the car understands how it can work."

This logically leads to the rather startling conclusion that, given the perpetual increases in computing power, these algorithms will get to the point where a grid of autonomous racers, bestowed with machine learning capabilities, will all perform identically perfectly, something Georgiev sees as "inevitable".

"We will get to the point where all our algorithms are going to be able to teach themselves so well that we won't be able to distinguish between algorithm A and algorithm B. All of them will drive better than us and will be within a very small margin of each other," he says.

"Machines are just better at some things than humans." RT

UTA TURNS BACK THE CLOCK

Twenty years on from its victory at the inaugural Formula Student event, UTA's F98 was back in action. **William Kimberley** reports

IT was a cold, wet and windy MIRA that hosted the inaugural Formula Student event 20 years ago. Just seven cars turned up, three from the UK and four from the US, the winning machine being the highly experienced University of Texas Arlington (UTA) car. To celebrate the 20th anniversary of the event, the Institution of Mechanical Engineers (IMechE) invited the winning car back.

As an additional enticement, it was arranged for UTA to have a 100-metre drag race with last year's winner from Cardiff University on Silverstone's main straight during the British Grand Prix weekend. "It was just a really special treat for the students," said Bob Woods, UTA professor and founder of the UTA Racing Formula SAE team.

> *"From Formula SAE to building rockets"*

One of those present at Silverstone for Formula Student was John Burford, the '98 car's designer. He is now involved in the aircraft industry as a dynamics engineer, working on various projects including long endurance drones.

"Formula SAE and Formula Student directly led to my first job," he said. "I won an award at one of the competitions from Altair Engineering, which then went on to hire me, which gave me a great opportunity to learn. This then led me into aerospace engineering and doing some optimisation on weight reduction on the Boeing 787-9 and 737-MAX. When Bob contacted me to come to England as part of the team, it was too good to miss."

Established in 1982, UTA Racing is one of the most successful teams in Formula SAE, having won eight championships in the US and three abroad. When Burford took on the role of designing the F98, the '98 car, he had a lot of experience to draw upon.

DESIGNED FOR TUNING

"A great deal of the engineering that went behind this vehicle was in developing the team's understanding of a tuning process," he recalled. "We therefore thought about how to tune it at the track and then design those specific adjustments into the car so they could be trackside adjustments. For example, part of our tuning process was starting out with large diameter skid pads to get basic balance setup. Once we had that, we learned over the years that you're definitely going to push on a smaller diameter skid pad, and so a primary tuning parameter that we were using which is unique to Formula SAE.

"You don't see it used in tuning production or race cars. There's far more steering angle in a Formula SAE car on a Formula SAE-sized course. What tuning parameter can be done to affect grip at the front of car? The answer is castor, so you can start to add it in on a small diameter skid pad until you get a balanced car. The combination of steering angle, scrub radius, and castor gives more grip at the front for a small radius turn. It means we get a higher speed balance on the large diameter skid pad and then add in castor on a smaller diameter skid pad until we're balanced at high and low speeds and then we can move on to damping and transitions. So we designed the car so that we had castor as a trackside adjustable item."

The F98 has not been driven in anger for

ABOVE Back in business: The F98 hadn't been driven in anger for 15 years prior to its readying for Silverstone

the last 15 years, but as Burford noted, the only thing that needed adjustment was the front sway bar along with one quarter turn of the pivot rods for weight on wheels.

The car was powered by a 250 cc Honda CBR 250RR engine that UTA turbocharged and added a student-built fuel injection system with methanol as the fuel of choice. "We are running it very close to the original system that included a fifth injector that has since been removed," said Burford. "However, we had to replace the fuel injection system as over the years it had got damaged and so it was replaced by an off-the-shelf aftermarket system."

The team had opted for methanol because back in the 1980s and '90s, Argon National Laboratory was giving a monetary incentive for winners. "We would fund about a third to a half of the team's budget due to wins with methanol," said Burford. "We knew that methanol had a power disadvantage to gasoline with the theoretical limit being around 85 hp, whereas it was more like 95-100 hp with gasoline. However, these cars were more traction-limited so it really wasn't a problem.

"Eventually, though, the Argon National Laboratory's interest in methanol waned while the interest in the US in ethanol increased. The incentives went away, so the team switched to gasoline. However, the engine in the '98 car was still methanol."

Asked what he noticed about his 20-year-old car and those being seen in the paddock at Silverstone, he replied that it was the greater reliance on the computer and that things are gone into in far greater detail: "When we were designing the cars, we would get stick figures of what frame numbers would be and then get some tubing and more or less cobble it together in the shop. Nowadays it's drawn on the computer that includes every little bracket which will be built to print. I think that ▶

mirrors what is seen in industry, so it's probably good that students are following that trend. It was a great training ground for me and I think it's a great training ground for the future."

Burford has retained his links with Formula SAE and has been quite involved as a scrutineer and design judge over the years. "One of the things that has astounded me as a design judge is that when you start to ask questions that go quite deep, such as the impact of a cone on steering linkages to see if they would buckle, you get a few scratches on the head in the first year, but in the second year you hear that they had run a test.

"It was the same in scrutineering. I would ask the composites guys in their first year about their three-point bend test, whether they had simulated it and were they able to correlate results? When they came back a second year, they had done all these correlation studies. Some teams could correlate the linear force deflection and other teams said they thought they couldn't simulate failure accurately with their analysis methods.

ASTONISHING DETAIL

"There was one team that said it had correlated the failure to the three-point bend test, but the way they had to do it was to mesh the full sheets of the composite and all the cells of the honeycomb for buckling stability, because that's what failure is intended to be first by the design of the rules. So they figured that out, and how to simulate it, and to mesh the honeycomb so that they could correlate that test, which was astonishing. The level that these students would go to was just amazing.

"My three principal motivations for being a design judge at Formula SAE is that you want to give back to the students, you want to see what new things they bring, some of which I see rivals what I do in my professional job, and also recruitment. I think it's not generally appreciated how much some companies value those students who have been part of a team. At the 1998 Michigan Formula SAE event I competed against Bill Riley on the Cornell team. Cornell got first place and the UTA 98 car got second place. Today, Bill is a Director of a structural analysis group at Elon Musk's SpaceX. Bill has told me that as much as half of his 120 staff engineers have Formula SAE experience. It means that a very large number of people are going from Formula SAE to building rockets.

"Having been part of a Formula SAE/Formula Student team has been an enormous benefit throughout my career and keeps benefitting me even 20 years later."

Formula Student/IMechE

ABOVE The team's understanding of the tuning process was a pivotal part of the car's success

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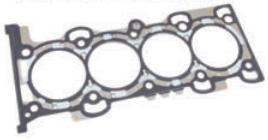

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COOL, CALM AND COLLECTIVE

Harley Olsthoorn and **Alan Stoddart** examine the innovations employed by the Australian Formula Collective

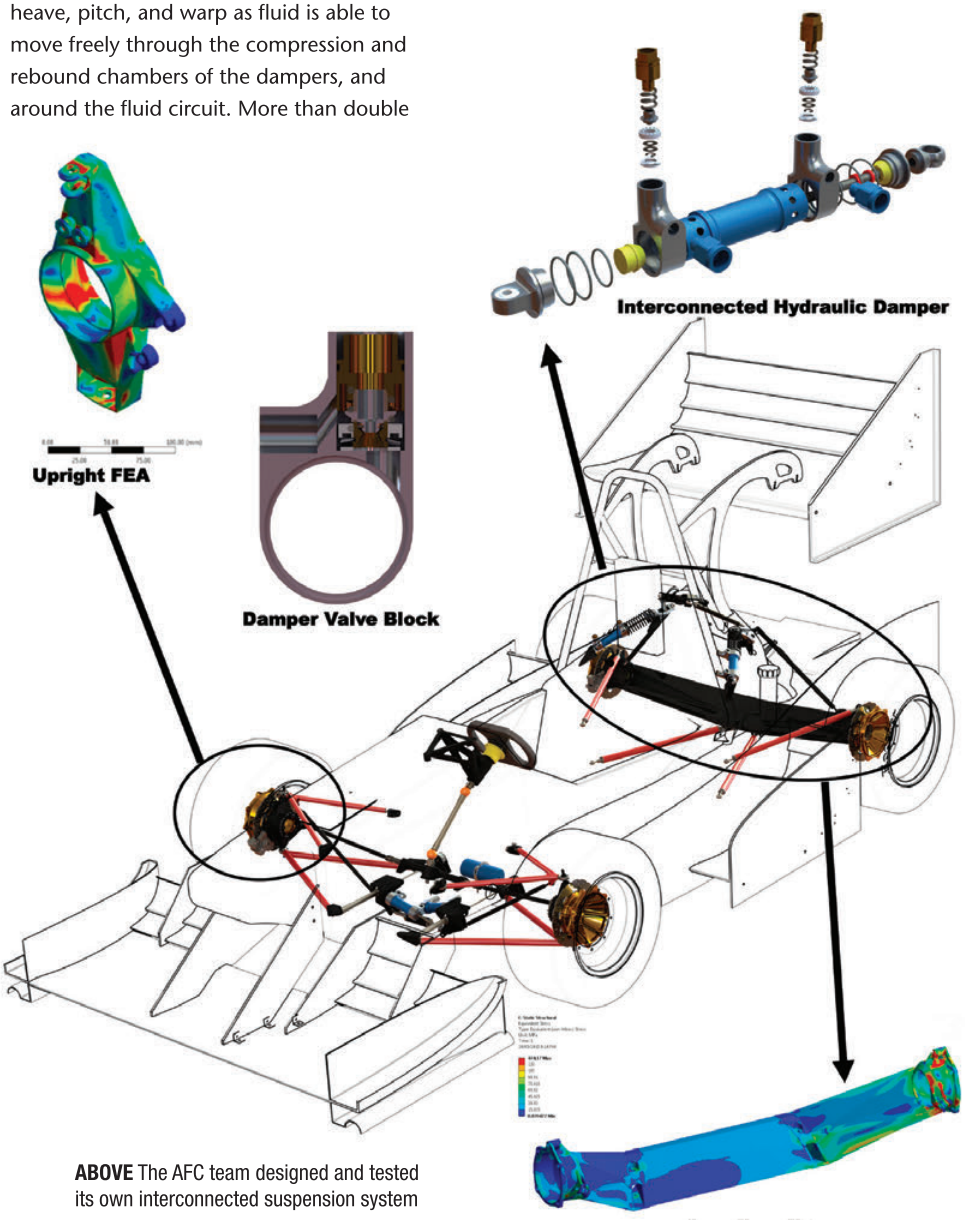
AMONG the teams with the most interesting systems at Formula Student was the Australian Formula Collective. This effort, which was mounted collaboratively by students from both Edith Cowan University and the University of Western Australia, relied on a particularly innovative suspension system, which was designed to provide the car with excellent aerodynamic stability without compromising single wheel bump performance. The combination of these two things helped improve the lateral acceleration ability of the car, decrease dynamic tyre load variation and increase average track velocities.

Typically, Formula Student teams which choose to run a 'sprung' aerodynamic package attached to the vehicle body must accept the compromise of higher corner spring rates and/or the addition of a third spring and anti-roll bar. Stiffer corner springs and suspension dependencies in general prevent significant (and in most cases, unwanted) changes to the vehicle ride height, which are usually accompanied by greater static ground clearances to allow for a compromise between desired wheel rates and loaded suspension deflection. These requirements come at the expense of mechanical grip during single wheel bump manoeuvres. Alternatively, in other cases, aerodynamic packages are mounted to the un-sprung mass of the vehicle, however these mounting methods increase complexity, weight, and still require an accompanying anti-roll bar to ensure sufficient cornering stiffness.

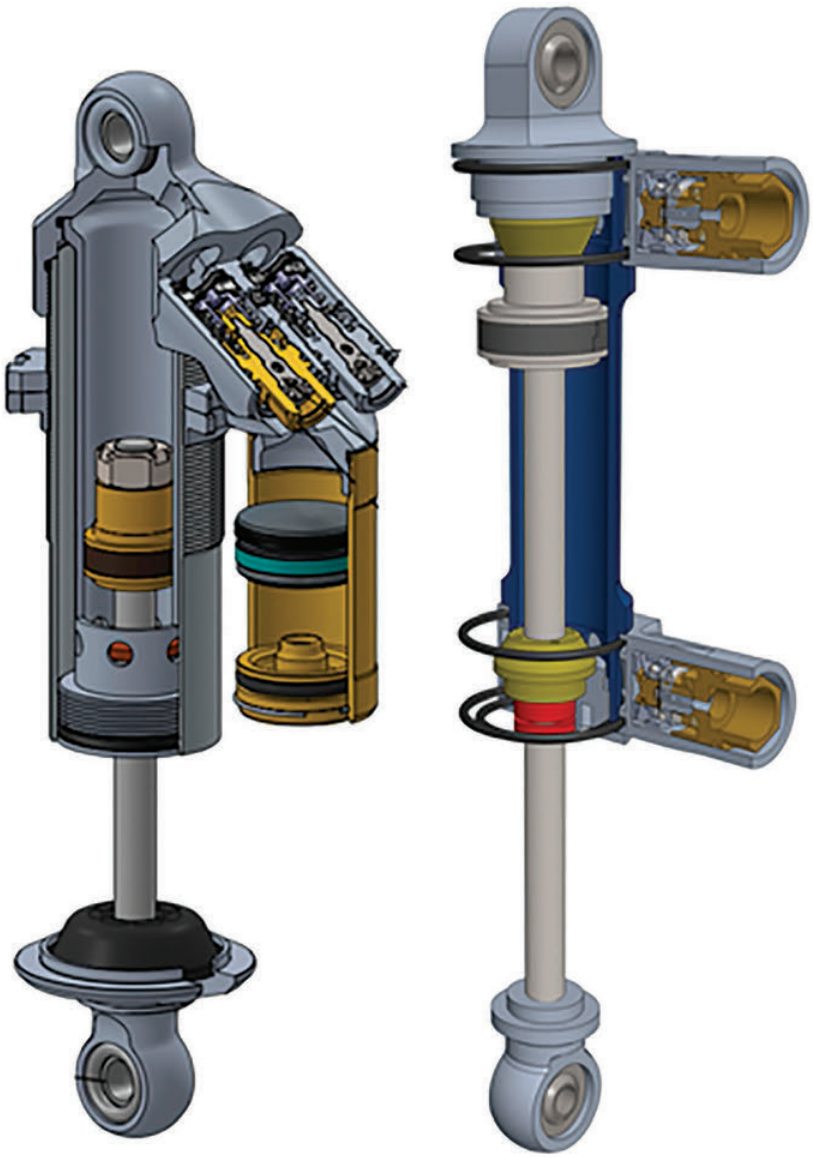
The AFC team have attempted to resolve these compromises by using a bespoke hydraulically interconnected suspension system it designed and made itself. The core idea behind the system is the isolation of the four possible modes of vehicle travel (pitch, heave, roll, warp) so as to allow them to be sprung independently of one another. On a conventional spring and damper suspension system these modes of travel have conflicting requirements as far as stiffness is concerned. The AFC suspension utilises four interconnected, remotely actuated, hydraulic damper units, which allows for independent tuning of the vehicle's modes of travel.

The layout design of the interconnected suspension provides minimal stiffness in heave, pitch, and warp as fluid is able to move freely through the compression and rebound chambers of the dampers, and around the fluid circuit. More than double the fluid is displaced during roll and provides greatly increased stiffness via the system's piston-type, gas accumulators. During roll the outer pistons move upwards, pushing fluid from the top of their cylinder to the bottom of the inner cylinder on the opposing side of the vehicle. As the inner cylinder attempts to extend, it opposes the fluid movement from the outer cylinder and displaces it into the transmission line.

