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PRODY LOWE: MY NEW MISSIO

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Volume 28 Issue 7 Published May 2021 The next issue will be published in early June 2021 ISSN 1356-2975

SUBSCRIPTIONS

Subscriptions from Kimberley Media Group Ltd 841 High Road, Finchley, London N12 8PT Tel +44 (0)20 8446 2100 Fax +44 (0)20 8446 2191

Overseas copies are sent via air mail 12 issue subscription UK: £71.40 Europe: £118, USA/Rest of World: £149 All major credit cards accepted. Cheques and money orders only in Pounds Sterling payable to Kimberley Media Group Ltd.

BACK ISSUES AVAILABLE IN PRINT:

8,9,10,11,13,14,15,16,17,18,19,20,21,22,23,24,25,26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139 140 141 142 143 144 145 146 148 149 150 151 152 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 240, 241, 242, 243, 244, 245, 246

Price including post & packing: UK: £5.50, Europe: £6.50, Rest of World: £7.55 You can pay by cheque or credit card but please note the minimum on Switch & Delta is £14

Race Tech (ISSN: 1356-2975) is published monthly by Kimberley Media Group Ltd.

Cover photo: Indy Autonomous Challenge

Design & Production: Paul Bullock, Maluma

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EDITOR

William Kimberley

CONSULTANT EDITOR Mark Skewis

HEAD OF DIGITAL CONTENT Sara Kimberley

PHOTOGRAPHY LAT

ART EDITOR Paul Bullock

ACCOUNTS Fiona Keeble

COMMERCIAL DIRECTOR Maryam Lamond

MANAGING DIRECTOR Adrian Goodsell

PUBLISHING DIRECTOR Soheila Kimberley







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

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OTORSPORT is following the automotive industry's headlong rush into electrification, but there's something missing: noise. Elsewhere in this issue, you can read how Paddy Lowe, a leading figure behind the success of Williams, McLaren and Mercedes in Formula 1, believes there is an alternative to all-electric motorsport. One of the points he makes is that the sound of a race or rally car at maximum attack is something at the very heart of the sport's appeal.

I recall seeing the revolutionary Formula E racecars on one of their very first appearances, at Donington Park. They were impressive technically, yes, but I will always remember one observer's comment: "They are like buzzing milk floats!"

No matter how many major manufacturers joined the Formula E goldrush – many, I'm sure, because politically it was too embarrassing *not* to be seen there – that moment has lived with me. Truth told, it's rather taken the edge off the racing for me!

Not only does the lack of noise arguably detract from the raw experience and excitement of motorsport, but it can also be dangerous. Especially in rallying, which is just starting to come to terms with how to introduce electric cars.

In Germany, the regulations sensibly require that spectators and marshals must be able to hear when a car is approaching. As a result, the Opel Corsa-e Rally – which makes its competitive debut later this month – will arouse interest not just because it is the world's first one-make cup for electric rally cars, but for its unique artificial sound system.

The problem the Opel engineers faced was that, as in other areas of the revolutionary electric rally concept, no-one had any experience of sound systems. There was no established 'play book', as it were, to consult for guidance.

For instance, in order for an electric rally car to be heard well by the spectators, the loudspeakers must be mounted externally, where they are fully exposed to vibrations, dust and moisture. But commercially available loudspeakers are usually installed inside vehicles or buildings, rather than mounted externally, so they are rarely waterproof. A slight problem the first time that the car tears through a water splash...

Little wonder, perhaps, that Opel's engineers resorted to some marine accessories in their quest for solutions.

The Corsa-e Rally's volume can be adjusted in two power levels. When driving on public roads between competitive stages, a quiet mode is used. The volume is turned up fully only on special stages. The regulations require the teams to adjust the volume accordingly. I wonder how long it will be before it becomes statutory on road vehicles?

On a final note, I am very sad to report the death of Darrick Dong, the longtime director of motorsports at PFC Brakes. His knowledge, experience and friendliness over 25 years made him one of the industry's most insightful, accessible and trusted authorities on motorsports and braking technology. He will be sorely missed.



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MOTORSPORTS PROFESSIONAL

FIA CREATES GT3-BASED ELECTRIC GT FORMULA

Battery development and integration the main challenges for ground-breaking FIA category. **By Mark Skewis**

AST CHARGING is one of several headline technical innovations targeted by the FIA's creation of all-new technical regulations for electric-powered GT cars.