This interaction between the cylinders is what increases the fluid flow into the accumulator and results in the effective roll spring rate based on accumulator pressure, sizing, and fluid volume. From here, the heave, pitch, and warp modes are sprung via the use of soft mechanical torsion/compression springs (warp), and Belleville stack third springs front and rear (heave/pitch). This combination allows for highly ▶



ABOVE The AFC team designed and tested its own interconnected suspension system



ABOVE Öhlins TTX-25 damper valves were the only purchased item used in the design

variable ride frequencies, and significantly improves the vehicle's performance on track.

The system was designed, manufactured, and tested in-house by the AFC student engineers. A bespoke, lightweight solution was required as no such system exists in an off-the-shelf configuration for this application. Öhlins TTX-25 damper valves were chosen (the only purchased item used in the design) for the valve blocks due to their availability and suitability for the Formula Student vehicle. This provided the team with a baseline for sizing the damper units based on fluid displacement and flow through the valves into the accumulators.

The system was designed to be simple, lightweight and modular, which reduced not only the cost, but also the time required for design and manufacturing. This translated to very direct fluid paths through valve block and system lines, which has measurably reduced damper hysteresis and parts count when compared with conventional adjustable twin tube dampers.

A seven degree of freedom Matlab-based Simulink vibrational model was developed for the purposes of investigating the transient responses provided by the interconnected system. Of particular interest in this system was the effect of stiffening modes of travel whilst maintaining the tyre performance characteristics typically seen on vehicles with soft suspension. The corresponding system design was then evaluated by the team utilising a combination of damper dynamometer and on-track testing. The empirical data gathered from these tests was used to evaluate the effect of damping adjustments, valve block orifice flow, hysteresis, cavitation, modal analysis, and general system performance, which ensured that the suspension system was ready for competition and worked flawlessly out of the gate.

STANDOUT FEATURE

The other standout technical feature of the Australian team's entry is its custom-made motor. The AFC outfit wanted to use a motorbike engine, but did not want the compromises which that usually entails, such as increased space requirements and unnecessary complexity. The team wanted the engine to be as low as possible to improve the centre of gravity, and also wanted it to be as small and narrow as possible in order to allow sizable aerodynamic packages such as wings and tunnels to be fitted to the car.

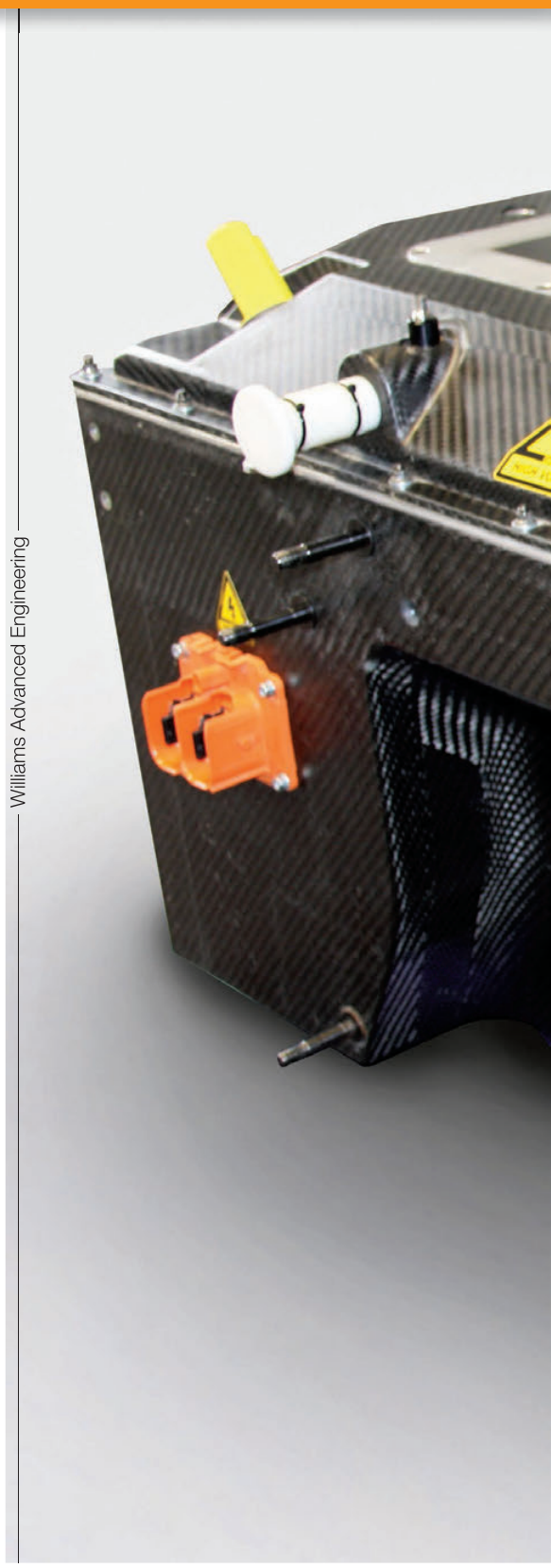
After conducting transient lap simulations the team realised that it would be possible to achieve these aims by making their own motor. This would also enable them to take out one of the most complex systems which also held a relatively high risk of failure: the gearbox. The team, which realised the Ducati 695 V-twin engine it used was torquey enough to propel the car from a standing start, therefore placed the final drive within the block casing itself, resulting in a single geared system. This was not only lighter and simpler from a mechanical point of view, it also improved the car's driveability. The other benefit of the Ducati V-twin engine, which fits into the Collective's ethos, is that it is air-cooled, meaning that the necessity of a water cooling system, another source of complexity, is therefore negated.

The combination of the interconnected suspension system and the bespoke motor helps facilitate a very large and stable aero platform, which is one of the keys to being successful identified by the team. The realisation of this aim has been aided by a holistic approach to the car's design. Rather than being looked at as distinct subsystems, the Collective has focused on creating a light and slim motor that, alongside the arrangement of the suspension, allows for very large underloor tunnels. These tunnels allowed by the suspension are also aided by it and the aerodynamically optimal position which it maintains. In this way movement of the centre of pressure is also reduced which, like utilising a single gear system improves driveability.

The car, not only has been designed as a whole, it has been designed as a whole that is perfectly suited for the Formula Student competition. RT

OVER THE MOON!

Chris Pickering finds out how battery technology has reached new heights across 240,000 miles of Formula E – the equivalent distance of a trip from the earth to the moon


Williams Advanced Engineering

THERE'S a revolution brewing in the automotive industry. Predictions may differ wildly on the timescale – from a few years to several decades – but everyone agrees that the passenger cars of the future will be heavily electrified. And that means that motorsport is sure to follow.

Earlier this year it was announced that the World Rallycross Championship would be moving to an electric powertrain from 2020. Admittedly, this is the low hanging fruit. Lots of low-speed acceleration plays to the strength of electric motors, while modest top speeds, frequent opportunities for regenerative braking and short race durations will limit the total amount of energy storage required (all of which, incidentally, could be legitimately said about road-going city cars too).

Nonetheless, this is the first pre-existing FIA world championship to abandon the internal combustion engine in favour of electric propulsion. And it's not some insignificant backwater that the federation can afford to gamble away either, but rather the world's fastest growing form of motorsport.

Inevitably, the biggest questions hanging over the series relate to the battery. All we really know at this stage is that it will be a control item produced by Williams Advanced Engineering. That's encouraging news, because Williams already has impressive form in this fast-emerging branch of motorsport.

The Williams Group's electric racing expertise stretches back to 2008, when its Formula 1 division began looking at the use of KERS systems. A flywheel design was investigated, but eventually turned down in favour of a battery-based system. Williams then set up the facilities to produce battery packs, control electronics and motors in-house, with the technology first used in anger during the 2011 season. In the run up to the 2014 season it became clear that the job of KERS development was going to switch from the teams to the engine manufacturers (in this case, Mercedes).

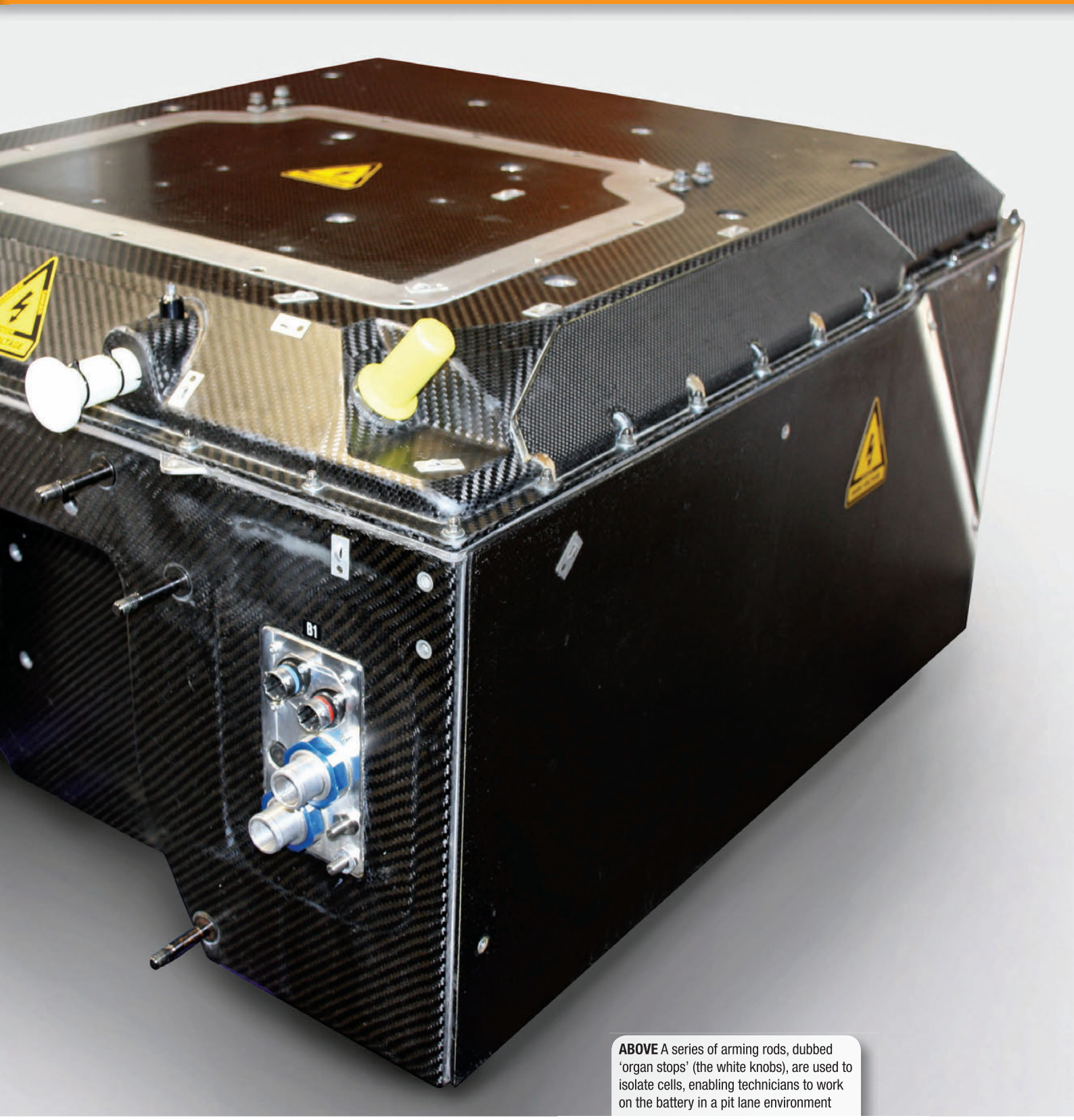
> *"A plug-in cooler is one of the concepts tipped as a possible technology transfer to road car applications"*

IN AT THE DEEP END

Around the same time, the original battery supplier for the first generation Formula E car pulled out and the contract came up for grabs. Williams seized the opportunity and was swiftly announced as the new supplier. It was good news for the engineers at Grove, but it left them facing a number of problems, as Paul McNamara, technical director of Williams Advanced Engineering, explains.

"The first challenge was simply the timing," he says. "We only had six months of design time and five months to develop, manufacture and deliver all of the race batteries."

But that was just the start. The technical specifications laid down by the FIA and by the chassis manufacturer Spark Racing Technology made for a sobering read. They included a 200 kg battery pack weight limit, a 1000 volt maximum bus voltage, a



ABOVE A series of arming rods, dubbed 'organ stops' (the white knobs), are used to isolate cells, enabling technicians to work on the battery in a pit lane environment

200 kW peak power limit and a maximum usable energy of 28 kWh.

The design required the battery to be a structural part of the car, sandwiched between the powertrain and the cockpit safety cell. That meant the shell of the battery would have to handle structural loads from the car as well as crash forces. What's more, it needed to be possible for the technicians to work on the battery in a pit lane environment, which meant that no part of the pack could deliver more than 50 volts.

The solution to the voltage problem was a series of arming rods, dubbed 'organ stops'. Inside the battery there are 165 lithium ion cells, grouped into a series of five modules. By removing the organ stops, the technicians were able to isolate these individual cells, taking them to less than 50 volts.

The next problem proved to be the relatively harsh environment of motorsport, explains McNamara: "Due to the suspension setup on a racecar, the cell gets subjected to high levels of vibration and high shock loads. It also has to withstand comparatively high temperature operation, with the series visiting places like South America and North America where there are very high ambient ▶

ABOVE The World Rallycross Championship goes electric for 2020, with some technology from the Formula E programme crossing directly to the new project

temperatures. Consequently you need a good cooling system in place and a way of managing the cells."

The Formula E battery uses off-the-shelf lithium ion pouch cells. Their construction – resembling a padded envelope with a pair of contacts on the end – is inherently lightweight and space efficient, compared to cylindrical or prismatic cells. In theory, this meant the engineers had plenty of volume to play with, but in reality the size and shape of the commercially available cells made them tricky to package within the shape of the battery compartment, which had been agreed by the previous supplier.

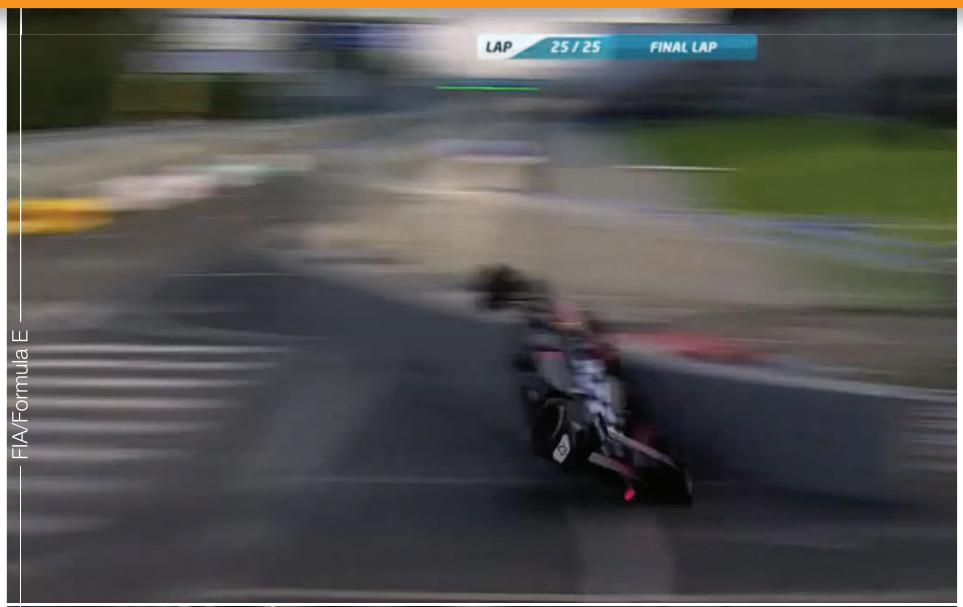
What's more, the pliable nature of the cells and the lack of a solid casing made them quite hard to hold in place, McNamara explains: "During the first season, we found that the cells could start pulling away from the tags due to vibration, causing internal damage and creating a hot spot within the battery. Engineering in the foams, the cassettes and the plastic components to hold those pouches together was a real challenge."

Maintaining low resistance throughout the battery pack was a key challenge, especially given the 'organ stop' battery isolators, which were effectively a series of switches. "You're putting several hundred amps through this assembly, so any breakdown or resistance gives you a pronounced hot spot," notes McNamara.

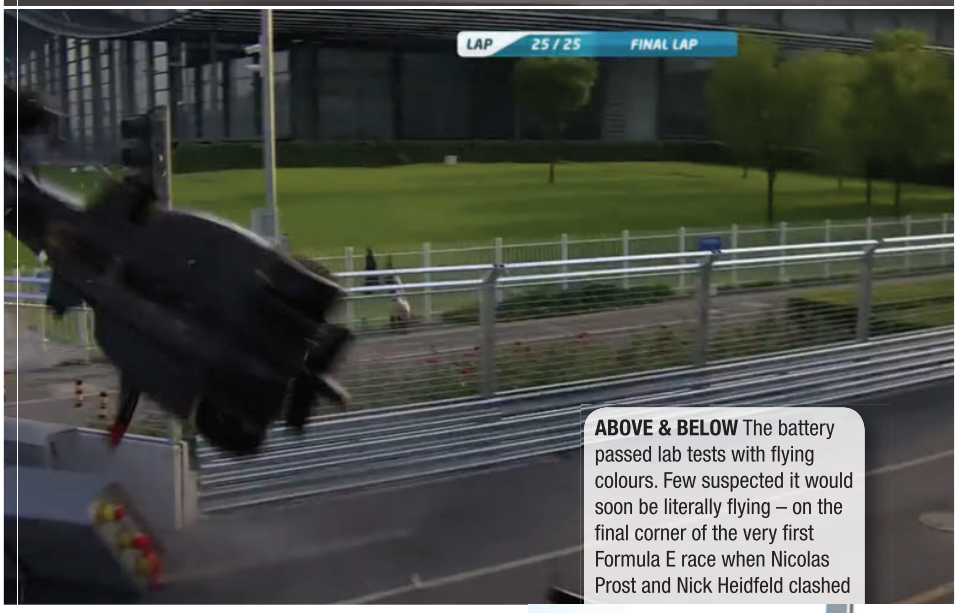
KEEPING COOL

The battery has its own cooling system using an oil-based di-electric coolant (with a separate water cooling circuit used for the motors and the inverter). This flows through a network of tubes, which cools every single cell individually.

"One of the interesting things about batteries – particularly in motorsport – is that you don't need a steady state cooling system; you need a system that can provide sufficient cooling for as long as the battery can discharge at its maximum power. So what we did was to de-size the cooling system so it could just achieve that, reaching its maximum temperature as the battery ran out of charge," comments McNamara. "Working with the di-electric coolant was also quite challenging. We needed something that would be compatible with the materials we had available for the various seals and components, so they didn't perish or degrade. We worked closely with 3M on that. Ultimately, the key thing was to deliver all of this in a battery that was also light enough for the requirements." ▶



FIA/Formula E



ABOVE & BELOW The battery passed lab tests with flying colours. Few suspected it would soon be literally flying – on the final corner of the very first Formula E race when Nicolas Prost and Nick Heidfeld clashed

Another interesting point is that batteries require cooling when they are charging as well as when they are discharging. In fact, in road car applications fast charging systems are already able to charge the batteries quicker than it's possible to discharge them in normal use (which means that the highest cooling demands actually come when the vehicle is not even in use).

PLUG-IN COOLER

On the Formula E battery, the charging system includes a plug-in cooler, which is one of the concepts that McNamara tips as a possible technology transfer to road car applications. For those applications, it would potentially allow the size of the onboard cooling system to be reduced, helping to offset the weight of the battery. In a Formula E context, it means the battery is cool and ready to race the moment it comes off the charger.

Alongside the cooling hardware, the battery management system (BMS) plays a crucial role in the car's thermal management. This constantly measures the voltage and temperature of every single cell inside the pack, McNamara explains: "We use that information for a de-rate strategy, so if the temperature of a cell becomes too high then we start to de-rate the battery. This offers slightly less power to the driver, which raises a unique challenge in a series like Formula E, where you need to ensure consistent performance between all the different battery packs. Essentially, we had to build enough of a margin into the system so that all the batteries would behave in the same way."

MONITORING

One of the hot topics in BMS development is long-term state of health (SoH) monitoring, which evaluates the battery's general condition and its fitness for purpose. Again, this is particularly relevant in motorsport, where 10 different teams are each relying on you to give them a fair shot at the race.

"The issue that we found during the first couple of seasons was that we were having a lot of batteries coming back to the factory due to damage," says McNamara. "In a lot of these cases, we noticed that the damage had actually been done the race before it ▶

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showed up, but our diagnostics weren't good enough at the time to flag this up."

Based on the data they had collected, the Williams engineers worked with researchers at Imperial College to develop an algorithm that would predict the SoH more precisely, identifying potential issues before they occur. This was introduced for the subsequent Formula E seasons and has already transferred to road car applications too.

LIGHTS, CAMERAS, ACTION

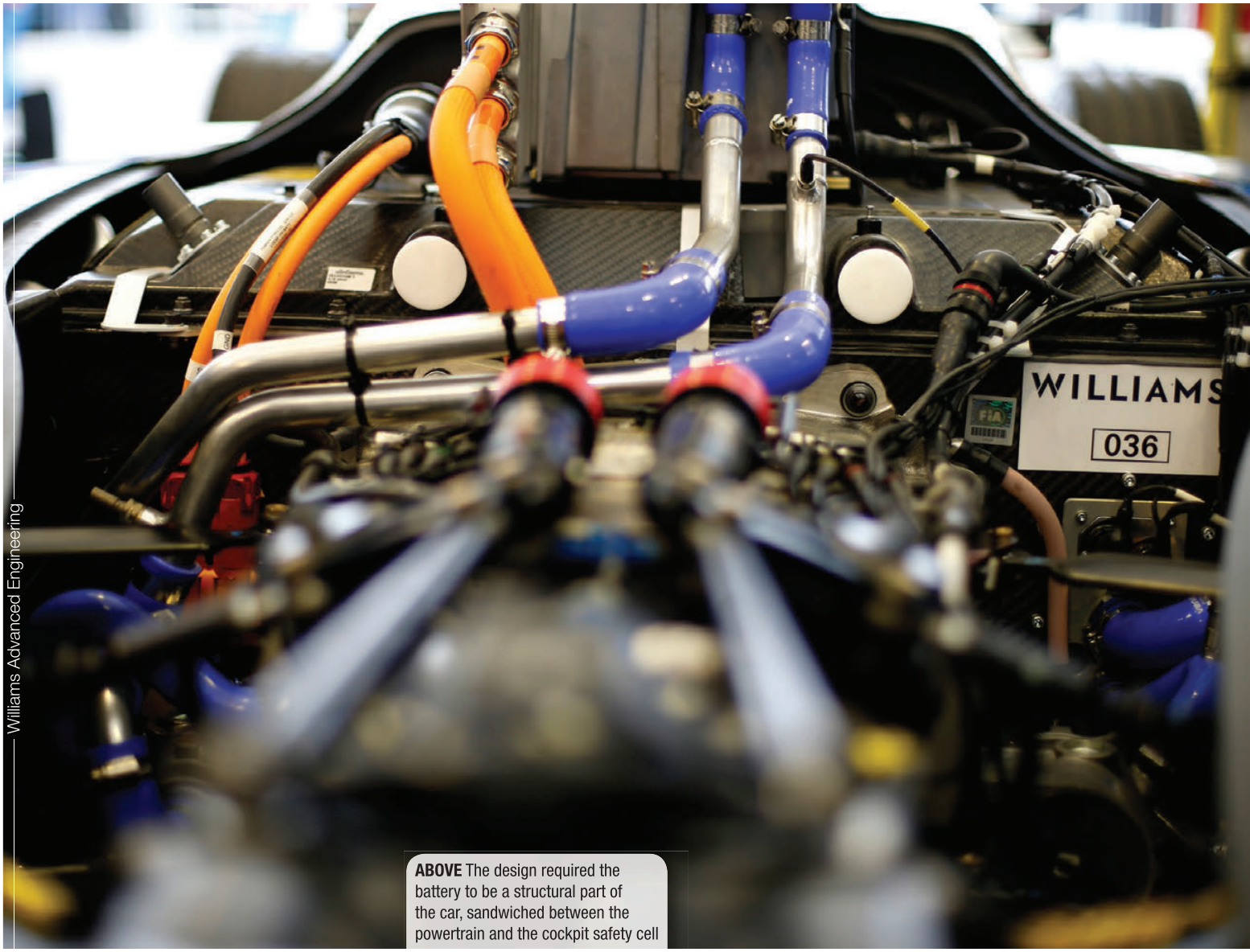
As a structural component of the car, the battery casing had to be resistant to crash damage. It also needed to be resistant to thermal events (inside or outside the casing), which meant a built-in fire containment system was required. It went on to be one of the first fully live crash-tested batteries, going through front and rear impact tests. Similarly, it had to be put through the UN 38.3 transport test in order to be airfreighted from one event to the next.

> *"We found the cells could start pulling away from the tags due to vibration, causing internal damage and creating a hot spot within the battery"*

The battery passed all of its laboratory assessments with flying colours, but it wasn't long before it faced a real-world test. On the final corner of the very first Formula E race, Nicolas Prost and Nick Heidfeld clashed in spectacular fashion. Heidfeld's car was sent skating over the kerb before briefly becoming airborne and smashing side-on into the crash barriers. For the promoters, this dramatic last lap tussle was the ideal riposte to those who feared that electric racing would be boring. But for the engineers, things were altogether more nerve-wracking.

"Everybody, including us, was very nervous about the state of the battery following that huge impact," admits McNamara. "It did crack the case, but it kept the whole internal structure intact."

From that point onwards, the championship has gone from strength-to-strength, proving it has the substance to survive as a top-level international motorsport series. Williams Advanced Engineering remained the battery supplier ▶



Williams Advanced Engineering

ABOVE The design required the battery to be a structural part of the car, sandwiched between the powertrain and the cockpit safety cell

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> *"We're already starting to think about the next innovations for Formula E"*

until the end of the fourth season, with the design evolving almost continuously.

"We had to increase the power of the battery throughout the four years," comments McNamara. "Starting with the first season's battery, which was 170 kW, and taking that up to 200 kW was a challenge with the cooling limitations in place. We ended up having to develop some new materials to cool the tags. The problem with pouch cells is that getting heat out of the side of them is not very effective; you need to try and cool the tags and the bottom of the cell. We had to develop a plastic-based material that would be thermally conductive but electrically insulated to tack onto the tabs and provide that heat transfer."

Overall, he says the greatest achievement has been the battery's reliability record: "We only had one car stopped in four years due to a battery problem in the end. The amount of work going on behind the scenes to maintain that situation decreased dramatically over that time. Initially we had a lot of batteries coming back to the workshop, but during the last season they just all stayed out there."

WE'LL BE BACK!

Now, of course, the Formula E battery contract has passed on to McLaren Applied Technologies, but the expertise it fostered at Williams is being put to good use elsewhere. "We're just embarking on the electric rallycross series," comments McNamara. "Some of the technology from

FIA/Formula E

our Formula E programme will cross directly to that project."

Don't think for a minute that this means electric single-seaters have dropped off the company's radar, however. "We're already starting to think about the next innovations for Formula E," McNamara confirms. "For season eight the battery tender will come up again – and we're very conscious that, at some point beyond that, the battery is likely to open up as a competitive element – so we're starting to examine that on a four or five-year horizon."

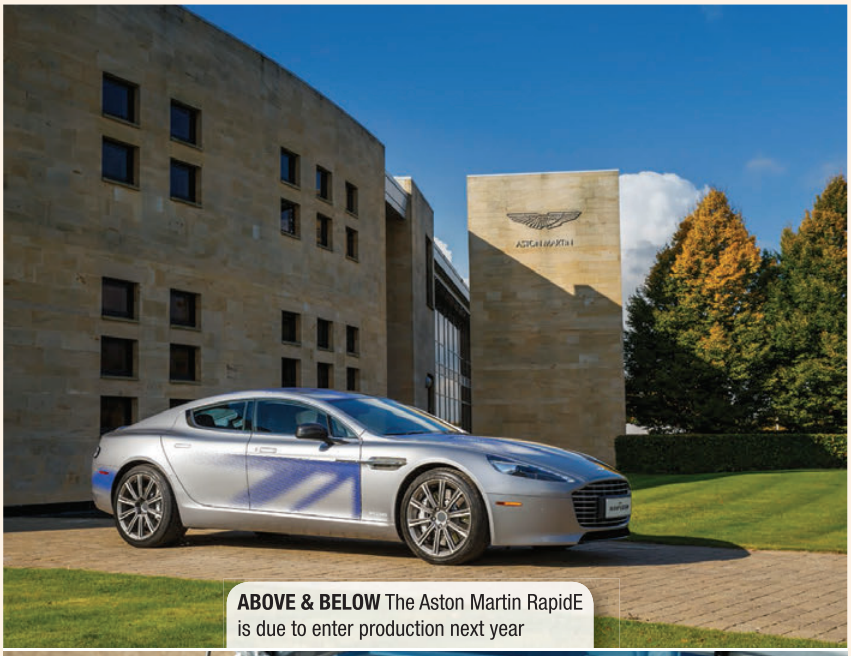
The message is clear: Electric racing is here to stay. And the biggest names in the business already take it very seriously indeed. RT

From racetrack to road

THE Formula E programme has been notable for the amount of technology transfer it has created. The construction used for the Williams battery casing, for instance, has since been transferred to the base plate of a battery pack that the company is currently developing for a low volume project with a major European OEM. This uses glass reinforced plastic (GRP) on the inside to provide an insulating layer, followed by carbon fibre to provide structural rigidity, then a Kevlar outer shell to provide retention in the event of a crash.

Likewise, the cooling concept developed for Formula E is understood to have been transferred to a road car project, along with the expertise gained on thermal management, weight reduction and crashworthiness.

The company is understandably coy about where each of these technologies has gone. However, since the Formula E programme started its projects on the OEM side are known to have included an electric Range Rover Evoque concept and the Aston Martin RapidE, which is due to enter production next year. RT



ABOVE & BELOW The Aston Martin RapidE is due to enter production next year

OVERTAKEN BY EVENTS

Our **Expert Witness**, a GP insider who must retain anonymity, was buoyed by the decision to base F1's next generation of cars on the results of careful research. So why the stampede into short-term changes for 2019?

WHAT makes for exceptional motorsport? The question is simple, but the answer is obviously not.

Over an extended period, fans and the public have been surveyed, and some of the finest minds have been assembled and appointed to mould the future of Formula 1. Yet it is not just the finer points of the grand plan that still remain elusive and mired in conflicting opinion, but many of the key fundamentals.

What is the best way forward? When developing a race vehicle, you already have today's picture as a baseline; from there you need to improve it, normally by an extensive period of R&D. Where is it already competitive? Where is it lacking? And how much progress are your opposition going to make? You have to measure today's version, then definitively change it for the better.

I see no difference between this approach and the correct way to develop the sport as a whole.

When Liberty Media and FOM announced that they would set up a research group of technical experts to help determine the future shape of F1, I for one was finally relieved. Too many times in the past we have seen knee-jerk reactions to events or accidents, nostalgic returns to routes previously abandoned and worst of all, random ideas from inside or outside with political power applied for adoption. At last, we were going to plan our approach with proper science and with the correct timescale to investigate things thoroughly before implementing them in 2021.