What the sport's governing body refers to as a "ground-breaking" new concept will, it says, set new standards for electric vehicles in motorsport in terms of performance and range.

The category aims to hit the sweet spot in the current market for GT3 machinery. The vision is that GT3 will remain the focus of the customer racing market worldwide for the time being, while this new world-level category offers manufacturers a platform to develop technology relevant to their highperformance road cars.

The new breed of cars will operate in a similar performance window to the current generation of GT3 cars, but will exceed their combustion enginepowered counterparts in areas such as acceleration and qualifying pace.

Jean Todt, FIA President, said: "The FIA's vision is to make motorsport a laboratory for sustainable mobility. The announcement of this new electricpowered GT car category is a key milestone serving this goal as it will pave the way for new battery and fast-charging technologies. A perfect illustration of our race-to-road approach."

The regulations have been conceived to tread the fine line between inspiring cutting edge technology and preventing cost escalation. It will be open to both specialists in electric vehicle construction without previous combustion engine motorsport experience, as well as manufacturers already committed to the GT3 class. The latter will be able to utilise the **RIGHT** Fast charging pit stops will be a feature of the formula

BELOW The choice of powertrain configuration will be free but manufacturers will build bespoke battery layouts around Saftsupplied cells architecture and certain design elements of their existing cars and convert them to electric power. Depending on the base model, the minimum weight of the cars will vary from 1490 to 1530 kg, with maximum power reaching 430 kW. Setting the weight threshold higher than it is for the GT3 class is intended to limit the use of expensive materials.



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BATTERY EXPERT

The new class will be the first in electric-powered motorsport not to rely on standardised batteries. It will accommodate cars of vastly different architectures with different spaces available to install key components.

Through partnership with industryleading firm Saft, a subsidiary of TOTAL, the category will allow the manufacturers to build their own bespoke battery layouts based on Saft-supplied cells.

Saft has developed bespoke lithium-ion pouch cells optimised for the needs of the new class. The cells were designed to allow for 700 kW peak regen and 700 kW fast recharging that will enable them to replenish to 60% of their capacity within a few minutes during a mid-race pit stop. The charging network will be developed to meet the fast charging requirements and depending on the venue, will include elements of permanent and temporary infrastructure. ► **RIGHT** The battery system used on the F-35 fighter was initially tailored to F1 requirements by Saft when KERS was first introduced

FIA turns to battery pioneer

THE FIA has turned to space and defence expert Saft for its battery technology.

A wholly-owned subsidiary of TOTAL, Saft has increasingly become a go-to company for pioneering projects as motorsport embraces electrification. In addition to its involvement in F1, where it has enjoyed a longterm partnership with Ferrari, the company is involved in Peugeot's Hypercar WEC programme and Mission H24's hydrogen Le Mans project.

Its motorsport activity dates back to 2006, sampling high power cells for evaluation. Lithium ion batteries were still in their infancy when Kinetic Energy Recovery Systems were introduced in F1 – and Ferrari came calling.

"At the beginning of our work in Formula 1, the very high temperature, high power requirements were something we hadn't really seen before," Annie Sennet, CEO of Saft America and executive vice president of the company's Space and Defense division, told RACE TECH recently. "But between aerospace, defence and racing, I think we've covered pretty much all the possible combinations now. "It's remarkable where some of these similarities [between

these sectors] occur. There are parallels even between the F1 systems and the extreme environmental conditions encountered in deep sea drilling.

"And it's not just in the applications but in the customers. We work with NASA and we work with racing customers, and we see the same type of people and the same approach to innovation at both." In addition to fast charging, the category will feature several other innovations relevant from a technology transfer standpoint.

Manufacturers will have the freedom of choosing their own powertrain set-ups, comprised of either two or four electric motors, with both two- and four-wheeldrive configurations allowed.

The cars will also feature dynamic vehicle control that will automatically adjust the torque of each wheel independently based on speed, acceleration, traction and steering angle.

Leena Gade, FIA GT Commission President, said: "The market for highperformance electric road supercars is on a constant rise, hence a platform to allow manufacturers to develop and showcase their technology was much needed. Creating these technical regulations has been a key project for the FIA GT Commission over the last 18 months. We've held regular discussions with GT manufacturers through our Technical Working Groups and there's keen interest in this new category."