Er, no, of course not. That would be

Tee/LAT

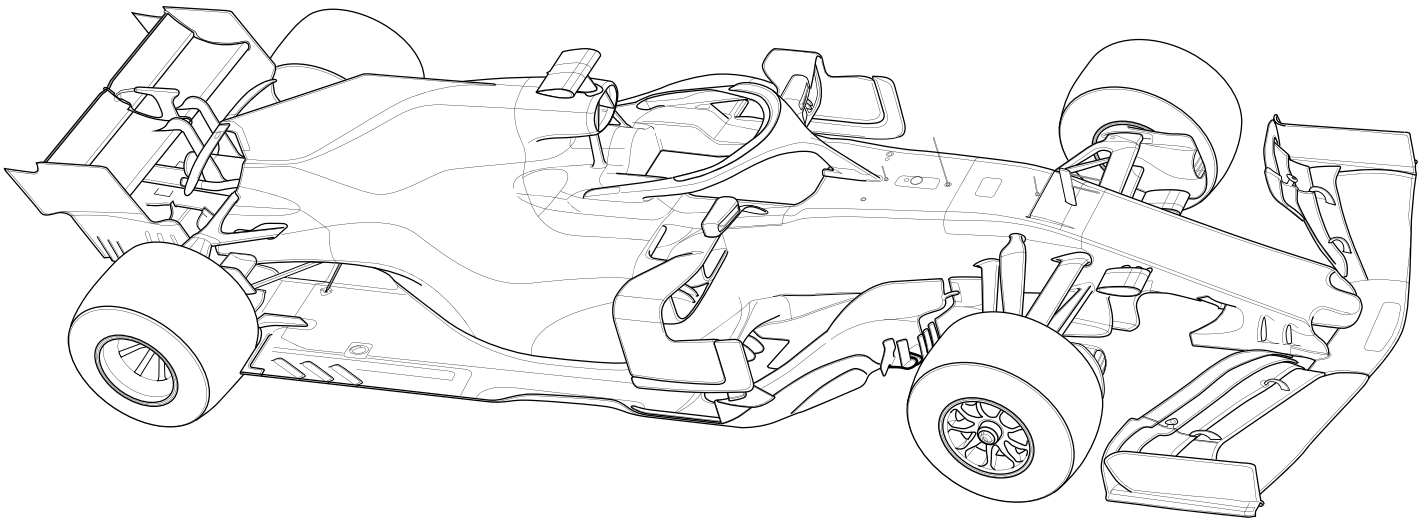
sensible and logical progress. I don't know if pressure is being applied or there are some egos who know better, but the early findings are being introduced for 2019, having been rushed (or was that sneaked?) through on the last available day to apply them. This is dangerous ground: if the original FOM plan was right, why undermine it by forcing through changes after only a third of the project learning is complete? Old habits die hard?

ATTRACTION

This literally takes many forms, but what draws you to a motorsport category, apart from what your objectives are? Let's start with aesthetics: what do the vehicles look like, how do they perform, what noise do they make, how fast are they and is the racing a superb spectacle and platform? If you list the current highest profile categories – F1, LMP, GT, FE, WRC, NASCAR, DPi, ▶

Hone/LAT

ABOVE & BELOW The introduction of half-baked rules changes to F1 for next season was a knee-jerk reaction to less overtaking in the early races



ABOVE The shape of the future: how the 2019 cars could look, with their wider and deeper rear wing, mandated mirror position, lower bargeboards and simplified front wing

Illustration: Craig Scarborough

IndyCar, MotoGP and World RX – you quickly realise some are getting aspects of this so much more right than others.

The two I would like to draw your attention to are LMP1/2/3 and Formula E. LMP1 was a manufacturer stronghold until very recently. The cars, with their fuel flow and choice of hybrid power levels, were a technological tour de force. However, it soon became apparent that this cutting-edge arms race, though incredibly impressive, was not cheap. So much so that such outlay, allied to some other environmental factors, caused even the OEMs to call time, leaving Toyota as the last one standing at this year's Le Mans 24 Hours.

With a massive budgetary and tech advantage, and the high profile Fernando Alonso on the driving squad, its victory was a formality. Certainly it was deserved after the misfortune of 2016, but this time they only effectively had themselves to beat.

That's not to say there were not other LMP1s there, for Dallara, ORECA, Rebellion, Ginetta and ByKolles all produced cars, but with such a gulf in performance to the sole manufacturer they had, apart from repeatedly tragic unreliability, no hope of winning. Zero.

Privateers participating, but with absolutely no chance, at least meant the grid was not embarrassingly thin. Except having committed to do this, the new ACO future direction now seems to be 'Hypercar', ultimate GTs intended to entice the big money manufacturers to come back and play all over again. Pity about the privateers. Oh well.

While I like the new category's aesthetic and strong brand identity, I do really feel for the independents which have gone to the time and trouble of subsidising the ACO

> *"Tick tock: we have to do something now, even if the homework is half-baked. Good luck with that"*

The five steps to haven

THE ideal template for the future of motorsport has preoccupied us for some time. We are aware of the many threats we face, but seem no closer to unearthing any solutions that will offer the sport a safe haven amid the uncertainty of changing times.

With that in mind, here are five things that I feel are currently restricting our growth and appeal.

Simplify: Don't confuse and then alienate the audience. Make global frameworks clear and transferable. The same platforms, rules, standards across borders. E.g. WEC, run by the ACO and FIA, currently operates a different rules framework compared to IMSA's DPi category.

Access: Communicate. Show data, people, design, technology and live team radio. Use multiple platforms. Showcase what we do: don't hide it away behind screens and fencing.

Competition: Ability should prosper, not team size or budget. We should not know the winner beforehand; victory must be hard-earned, with multiple potential outcomes every event.

Value: What am I getting for my money? As a fan, participant, sponsor, OEM, promoter. Does it make commercial sense? What's the ROI? Should I do/view something else?

Diversify: Variation changes outcomes, be it in formats, types of circuit, weather, vehicle type, energy, or multiple manufacturers. Drive and utilise the R&D road map potential.

in its hour of need. The other point is we seem to be going around in circles all over again, not forward: Porsche GT1s and flying Mercedes don't seem very long ago. But they all got too expensive. Sound familiar?

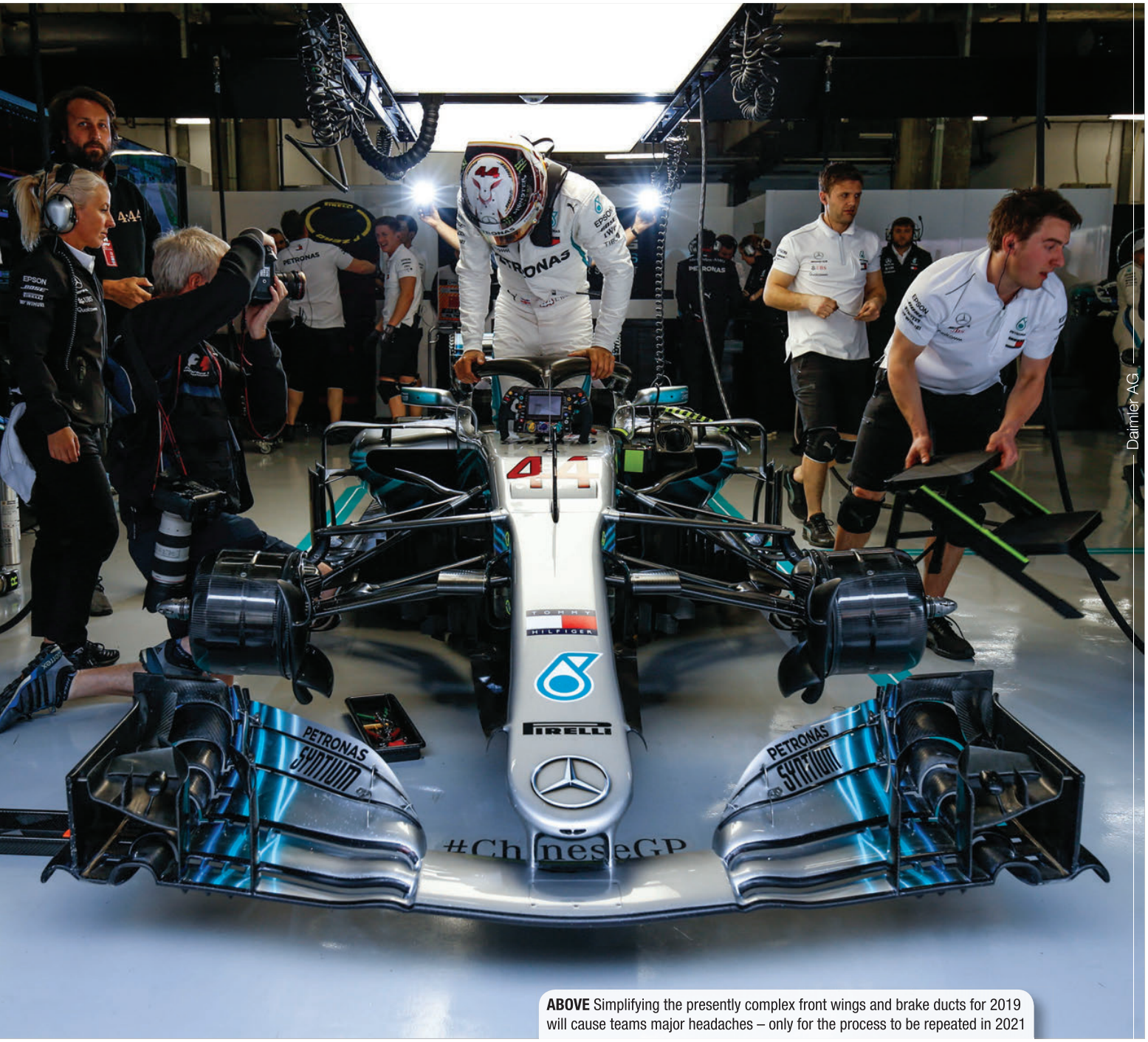
This time around the saving grace, it will be argued, is the aero "revolution" the organisers promise. Limiting the downforce to a sensible level is an interesting idea, which might even protect the visual identities of the individual cars. But while it might sound great in concept, executing it well is a whole different, and more difficult, matter.

We already know from the success of multi-manufacturer GT racing that the Balance of Performance (BoP) allows very different machinery to race closely together, through the adjustment of aero, power and weight within specific windows. But the process is an artificial one and hard to police. Most of these cars seem to suddenly change their speed significantly, as if by magic, when the events that are key for their brand approach, with last minute adjustments needing to be applied by governance, not always successfully.

The ACO needs to take on board the lessons learnt by other categories. It's no good putting cars in the full-scale wind tunnel for homologation six months before an event, because you tend to find that the fit and finish of these cars isn't perhaps as good in the tunnel, when its performance is being evaluated, as it will be come the race itself!

FORMULA E 'CATNIP'

If you want to look at manufacturer attractiveness, Formula E seems to be the proverbial 'catnip' for some reason. Could it be that they feel its battery and electric ▶



— Daimler AG

ABOVE Simplifying the presently complex front wings and brake ducts for 2019 will cause teams major headaches – only for the process to be repeated in 2021

FIA/Formula E

ABOVE The purists might object, but Formula E is offering the manufacturers an appealing platform

motor insights, or is it just a case of being seen to be involved? Whatever the answer – be it too good an opportunity to pass up, or too big a risk to miss out on – one thing is in no doubt: it is compelling.

The series is certainly forward-facing and progressive, with a clear road map of technology freedom, the drivetrain being the enticement area currently. The Generation 2 car is also futuristic and a significant step forward from the initial design. Quicker than its predecessor, it also crucially removes the need for mid-race car changes.

This feels like the organisers are moving in the right direction. They are offering an appealing platform for the future, but what are the viewing figures like and how good is the racing?

What do the fans want? We keep on asking, but what are the real answers? Ladies and gentlemen, I give you MotoGP and NASCAR. With an honourable mention to the Isle of Man TT and WRC.

Who's going to win? You can pose that question before the event, after qualifying, or even during the last five laps/minutes of the race and normally, though not always, you have no idea. So what are the common ingredients? Closeness of machinery, ability to overtake, a huge reliance on rider/driver bravery/ability and a level of gladiatorial difficulty that produces true modern day heroes. As a fan I think we all want to be completely awed: "There is no way I could do that, ever!"

"I'LL WATCH THE START"

So, vehicles, tracks, categories and event formats that line up competitors in speed order and proceed to a race with processional gaps getting ever larger with no prospect of change. Why would you watch this? This is not interesting, it's boring. Nothing happens. You know the outcome. Do you pay significant money or time to watch a film, read a book, see a play or go to watch other sports for this? No.

"I'll watch the start," is a common refrain you hear from even ardent F1 fans, because the race into the first corner offers the sole opportunity for unpredictability. Sorry F1 2018, but under the new rules, some (not all) of this year's races have been absolute stinkers, as we knew they would be. Except Canada, surely? Ah, this was the clincher for me. Without fail, year after year, even in a bad season, Montreal always seems to throw up a great race. This year offered the Hartley and Stroll collision on lap 1 and a Ricciardo overtake, in the pits. Zzzzzzzzz.

The main repeat culprits here are vehicle and track configuration. Aerodynamics have long been developed to a fragile and temperamental peak with only your own singular vehicle performance in mind. Run ▶

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that car in traffic, or close behind another in order to try to overtake, and its performance degrades dramatically. This is never researched properly and is certainly not a team consideration.

Track layout? Worst by far is Monaco. Yes, money, tradition, spectacular views, driver challenge, but not a race. Where are you supposed to overtake? Why even bother with DRS?

"RUSHED THROUGH"

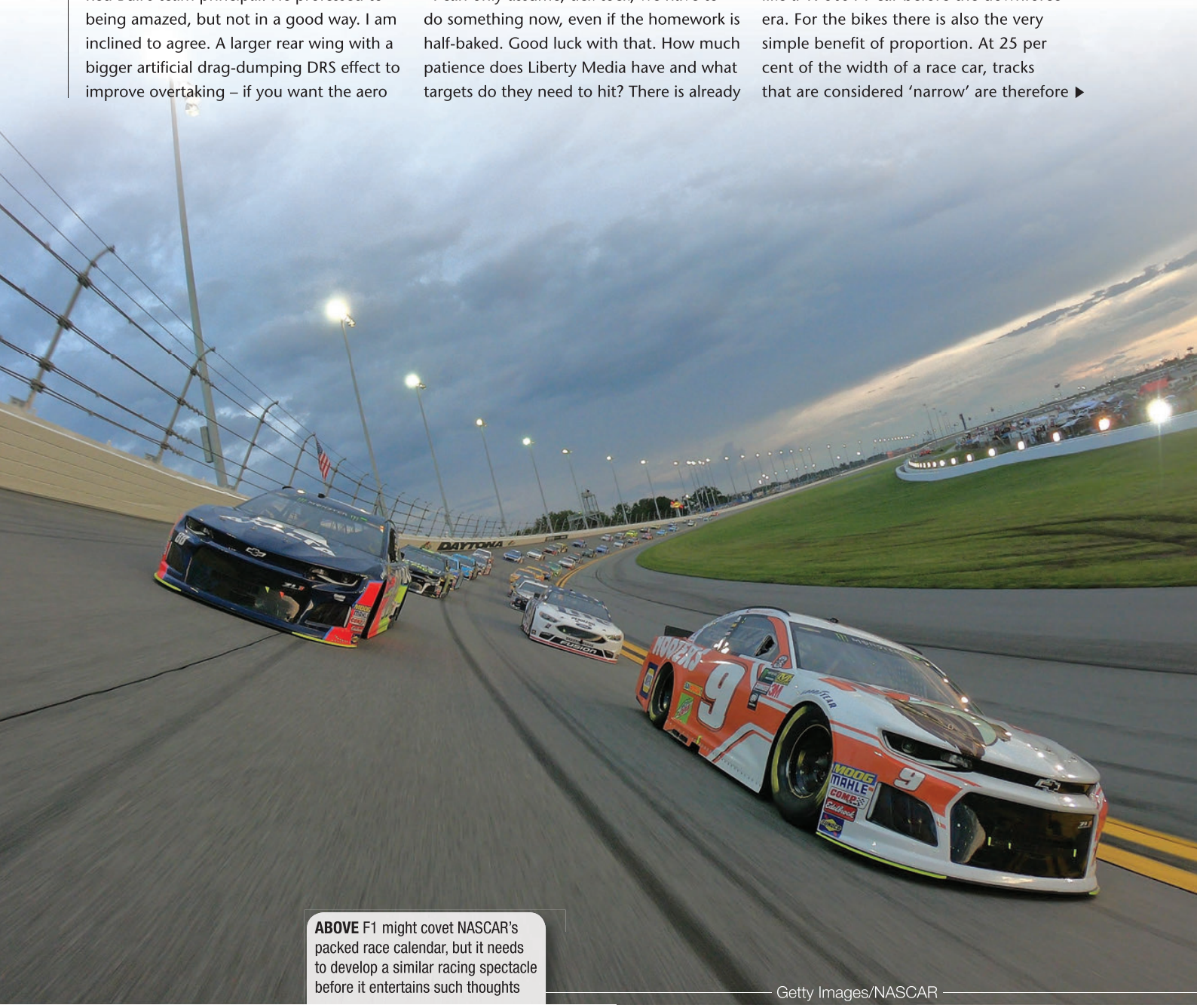
The F1 changes for 2019 were branded, "immature research", "rushed through" and "cherry picking" by Christian Horner, Red Bull's team principal. He professed to being amazed, but not in a good way. I am inclined to agree. A larger rear wing with a bigger artificial drag-dumping DRS effect to improve overtaking – if you want the aero equivalent of a sticking plaster, DRS is it. If you want to pretend that isn't the case, why is it getting larger?

> *"If you want the aero equivalent of a sticking plaster, DRS is it"*

The short-term move to simpler front wings and front brake ducts is equally frustrating. These are devices that dictate the whole of the rest of the flow over the car, therefore entailing a complete reinvention, and then we would have to do it all over again with the proper solution in 2021 as scheduled.

I can only assume, tick tock, we have to do something now, even if the homework is half-baked. Good luck with that. How much patience does Liberty Media have and what targets do they need to hit? There is already noise about more races on the calendar, something you can only do if the product is strong enough and the market is there for it. Why sell something 18 times a year if you can sell it 25 times over? Team, people and travel fatigue beckons. Over-exposure equals devaluation.

So why do MotoGP and NASCAR work? Well they can overtake without artificial aids: the person following benefits in the slipstream – draft – rather than suffers, a bit like a 1960s F1 car before the downforce era. For the bikes there is also the very simple benefit of proportion. At 25 per cent of the width of a race car, tracks that are considered 'narrow' are therefore ▶



ABOVE F1 might covet NASCAR's packed race calendar, but it needs to develop a similar racing spectacle before it entertains such thoughts

Getty Images/NASCAR

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Toyota Gazoo Racing

ABOVE & BELOW The new hypercar-based top class at Le Mans will see downforce limits introduced, but the figures arrived at in the full-scale wind tunnel need to be verified on the racetrack

Ford

four times wider for MotoGP. Overtaking ensues. Try and imagine if Monaco was four times wider.

These series are also not extremely expensive. Finding a way of making throwing money and people at the best solution relatively ineffective has to be a useful way of controlling costs.

But enter any conversation heading in this direction, and you have to navigate your way through a world full of vested interests. Max Mosley, the former FIA president, recently told Race Tech that Liberty Media and the FIA need to be prepared to call Ferrari's bluff when it comes to financial matters. I agree. 'Grow some', I believe is the term…

Any sport – and I believe and hope it *is* a sport we are talking about when we refer to F1 – needs a strong, impartial, transparent and fair body to police and regulate its running. This we know from other codes or areas in life, becomes increasingly challenging as the profile, budgets or corporate vested interests become ever larger. The way the decision-making process is structured, who is involved and how quickly correct implementation is made, is increasingly critical.

For our world we have the FIA and the WMSC (World Motor Sport Council) as the central core over national federations and clubs, with a highly complex plethora of categories, classes and types of racing worldwide. Everything stems from here: from the length of car to the length of the race, the number of wheels, engine type etc. It is either permitted or not and the same framework for all. How effectively you interpret that evolving picture determines how successful you will be. However, if the outline is wrong, you will get a boring, stale, expensive, unsupported or unsustainable series.

At the moment the inputs of commercial rights holders, manufacturers and competitors are all mixed in to Formula 1's decision-making process. I honestly cannot see how this enables rapid change, for while opinions are important, when integrated as votes they can seize up essential policy being made.

> *"If you started races in reverse championship or finishing order, overtaking would become an essential requirement"*

AND FINALLY...

Lastly, I have to throw something out there, going all the way back to regulations, but this time Sporting rather than Technical.

The true hidden power of rule framework is cause and effect. If you started races in reverse championship or finishing order, overtaking would become an essential requirement, rather than a rarity. Entertainment, incident and motor racing would be inevitable. Who knows, teams might then actually have to start researching how good their cars were at running in traffic out of necessity. How much would that rule change cost? Nothing. RT

Gold and Goose/LAT

ABOVE MotoGP: overtaking without artificial aids

Ferrari

ABOVE The amount of power wielded by the big-hitters like Ferrari complicates the decision-making process

TORO ROSSO'S ROLLER COASTER RIDE

William Kimberley talks to Scuderia Toro Rosso technical director James Key about a campaign that has amounted to a successful Red Bull audition for Honda

IT has been a turbulent year for Scuderia Toro Rosso, Red Bull's junior squad, as it is currently only ranked eighth in the teams' standings with 29 points, just two points ahead of Sauber.

As technical director James Key admits, it's been what he describes as a roller coaster ride for everyone concerned. By the time of the British GP, the team had failed to score a single point since Monaco.

"It's been a case of good aspects and bad ones so far this year and more often than not we've not got the maximum out of the car," says Key. "The tyres this year are very sensitive. At Monaco, for example, Pierre (Gasly) did the longest stint of anyone, 37 laps on the hyper-soft compounds, having already run the same set for six laps in qualifying; but at the cold race at Azerbaijan we just couldn't get them to perform. We've had to stabilise the situation from this see-saw of either being really good or really poor when it comes to tyre performance and that has been the thrust of our development programme as we reached the mid-season.

"It's therefore been a mixture of vehicle dynamics, aero, driver, engine, but predominantly track and ambient conditions along with the nature of the track surface with its macro-roughness: all manner of different things that go into heating tyres or keeping them cool. They are peaky so we've got to close up our operating range to be centralised more around the peak, but not losing the ability to be very flexible with strategy when that can be used to our advantage.

"Each compound has its own characteristics and I think it's more dependent on the nature of the track and the ambient conditions. So if you look at our performance in Bahrain, it was perfect while ▶

BELOW Honda landed its big deal with Red Bull's senior team on the back of the promise it has demonstrated through its work with Scuderia Toro Rosso. However, data from Gasly's car at the British GP (bottom) illustrated that the team's engine partner still has significant work to do

Honda

Getty Images/Red Bull


Honda

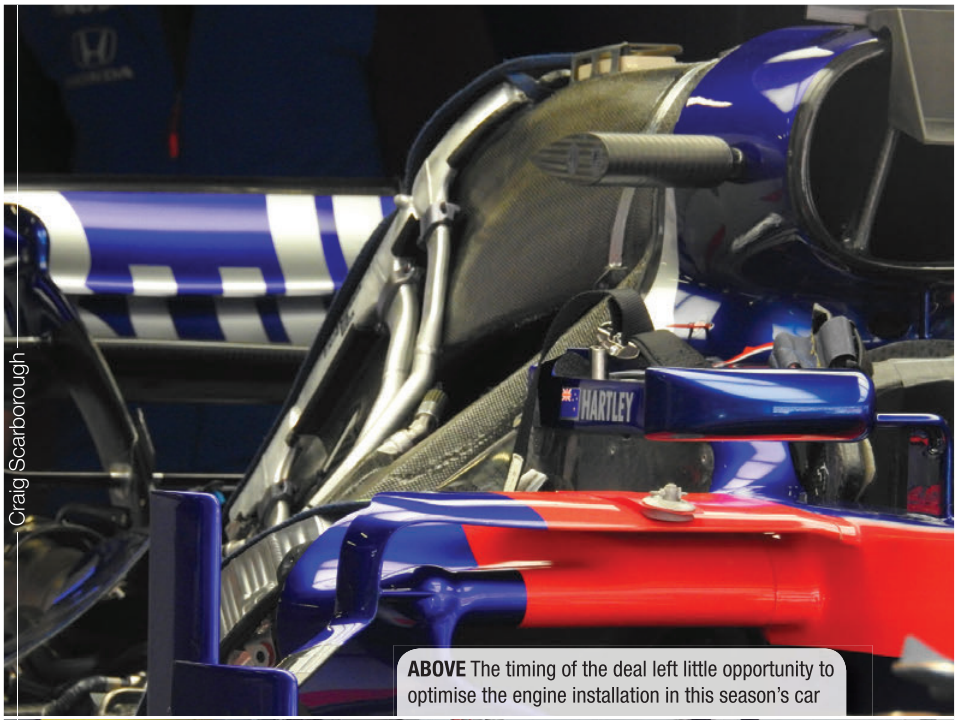
ABOVE It took just two races for the new partnership to eclipse any result Honda had achieved in three years with McLaren

others struggled a bit, but it was the opposite in China and Azerbaijan where the conditions were predominantly very cold and worked against us."

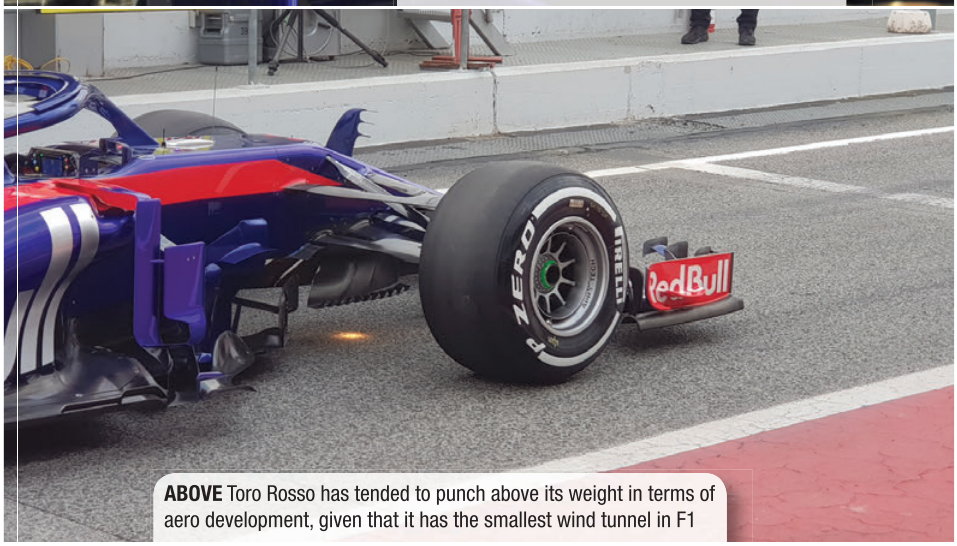
Key says that on the chassis side there's still some work to do: "There are some mechanical tools we could have done with earlier, but which we are introducing soon to help mechanical grip and there's also some aero work that needs to be done."

Considering its more limited resources compared to the Big Three teams, Scuderia Toro Rosso has done phenomenally well to get to grips with the intricacies of Formula 1 aerodynamics. The aero department comprises around 100 people who are mainly located in the UK, as is the wind tunnel, which being just 50% is the smallest in Formula 1.

An upgrade to 60% has been talked about, but Key is reluctant to request it. "We've costed out a new wind tunnel on several occasions," he says, "but it would take a lot of courage to ask the owner to fork out a huge amount for it. We've therefore tried to compensate with the accuracy of our model, not just in replicating the intricacies on these cars, but also their stiffness and even surface finish that all need to be as good as a 60 per cent model. A lot of work has gone into that, but also on the technology we've introduced as well to get more out of what we have. The aero department as a whole has done a really good job on this."


Craig Scarborough

ABOVE The timing of the deal left little opportunity to optimise the engine installation in this season's car



ABOVE Toro Rosso has tended to punch above its weight in terms of aero development, given that it has the smallest wind tunnel in F1

GAME-CHANGER

While tyres play a big part in the team's performance, the game-changer for the squad has been the Honda engine. For the first time, the team has become an official partner to an engine manufacturer rather than just a customer.

"The nature of the agreement we have with Honda is different to ones we've had with engine suppliers before as it's now a partnership," says Key. "We are currently Honda's only team and representing it in the championship this year, so it's relying a lot on us for certain things and that's been a very new experience for us. It's been an enormous challenge and a massive responsibility when you consider that a huge company like Honda is putting its faith in a chassis team, and you've got to live up to that expectation.

"When you're a customer you always dream about getting that dyno and sorting out the cooling system and optimising various items, but when you've actually got that available 24/7, as we have, it's great, but then the downside is that you need more people to capitalise on it. We haven't taken anyone extra on so what we have achieved with Honda has come off the back of everyone's hard work. There have been a few glitches, but because it's been only a few, they've been able to concentrate on performance development and that sort of thing, and it's actually beginning to come quite prolifically now.

"What's been pleasant about working with Honda is that it isn't protective and there's no finger-pointing or anything like that. They're very open to suggestions and we are very

honest with each other which has helped us work our way through issues very easily, and in a very straightforward way. It also has got a lot of resource and a lot of fire power while an internal reorganisation there has also meant that an extremely high workload for one person has since been split now into two, which has greatly helped.

"All they want is the quickest package overall and I think we have provided them with the much needed fresh input. As we had experienced a different power unit the year before, we generally had a good idea of what's going on, how certain things were working, and what's achievable. Its confidence has built up and they're willing to stick their neck out a bit and try different things. A lot of their own internal work is also just coming good now that they've got the opportunity to do it without reliability concerns.

"As we have regarded this as the building year, when it came to the engine and chassis, we knew we were going to be handicapped and weren't in a position to do everything we wanted, so Honda and ourselves agreed on the areas that would be prioritised. It was a question of getting the fundamentals right first, which meant reliability on Honda's side and ours on the chassis side. Having achieved that, we're now in the cycle of development.

"So despite the language and time difference, we've very much been on the same page. The only regret to a certain extent for the '18 car is that it was so late. That meant we weren't able to influence the architecture of the '18 engine; not that we particularly needed to, but maybe to get a better fit in our car. However, we began discussing the '19 engine last November and so have started very early on it from an architectural point of view.

CUSTOMERS GET WHAT THEY'RE GIVEN

"Being able to influence the engine installation and everything that goes with it is something you cannot do as a customer. There you really do get what you are given, and in the power unit era, you don't know exactly what that is – it can be very uncomfortable when spending nine-figure sums. It's therefore a totally different situation and quite a challenge, but a satisfying one and we have enjoyed seeing the progress and how we are making a difference."

Next year Red Bull Racing will become a Honda runner after severing its ties with Renault, with whom it has won four world titles, 58 races and racked up 59 pole positions. In other words, it is coming in with high expectations which could unsettle the relationship with Toro Rosso, as Red Bull has apparently approved a plan to use its junior squad as a test and development operation for the rest of the season.

Red Bull team principal Christian Horner has gone on record to say that it will not "sacrifice" Toro Rosso's performance to help Honda improve its engines for 2019. But he has made it clear that he wants his new engine partner to close the gap to the top engines within the year, so that in 2019 it can be in the mix for the title fight.

That does mean in effect that Honda will need to push through more upgrades. The knock-on effect is that it could force the Toro Rosso drivers to take penalties – as was the case in recent races – as both have already exceeded the maximum number of three of each power unit component allowed to each driver in a season under the rules.

The Honda power unit has already made notable progress: the Canadian GP in particular was a watershed moment, with GPS data illustrating that the engine's performance was now on a par with that of Renault's. However, there is still some work to do as data from Gasly's car from the British GP showed that it was almost a second slower than Ferrari or Mercedes on the Silverstone straights, so perforce there need to be further upgrades.

"Our relationship with Honda will continue on the basis that we have an agreement and will continue working in the same way," says Key. "What's very beneficial is that we have Red Bull joining us so that Honda will now have the benefit of two inputs and more resource to support them with its development. Having Red Bull join us can only strengthen everything." RT

ABOVE The Canadian GP, where Honda's performance was demonstrated to be on a par with Renault, was a watershed moment

Getty Images/Red Bull

"It doesn't look very clever from the outside, but the team has grown around this system"

Soheila Kimberley quizzes team principal Guenther Steiner on Haas F1's structure and its struggle with the rest of the midfield pack

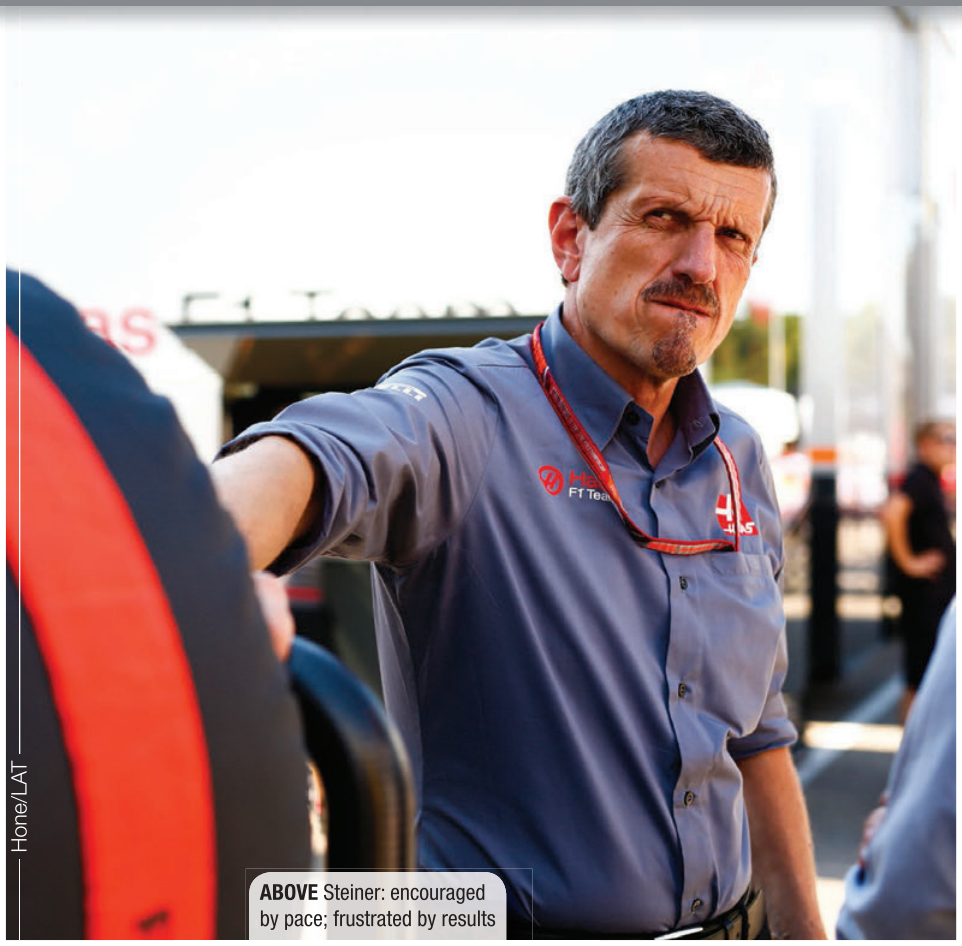
ABOVE Kevin Magnussen's VF-18 heads rivals in an increasingly ferocious midfield battle

THE fight for fifth place in the Formula 1 Constructors' Championship could not be closer after the British Grand Prix.

Had it capitalised on its success in the Austrian GP, where it harvested 22 points compared to the zero that Renault recorded, Team Haas F1 could have edged past the French team into fourth place. As it was, though, it collected just two points and so the gap was 19.

More to the point, though, it was just two points ahead of Sahara Force India F1 and three ahead of McLaren Renault. Bearing in mind that this is still a relatively new team operating from three locations, it's an impressive feat.


Haas F1


Hone/LAT

ABOVE Steiner: encouraged by pace; frustrated by results

"There isn't really a midfield anymore," says Guenther Steiner, Haas F1's team principal. "There's the top-three and then the rest. Everybody from fourth to 10th can be competing for points this year, as we've all seen. It's great to be fifth but we are very conscious that it has required hard work for us to be there and even more to maintain it."

What has annoyed him, though, are the number of points that have been thrown away this season, the team not scoring any in four races: "We are through half of the season and have lost a lot of points due to our own mistakes, and that isn't acceptable." That remark was made before Haas F1 team-mates Roman Grosjean and Kevin Magnussen threw away good grid positions when the two came together on the opening lap of the British GP.

Because of the team's close relationship to Ferrari, there are some who claim that it has been given an unfair advantage and is operating as its B team. McLaren driver Fernando Alonso has even hinted at what many people believe and that is the Haas VF-18 might have too much technological overlap with the Ferrari SF71H.

Steiner acknowledges the close relationship between the two teams, and says that Haas F1 would not have risen so quickly without the Scuderia's help, but at the end of the day, the US team is a standalone organisation. "The relationship with Ferrari is crucial," he accepts. "We buy a big part of the car from them and without them we wouldn't be where we are."

A QUESTION OF LOCATION

What makes Haas F1 so different to the other teams on the grid is its geographical spread. Located in Charlotte, North Carolina, it also has extensive operations in the UK and also in Italy, but it doesn't seem to be handicapped by this set up.

"It's not ideal to be on so many locations but I think we don't have too many inefficiencies because we don't know any other way to do it," says Steiner. "When we set the team up, it was the best option at the time and while it doesn't look very clever from the outside, the team has grown around this system and it seems to be working.

"People do need to interact with each other, but you can often have a situation where two people sitting beside each other don't communicate for whatever reason. These are the things you need to see when building up a team. For sure we do have challenges and when we fix a weak point, another one pops up, but that's how you grow.

"It's a never-ending process and the day ▶

you stop doing this, you go backwards, especially in Formula 1. We're doing a respectable job and it could always be better, but we have a very mature staff who are prepared to work efficiently together."

Much of the talk at the moment is about the proposed cost cap. This was something that Max Mosley unsuccessfully tried to impose a few years ago when he was head of the FIA and it has come up again. The intention is to restrict budgets to $150 million a year across the board. It wouldn't include driver and team executive salaries, nor marketing ones either, but development budgets for the car.

It would form part of a package aimed at decreasing expenditure and closing up the grid between the front and back to make the racing more exciting. Some teams such as Red Bull Racing are pretty vigorously opposed to it, Red Bull Racing team principal Christian Horner warning that it would lead to thousands of jobs being lost across the UK motorsport industry. As far as Steiner is concerned, though, it is an initiative he welcomes.

CAREFUL SPENDING

"I welcome it because we're not spending that amount of money anyway and I hope it comes as planned. However, just going racing doesn't do it for the fan base any more. There are a number of single-seater one-make series, but one of the principal things about Formula 1 is innovation, which is something that the fans love. I think a cost cap stimulates this more because it's all about investing your money wisely."

Until this is resolved and key decisions about technical regulations, governance and revenue sharing from 2021 are made, he is not prepared to sanction any major investments in the team, especially when it comes to employing more people. "We're not going to invest another $20m or $30m or recruit another 100 people as that would be unwise at this moment," he insists. "We will therefore stay where we are."

What he would like to see is a better offering for the fans. "We need to get better at showing the technology to the fans, spectators and the general public. The cars themselves are monsters of technology and they're beautiful," he says. "There's nothing in the world like them, but we hide it and show just 30 per cent of what we are doing and the fans still love it. However, if we could show them everything it would be very good for Formula 1."

> *"A cost cap stimulates innovation because it's all about investing your money wisely"*

For an increasing number of people, watching a race on TV just doesn't do it any longer. There is a growing demand to be fed more data to make the racing more lively, but such a thing would mean that teams would have to share some of their data for public consumption, which isn't very popular.

However, Steiner is prepared to give up more data for public consumption but only if every other team does the same thing. "It needs a level playing field, which I think would be very difficult to achieve," he admits. "Perhaps what we can release is more about how these cars are made inside. At the moment everything is so secret. If you need to change something or see how it's done, you go to YouTube for advice and we need to do that in Formula 1." RT

Haas F1


Tee/LAT

ABOVE & BELOW It's coming home: The World Cup didn't, nor did the expected points haul that Romain Grosjean's British GP weekend had promised

BACK TO THE DRAWING BOARD

Citroën set itself ambitious targets for its C3 R5. **Hal Ridge** looks beneath the skin of the French marque's latest rally challenger

HUNDREDS of R5 specification rally cars have hit the world's stages since the category was formed in 2013, with a number of the programmes, like those from M-Sport, Hyundai and Citroën, running as a customer supply operation under 'works' World Rally team efforts in the sport's top flight.

M-Sport's Ford Fiesta and Hyundai's i20 have been among the best in the category, where cars are price capped at €180,000. But Citroën's DS3, one of the first R5 models to be released, didn't mirror the successes of its bigger WRC brother, which claimed 26 victories and two titles between 2011 and 2016.

Keen to put that right, the French marque has developed an all-new R5 category machine intended to compete with the best in the business, both on the stages and in the sales tallies. Naturally, those elements generally go hand in hand, which is why Citroën Racing's effort in developing its latest customer rally machine, the C3 R5, has been significant.

"The idea was to start from scratch. Obviously, the aim was for it to be reliable and fast, especially given that the standard in the R5 class, which was already high a year and a half ago when we began development work, just keeps on going up as new competitors join the category," says Francois Wales, Development Director for Citroën Racing's Customer Racing Vehicles.

As with its DS3 predecessor, the new-for-2018 C3 followed in the footsteps of its sibling in the WRC. But unlike many of the other R5 machines available on the market, the C3 R5 shares suspension DNA with the WRC version of the Versailles-developed hatchback, having different geometry options for gravel and Tarmac surfaces to optimise the car's performance on each terrain.

SHARED SUSPENSION DNA

"In terms of the chassis and suspension systems, the number of potential interfaces is very limited [in R5 regulations]," says Wales. "We set ourselves the ambitious target of developing both the Tarmac and gravel versions, opting for different designs. On Tarmac, the front strut is angled towards the rear, whilst it leans forwards on gravel. We are the only manufacturer to have proceeded like this, and whilst it is fairly straightforward to do this in the WRC, it's a lot less easy in the R5 class."

That task is made less easy due to the ▶

All photos: Citroën

ABOVE The C3 R5 announced itself as a contender on gravel when Lefebvre held the lead on eight of the 20 stages in Portugal

limited number of interfaces allowed between the hub carrier, strut, suspension arm and toe rod. "We chose to incline the strut towards the rear on Tarmac, for the purposes of kinematics, and towards the front on gravel, mainly to do with travel," says project manager Olivier Maroselli. "We didn't have to compromise on the designs chosen at all and were also determined to ensure all of these parts were at the minimum weight. This involved using Reiger shock absorbers. Not only are they very fine-looking products, which provide plenty of room for manoeuvre when it comes to defining the appropriate set-up, but their aluminium struts also helped us to keep the weight down."

> *"On Tarmac, the front strut is angled towards the rear, whilst it leans forwards on gravel"*

Those MacPherson strut Reiger dampers are three-way adjustable, for low and high speed bump and rebound. They are mounted to

ABOVE & BELOW A root and branch review of the R5 design was undertaken, producing a radically different car to its predecessor

ABOVE Citroën deliberately limited its assembly capabilities for the first year, before ramping up to being able to provide close to 70 cars next season

each corner along with a square-braking package from Alcon, with four-pot callipers used all round together with 355 mm vented discs for Tarmac, 300 mm for gravel.

Preliminary work on the C3 R5 began at the close of 2016, but the design didn't begin in earnest until January 2017, with the first road tests taking place in September the same year. It's understood that in the meantime, a DS3 R5 was adapted as a test mule, which may have included endurance running of the in-house developed 1.6-litre turbocharged DI engine, fitted with the regulation 32 mm restrictor.

"The restrictor and pop-off valve combination makes these machines particularly complicated; everyone has more or less the required power and torque on the engine test bench, but the differences then come at the rallies, when factors like altitude and temperature vary, as well as in all the transition phases," says Wales. "This is why we invested in a much more powerful ECU, involving considerably more fine-tuning, but which has delivered very good results."

ENGINE FOCUS

Engine development focus was especially concentrated in three areas, with a major factor being the electronics, using a more advanced Magneti Marelli ECU than had been used previously by the French marque. That gave more functionality around the anti-lag system, facilitating better throttle response under acceleration, but it was also an attempt to maintain as near to the maximum allowed boost pressure, without opening the pop-off valve which would sap power. The reliability and heat management of the engine internals was also a key area of interest for the French boffins, "which proved to be very sophisticated," says Maroselli.

"We also paid very special attention to the cylinder head, to increase permeability as much as possible on the intake and exhaust ducts. All of this means that the engine is now undoubtedly one of the car's major ▶

ABOVE & BELOW Citroën entered its first development test with a year of research, calculation and design work already under its belt

> *"A car that can be driven by professional drivers and amateurs alike"*

strengths. All the drivers were in agreement that the car has bags of torque, but we also know that it is also well placed in terms of power, with a higher rating than its rivals." The four-cylinder 16-valve engine (with a bore of 77 mm and a stroke of 85.8 mm) produces 282 horsepower at 5,000 rpm, and a maximum torque of 420 Nm at 4,000 rpm, with a specific output of 178 horsepower/litre.

Like all of the marques producing R5 cars, Citroën used a pool of available drivers for initial feedback. Alongside appointed development driver Stéphane Lefebvre, the roster included the works line-up at the time of Kris Meeke and Craig Breen, plus French Championship contender Yoann Bonato and a number of others. That range of opinions is crucial to forming a car that can be driven by professional drivers and amateurs alike at their own level, unlike the works world rally and world touring car machines that Citroën has been most famous for creating in the current era, designed to be handled by thoroughbred racers.

The same goes for the durability of components and maintenance of the C3 R5, which once sold to its customers will be run by private efforts, potentially without the specialist tooling or expertise that the manufacturer squad has at its disposal in-house. "This was clearly one of the areas we worked on, without however compromising on performance. The gearbox and the front end, for example, can be removed very easily. We have also made a lot of progress on the bodywork, by investing in multi-material technology so that there are rubberised components in all the lower parts of the bumpers and in some areas on the wings. They are therefore more resistant to wear and distortion," explains Maroselli.

"We covered a lot of miles in tests on really rough gravel surfaces such as at Fontjoncouse [a renowned rough rally test venue, designed to break cars] and noted a vast improvement in the ageing of the body and all of the subframe. Damage to consumable parts, like the protective skidplate [sumpguard] is at a really very good level and that is undoubtedly a plus for running costs."

PADDLE-SHIFT U-TURN

To further aid the ease of running the machines, cars bought from Citroën come supplied with spare wheels, lamp pod, a Stilo intercom, even a torch for the co-driver. Thirty sales were targeted for year one, projected to ramp up to as many as 70 in 2019.

The gearbox, like in the WRC C3, is courtesy of Sadev, although the five-speed R5 version has been designed specifically for purpose, with its own architecture. Uncertainty over transmission regulations was however responsible for the delayed homologation of Citroën Racing's latest creation. The car was initially designed around an anticipated rule change for the category, and indeed the C3 R5 concept was launched with a hydraulic paddle-shift gearbox, like the top-level WRC cars.

But, in a World Motor Sport Council meeting in Paris on September 21, plans for automated gearbox controls in the category were revoked, cars remaining with a manual sequential system. 'The introduction of automated gearbox controls for R5 cars has been cancelled, due to the excessive cost of retrofitting on existing homologations,' said the WMSC statement following the meeting. The knock-on redesign and testing delayed the C3 R5's planned homologation in time for this year's Monte Carlo Rally to the Tour de Corse.

Regardless, Maroselli speaks positively

ABOVE François Wales, Customer Racing Director, says the manufacturer started its R5 project again from scratch

about the car's final transmission configuration. "The packaging is different in terms of both the width and the height of the gearbox outlets, because they have a direct influence on the transmission angles and therefore the maximum travel allowed," he says. Mechanical differentials are used front and rear, while a cerametallic twin-plate clutch is located between the engine and gearbox.

Development options are limited once R5 cars have been homologated, with only five joker 'tokens' allowed in the first two years, and five more thereafter, far less than with current new WRC cars. It's therefore critical that the cars are thoroughly designed and tested. The C3 R5 underwent over 6,000 km of testing before it hit the stages in anger, having made its first public appearance as a course car on Rally du Var in November 2017.

Lefebvre was tasked with no less than winning world rallying's second tier WRC2 title in the car's first campaign this year to prove its performance and reliability against some seriously tough opposition, in the shape of M-Sport's Fiesta, Hyundai's i20 and Skoda's Fabia.

On its Tour de Corse debut, Bonato finished second overall. Lefebvre set a brace of fastest stage times after opening test brake problems had dropped him down the order, but he crashed out with those brake issues on stage five, the French team describing the issue as "inevitable teething problems".

The works driver then led the WRC2 category on Rally Portugal for eight of the gravel stages and wound up third, before again setting a quartet of fastest times on its next WRC appearance on Rally Sardinia. The car has also won French Championship events in its fledging months in competition.

The potential is clearly there for Citroën to climb the results sheets and the sales charts with its latest rally hatchback iteration. But the real test for all R5 cars, new and old, will be when Volkswagen's Polo hits the stages officially in the coming months. RT

ABOVE The aluminium struts help keep the weight down

RALLYING TO THE CAUSE

Hal Ridge investigates Subaru's bid to emulate its rally success in the newly formed Americas Rallycross Championship

Tom Banks

ABOVE Subaru, working with motorsport partner Vermont Sports Car, has joined the Americas Rallycross Championship fray with three cars – and some serious intent

Go to any rally in the UK or Europe and the chances of seeing a fan wearing a Subaru jacket are high. Through the 1990s and into the new millennium the Japanese marque won three Drivers' and three Constructors' World Rally titles with some of the sport's top names.

To this day, the blue and yellow of Subaru's livery remains synonymous with rallying and success. But, Subaru has never enjoyed the same kind of achievements in rallycross. This season, competing in the new Americas Rallycross Championship, Subaru Rally Team USA is hoping that the latest version of its WRX STI propels the marque back to the top step of the podium.

Run by Vermont Sports Car, the SRTUSA team has been operating in American rallycross events since their inception in 2010. Yet despite competing in the now defunct Global Rallycross Championship and at X-Games, it has seldom achieved the glory of the squad's sister programme in the American Rally Association Championship.

The 2018 WRX STI is 40% new underneath, according to Vermont Sports Car's technical director Jonathan Carey. The car underwent a number of upgrades through the 2017 campaign which, when added to this season's developments, makes for a rather different machine to that which hit the dual-surface circuits 12 months earlier.

AGGRESSIVE DEVELOPMENT

"We progressed quite aggressively through last season. There have been improvements to the cooling system: we've revised the design of the front-end cooling pack both for cooling efficiency and for race worthiness," says Carey, referring to the need to avoid damage from flying stones or sometimes inevitable contact. "We also reviewed the installation of the (rear-mounted) radiator pack. Through 2017 that area of the car had been revised three times; every time was a kind of temporary fix so this time we just reset it all, made some proper ducting for it and tried to save some weight. That was a very good improvement from a centre of gravity point of view and the airflow was a good deal cleaner than what we had last year."

Aside from the cooling front and rear for the PWR radiator and intercooler, the major architectural differences on the 2018 machine are to the rear suspension. "At an early event last year we had some unexpected severe loads breaking our rear suspension. We did a fix on that for the rest of the season, but then did a complete redesign in the winter. It's more robust and significantly lighter now," he says.

The suspension configuration options of a rallycross Supercar are well documented in the pages of Race Tech, but the majority of top-level teams use either double-wishbone or ▶

Subaru Rally Team USA

ABOVE The team has been granted dispensation to run a custom version of the Subaru boxer engine

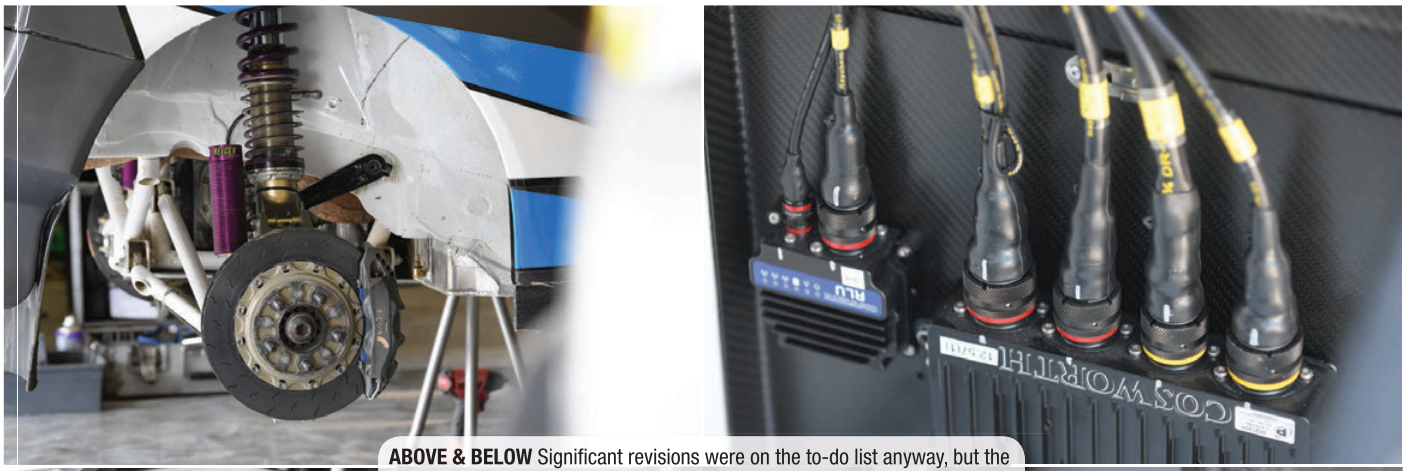
MacPherson, aside from OlsbergsMSE's Honda Civic and Ford Fiesta, that have an in-board setup. For 2018, Subaru's rear suspension has been reconfigured to match the front, in that it is now also MacPherson in design, with a lower A-arm, and uses Reiger dampers.

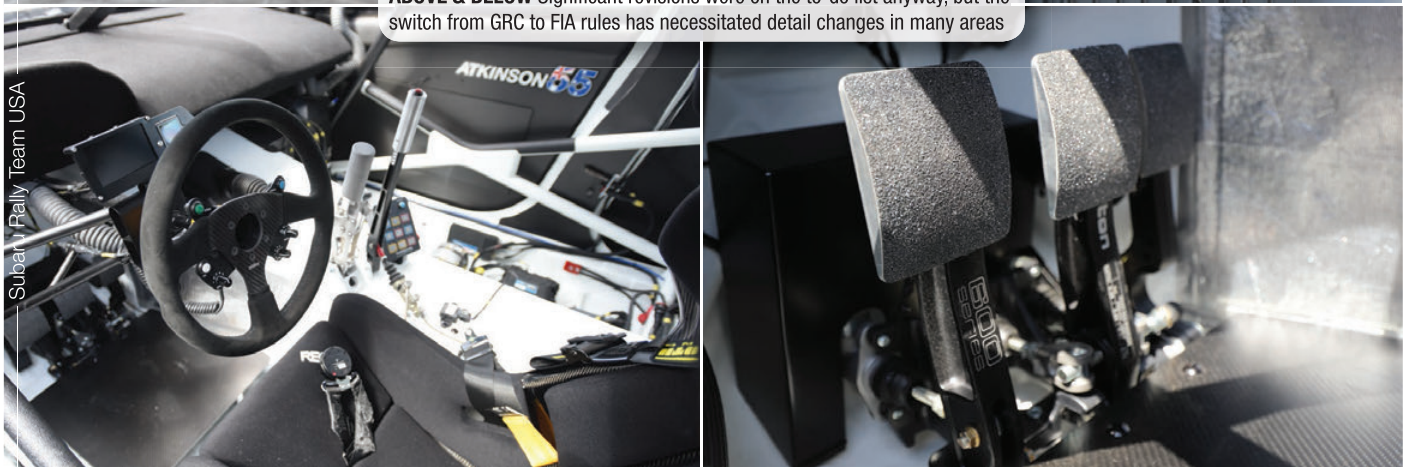
"MacPherson worked better when we did comparisons with the geometry we were looking for – it seemed to make sense to go for a simpler layout for what we were trying to achieve," explains Carey. "We're working very closely with Reiger in terms of damping characteristics too. It's our own curve that we've developed together. Reiger can supply a rallycross damper and curve that can be just used, but we've worked with them to develop a specific valving characteristic front and rear for our car."

While the WRX STI is four-wheel drive as standard and historically the Impreza has been one of the go-to production-based rally cars, Vermont Sports Car's current machine bears little resemblance to its road-going counterparts. Even the squad's uber-successful rally car, in which Travis Pastrana won the American rally title last season – the 11th crown in 12 years for Subaru – has few similarities to the latest rallycross machine.

"We carry over elements of how the suspension works. There's things the drivers like about the rally car that we've engineered into the rallycross chassis, more this year than before. But in terms of components, there really isn't any crossover now," says Carey. "That is a significant difference. If you looked at the last four years, they were more alike and slowly it's got less and less. Rallycross requires different loading inputs. It maybe doesn't have the roughness of a gravel stage but maybe has impacts from door to door racing."

One thing the WRX STIs share across the two disciplines is the Subaru's heart, the longitudinally-mounted, horizontally-opposed, four-cylinder boxer engine. But, the engine configuration is really where the similarities end, although both use a Garrett Motorsport turbo. The two-litre machine in the rally car produces around 330 horsepower and 420 lb-ft torque (using a regulation 34 mm restrictor and a 32 psi ▶





Subaru Rally Team USA

ABOVE & BELOW Significant revisions were on the to-do list anyway, but the switch from GRC to FIA rules has necessitated detail changes in many areas

ABOVE VSC has given the works-backed trio of WRX STIs a major facelift

boost limit), while the rallycross car has a gaping 45 mm restrictor by comparison, delivering 600 bhp and 680 lb-ft torque.

Nevertheless, getting that power out of the boxer unit reliably is a challenge. "We found in the WRC many years ago that it's just a completely different process to make a boxer work. They just have completely different principles for how the engine works compared to an inline four – how its natural response is from one end of the RPM range to the other is very different."

The FIA introduced a 'custom' engine regulation to rallycross for 2015, allowing for a car to use a custom block, rather than the previously mandated requirement to have a block from the same manufacturer as the chassis. Now anything goes as long as it fits within strict component weights and sizes.

But, there is no provision for a boxer engine in those rules. The GRC regulations, which were significantly more open, did allow VSC to introduce a custom version of its Subaru boxer. As such, the new ARX series which has been formed by World Rallycross promoter IMG, has given dispensation for the existing engine to be used, with all ARX Supercars carrying a 25 kg weight increase to compensate for some of the discrepancies (1,325 kg instead of 1,300 kg).

"It still has some items carried over from our historical family engine, but it's in principle a custom engine. It's very much a boxer, we haven't broken away from the core of a Subaru and that is a deliberate strategy because that's what Subaru wants: they don't want us to put an inline four in," stresses Carey. "The regulations allow a lot of freedom on cylinder heads anyway, so you can do pretty much what you like on the heads, but the block was a big one (to make a 'custom' unit) to withstand rallycross loads. It's very difficult."

Although secretive about details of its engine, the VSC machine does use a stainless-steel exhaust system with Dog Fabrications manifolds. The engine is controlled by a Cosworth Pectel SQ6M ECU, coupled with a GEMS data logger. The WRX STI uses a PRS lightweight motorsport wiring loom, together with a Cosworth power control module and switch units.

Connected to the engine via a triple plate carbon clutch, the WRX STI uses a Sadev six-speed sequential gearbox and mechanical centre, front and rear differentials, with bespoke RCV driveshafts and prop shaft.

At the end of each driveshaft, custom made uprights connect the tubular subframes and suspension to the 17" Method Race rallycross

Tom Banks

ABOVE The WRX STI in action at the opening round of the series

ABOVE & BELOW The latest development is a huge roof scoop to duct air to the rear-mounted radiators

wheels, housing Alcon brakes, but the WRX STI doesn't use Alcon's square braking package found on other Supercars in World RX, because, Carey says, that setup isn't as efficient when using a centre diff. Four-pot Alcon Monobloc callipers are used all round, with 355 mm vented front discs and 321 mm rears, increased from 315 mm last season. Brake pads are courtesy of Endless.

When the manufacturers racing in the GRC left, including Honda, Volkswagen and Subaru, the series folded soon after in early 2018. ARX was subsequently formed and the promoters brought the new series under FIA regulations. That made for some headaches at VSC's Colchester base.

"We had to make quite a few changes. How the GRC rules were written and how you could interpret them was really quite open, so the changeover to an FIA-based series did require quite a lot of addressing of some areas where we'd exploited the regulations," admits Carey. "We had to react and redo quite a lot of the car in a short time, but only small items, not any major redesigns. It was a big one to swallow when it was announced to us that the rules wouldn't be the same. The GRC rules ultimately allowed for you to do whatever you wanted in terms of lightening and reinforcing and placement of components. For example, with the fuel cell placement, in GRC it was allowed to be lower and overall bigger because the races were longer, so we've revised the fuel cell for this year (now 30 litres instead of 45), but it's housed in a much bigger hole because the GRC tank was massive. Also with things like radiator placements, because the wording of the regulation was such that you would move things 100 mm further forward than the FIA would have permitted."

> *"We'd exploited the freedom in the GRC regulations. It was a big one to swallow when it was announced that the rules wouldn't be the same"*

Although the above changes, and the many others that had to be undertaken, would individually have negligible performance advantages, arguably the biggest rule change was regarding the use of water spray on any cooling items, which is not allowed in FIA rules. "You can imagine if you designed cooling packs around having a water spray system, when you remove it, things can get hotter. That kind of item needed addressing," notes Carey.

The ARX series has also adopted World RX's single-supplier Cooper Tires, of crossply construction rather than the rally-oriented radial rubber used in GRC. Having undertaken its pre-season running expecting to use a radial tyre on its 2018 WRX STI, Subaru had an intense period before the ARX season-opener at Silverstone's new rallycross circuit in May to get on top of the differing setup requirements. "From a characteristic point of view of what the car's doing, it's very different: the tyre's significantly softer," he says. "We've changed quite a lot of the geometry to suit the tyres, more than we expected but they're a nice tyre and they do suit the style of World RX racing, which is a bit more sideways and cleaner."

BIGGEST CHANGE

But the biggest change to the 2018 WRX STI, aesthetically at least, is to the bodywork. In part to facelift the car and bring it up to the latest version of the consumer vehicle, the works-backed team also had to adapt the bodywork (all composite aside from the driver's door and the roof) to suit FIA regulations, meaning almost every panel was changed.

"We wanted to do a facelift for Subaru because we'd carried over the principal styling for a few years and the suspension revisions for 2018 meant that we couldn't run the original panels anyhow, so we chose to do as much of an aero study as we could in the time available and we came up with a new aero pack based on the styling on the new 2018 look. Really it ended up being a much more aggressive bodykit introduction than was intended and to finish it off we added a new rear wing. That was a busy couple of months for the composite shop," concludes Carey.

The development race never stops. In the second round of ARX at the Circuit of the Americas in July, the WRX STI turned up with a huge roof scoop, ducting air to the rear-mounted radiators to deal with the near 40-degree heat.

In the opening two rounds of 2018 the WRX STI scored a brace of fourth place finishes, but the Vermont-based team is clearly pushing harder than ever to return to the top step before the year's end. RT

ABOVE The FIA has officially homologated the EvoScann P-Series pressure scanner for on-car use. The company already has high profile customers

THE TINY PRESSURE SCANNER MAKING A BIG IMPACT

Weighing in at less than 15g, the EvoScann P-Series is revolutionising the world of pressure scanning. **Alan Stoddart** reports

THE best tool for a job is usually one that has been specifically designed for it. Unburdened by superfluous complexity, a carefully thought-out component can do exactly what is required of it without any packaging or weight penalties; crucial in a world where millimetres and grams can be the difference between victory and failure.

Such is the case with Evolution Measurement's EvoScann P-Series pressure scanner. The team at Evolution Measurement has been the UK distributor for Scanivalve products for more than 10 years. Scanivalve is a leading company in the design and manufacture of electronic pressure scanning instrumentation for aerodynamic development, which can mean everything from gas turbine development through to wind tunnel engineering, with the latter naturally leading on to the field of motorsport aerodynamics.

However, products developed for the analysis of gas turbines aren't ideal for use in top-level racing cars, explains Evolution Measurement's director, Paul Crowhurst. "The product we've got lends itself very well to that environment, but it starts to become too feature-rich, too expensive and with too high a channel count for on-car applications, as well as not being as robust as is needed for motorsport."

This is what led Evolution Measurement down the path of developing its own scanner. It started by looking at how it could address the areas that are particularly crucial for motorsport aerodynamicists, namely, how they can validate the data that is being generated in the wind tunnel and in their CFD models. For this purpose it doesn't make sense to have a larger, more complex scanner with a greater number of channels because the scanner needs to be able to be installed in very specific and often quite tight places, without taking up much space. Obviously, as with everything in the motorsport world, being able to minimise the weight of the scanner was also important.

The result of Evolution's hard work was an eight-channel scanner with a footprint of around 33 x 36 mm, a height of around

8 mm and a weight of just 12 grams. The EvoScann is also completely digital, which means that engineers can take data off the scanner more efficiently as it doesn't need any external conditioning. The scanner gives a fully temperature-corrected and compensated measurement directly into a car's CAN interface, to a level of accuracy within 0.1%. It also has a very wide operating temperature range, from -40 to 125°C, which allows it to be placed in hostile locations within a race car, including brake ducts, floor, coolers and air intakes.

"Obviously we have got to pay a lot of attention to where this product is going to be used, and what we need to do to make it work well in that environment," says Crowhurst. "It's got to be rugged and robust as it's got to be able to deal with those temperature extremes and it is also going to have to be able to withstand a lot ▶

ABOVE & BELOW Evolution Measurement's EvoScann P-Series pressure scanner is shrouded in a carbon fibre shell

of shock and vibration.

"We've had the scanners tested up to 9G at up to 1,000Hz for 24 hours and we believe that to be very conservative... we think the shock levels that the product would withstand would be *much* higher than that."

This resilience has been facilitated by Evolution's meticulously thought-out construction. The EvoScann uses an internal circuit board, onto which everything is mounted, before being shrouded in a carbon fibre shell which gives it its competition-ready strength.

A SPECIALIST'S TOOL

As important to the EvoScann as its physical properties, however, is the way in which it has been designed to be able to be customised in order to address the very specific needs of individual race teams, enabling Evolution to offer its clients a very consultative service, rather than one which is simply transactional. Traditionally, race car builders would buy a product that was originally designed for a wind tunnel application, for example. This scanner would not only be unsuitable for a hostile environment, it would be fairly bulky, which would prevent it being used in certain areas such as a Formula 1 car's front wing.

> *"We are able to engineer the instrumentation to meet the specific demands of a client's application"*

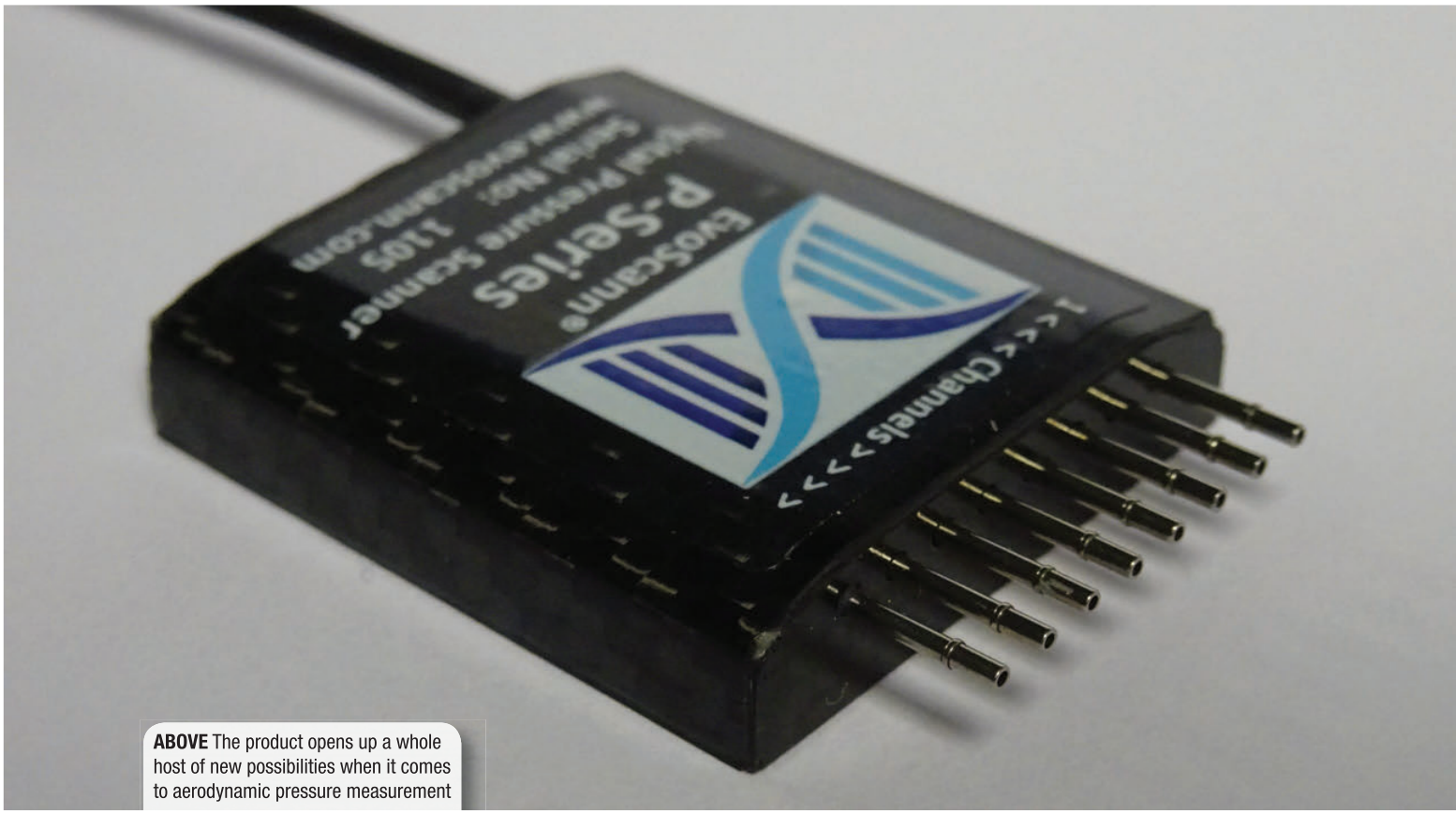
On top of that, using a wind tunnel type scanner would mean engineers dealing with about 75 percent more channels than they need, which adds to the complexity of interpreting data from the scanner, while the cost of the scanner itself would be about eight times higher than Evolution's purpose-built alternative.

"You had to take a product and make it fit the application," emphasises Crowhurst. "Now a customer could come to us and say, 'Here's my problem, I need, for example, 13 channels of data and I need to get this close because this is where I am going to place the product. I need a cable length of this amount and I need this type of specific connector on the end of it. Can you produce that?'

"The short answer is yes we can... We are able to engineer the instrumentation to meet the specific demands of a client's application."

Ironically, this focus on making a sensor that is perfect for on-board use has resulted in a scanner that is also an improvement on those used on rake arrays. Currently the scanners used on rake arrays are native to the car body, which then entails long tubes running from each sensing point back to the scanner. A further difficulty is that these tubes all have to be of the same length to deal with frequency response issues, which means that each of them needs to be as long as the longest tube. The EvoScann scanner solves this problem by allowing the scanners themselves to be fitted to the rake.

By making a product carefully tailored to its ultimate application, Evolution Measurement has surpassed the adapted scanners that would otherwise be used. Engineers in every series, from Formula 1 to WRC, are able to get accurate measurements from areas which would otherwise be impossible to assess. This in turn gives aerodynamicists better data and therefore the ability to confidently design more complex and effective aero packages, safe in the knowledge that they are able to easily validate these designs at the track, and that could make the difference between coming away from a race weekend a winner or an also-ran.



ABOVE The product opens up a whole host of new possibilities when it comes to aerodynamic pressure measurement

ABOVE & RIGHT A huge amount of research goes into producing injectors suitable for top flight race teams

INJECTED PERFORMANCE

Race series across the world are placing an ever greater emphasis on efficiency. One of the areas in which engineers see lots of potential in this regard is that of fuel injection. This, as **Alan Stoddart** finds out, is one of Bosch Motorsport's strengths.

AT present, most of the headlines pertaining to the motorsport and automotive industry focus on electric mobility, punitive legislation surrounding cars that rely on internal combustion engines, and technology that facilitates an electric future such as battery developments and charging logistics.

Despite this, Bosch Motorsport continues to develop components for internal combustion engines. Ignition and injection have been at the heart of what the company has done for decades, with ignition at the nucleus of the group alongside fuel injection, which replaced carburettors in the post war years.

With the petrol engine still at home on the world's race tracks across all different racing classes, Bosch is continuing to work on direct injection systems. The company is a huge proponent of the technology which is slowly but surely replacing intake manifold injection in the automotive world, which is in part down to improvements in direct injection systems that now allow pressures of up to 500 bar, facilitating finer fuel atomisation and therefore the output is improved.

Contrary to many people's perception of Bosch Motorsport however, the company does not just supply the leading original equipment manufacturers in millions and millions of units, for special applications and especially for motorsport applications, Bosch Motorsport has the technical capabilities to produce prototypes in the smallest quantities. Firstly, there is a process of extensive consultation to ensure the client is able to get exactly what he wants, and will end up with a product that will offer the greatest gains to the engine. Here the customer can specify a great range of specifics, from flow rate, to the number of holes in the injector and the spray image, an area in which Formula 1 development teams still see potential for increasing the competitiveness and efficiency of their engine.

Pushing teams to focus on fuel injection as an area in which they can gain an advantage over their rivals are the increasingly efficiency-driven regulations of Formula 1, as well as many other series, which have made the maximum utilisation of fuel more critical than ever. Maximum pressure and optimum atomisation are therefore of huge importance to teams' engineers, with the increase in efficiency being tantamount to the increase in performance and more stable combustion.

Bosch Motorsport makes sure that every customer enjoys the advantages that its decades of experience in direct injection technology and adapting spray images to individual combustion chamber shapes brings. With the importance of efficiency ever more significant, the bespoke injection work Bosch does is more crucial than ever. RT

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BELOW Rare jewel: Johnnie Rutherford at the wheel of the Chaparral 2K, an F1-inspired ground effect IndyCar, at Goodwood

Sergio Rinland reflects on Goodwood's Festival of Speed, where he witnessed glorious machinery of the past, present and future

DINOSAURS & DESTINY

I made the pilgrimage, as I do every year, to Goodwood for the Festival of Speed – this time it was the 25th anniversary. Twenty-five years ago feels like yesterday. Although the circuit was still active for testing back then, there were only a few cars and not many people attended. It is now an international event, possibly 10 times bigger than its first year.

This year we saw some very interesting machinery, starting with the 1938 Mercedes Benz record car, a six-wheeled monster with a 44.5-litre engine and 3,000 HP. It featured side wings (seen 10 years earlier in Opel's record cars RAK 1 and 2) and in its heyday could reach over 600 km/h.

On the other end of the spectrum we had the Robocar, an autonomous electric racer which will eventually be able to compete with similar machines on a race track and reach 320 km/h. We also got the chance to examine the VW I.D. R Pikes Peak electric car, which broke all the records at the famous hillclimb only a few weeks ago.

We saw enough supercars to please every appetite. Their presence this year was all the more notable because the ACO and FIA are targeting these same cars to be the base of the next LMP1, which is fascinating. Horacio Pagani told me "we don't sell cars, we sell emotions" and how right he was: these pin-up cars can fulfil the wildest dreams of their lucky owners.

We were treated to a variety of racing cars from a bygone era, cars I never tire of seeing year after year: Lotus 25, Porsche 917 and 908, Ford GT40, Chaparrals, Ferrari 312T, Alfa Romeo 33, Honda RA301, Mercedes W196… Yes, the list is long! This year we also had Johnny Rutherford with his Indy 500 winner Chaparral 2K – a jewel.

> *"We don't sell cars, we sell emotions"*

The Goodwood FOS constantly reminds me of why I fell in love with cars and racing – not that I need a reminder!

THE FUTURE OF MOTORSPORT

Is this kind of event the future of motorsport? Some people believe it will be. There were as many spectators there, remember, as there were at the British GP. The appeal isn't hard to pin down: they offer the general public the unique experience of getting close to cars and interacting with superstars, an incredible experience for many.

At Goodwood we had the opportunity to compare noisy F1 cars, from the Cosworth and V10 era, with the silent Electric Vehicles going up the hill. The acceleration and mighty performance of the VW I.D. R made us forget for 43.86 seconds that it made no noise. It was the fastest ever at the FOS, and the NIO EP9 was not far behind – another one-lap electric wonder.

The day when these cars can do more than just a few minutes at full blast is only round the corner – battery technology is advancing that rapidly. You have to wonder whether the day we will be able to extract a full GP distance, the rest will become part of the history we enjoy so much at the FOS.

EVs are not everybody's 'cup of tea', so is noisy motorsport really doomed? I don't think so. As much as I am a fan of EVs, I still enjoy, as do many others, the sound of a V12 at flat-chat. It is a miracle of engineering and technology that so many parts work in harmony. As the main character in the Spanish classic *Don Juan Tenorio* said: "Those you claim to be dead are in perfectly good health."

The Festival of Speed, and events alike it, are here to stay. They will delight motorsport and car enthusiasts for the foreseeable future, for their appeal crosses the gulf between different generations: from young children who want to see what is up and coming, to pensioners who want to see what made them tick in their youth.

Thank you Lord March. RT

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