Spec sheet

Chassis	Road car-based, possible GT3 conversion
Minimum weight	1490 – 1530kg
Powertrain	Up to four electric motors
Transmission	Rear- or four-wheel drive
Battery	Saft, based on a lithium-ion pouch cell
Total battery capacity	87kWh
Maximum power	430kW
Peak regen	700kW
Fast charging	700kW
Estimated acceleration 0-100kph	2.4s
Estimated top speed	300kph

The promoter of the new category will be announced in due course, as will the race format and rollout date – likely to be 2023. Where Formula E races in city centres, with rallycross and Extreme E both employing short format events, the cars built to this set of technical regulations will be the first all-electric competition machines to run at fulllength permanent circuits.

Xavier Mestelan Pinon, FIA Technical

Director, said: "The role of electric propulsion in automotive industry is everincreasing, as we want motorsport to be relevant to our industry, more and more competitions are going in this direction. The main technical challenges are battery development, battery integration in the cars and fast charging technology. This is crucial to the manufacturers who want to develop road-relevant technology rather than relying on standard components."



LEFT The new category responds to the emerging trends within the automotive industry. The drive is very much to make motorsport relevant



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New safety technology for IndyCar Series

+ ADR4

THE NTT IndyCar Series is to adopt two new safety devices that will provide detailed data about the forces on the cars and drivers during a crash.

Provided by EM Motorsport, supplier of electronic safety devices, sensors and custom-built systems to the motorsport industry, new Accident Data Recorders (ADR) and Ear Plug Accelerometers (EPA) will utilise the most cutting-edge technology to deliver highly accurate data quickly.

EM Motorsport's ADR uses internal accelerometers and gyros as well as a Controller Area Network (CAN) interface to capture "at the scene" accident data in order to aid post-event analysis and safety research. Additionally, the ADR is smaller and lighter than the unit it replaces in the series.

The EPA is a small device with a 3-axis accelerometer that fits inside each of the driver's ear plugs to help obtain crucial information about a driver when they are involved in an accident. This tiny device is a powerful tool in being able to assess ABOVE & BELOW IndyCar is to adopt new safety devices that can provide greater accident analysis and safety research

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ADR4

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the wellbeing of a driver whilst they're inside the cockpit. It includes the driver's radio communications as well as the accelerometer that detects the speed and amount of movement a driver's head has in an accident.

IndyCar has moved to use EM Motorsport's ADR4 and EPA devices after successful tests were undertaken during the 2020 racing season. This change sees it taking the next progressive step to the most sophisticated and top of the range electronic safety devices. EM Motorsport has been developing safety devices for the past decade. Many championships around the globe use its equipment, including Formula 1, Formula 2, Extreme E, Le Mans, FIA F3, F3 regional championships, W Series and FIA F4 championships.

Working with the NTT IndyCar Series will enable EM Motorsport to accelerate the development of future safety devices, with more data and an ability to see where safety technology currently needs improvement.

Pennzoil sponsorship coup

PENNZOIL has become the Official Motor Oil and Lubricant Partner of IndyCar and the NTT IndyCar Series. The brand is best known for its sponsorship of the Indianapolis 500-winning cars driven by Johnny Rutherford in 1980 and Rick Mears in 1984 and 1988.

The agreement also includes becoming the sponsor of the Pennzoil Technical Inspection area and the series' Chief Mechanic Award.

Selda Gunsel, vice president, Global Commercial Technology, Shell Lubricants, said: "The extreme stress put on an NTT IndyCar Series engine provides the optimal test bed for modern motor oils like Pennzoil Synthetics. The highly efficient and powerful engine technology used in IndyCar has presented Pennzoil with an opportunity to innovate and prove that

Infineon

our made-from-natural gas motor oils can make a difference on the track."

"Pennzoil has deep roots in IndyCar racing and is part of the sport's proud heritage," said IndyCar President Jay Frye. "Pennzoil is an industry-leading brand with huge name recognition and a fantastic partner that will engage with our fans in many unique ways."

Pennzoil has been used in competition in Chevrolet engines in IndyCar since 2012, powering more wins than any other motor oil-and-engine combination in that time.



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ALL three current WRC manufacturers have embraced the sport's exciting new hybrid era by committing to register and participate in the FIA World Rally Championship from 2022 to 2024.

Hyundai, M-Sport Ford and Toyota have pledged their futures to the production car-based series, which will undergo a landmark change in 2022 when top tier cars will be powered by a mix of an electric motor and the current combustion engine.

The agreement includes an equal contribution from the FIA and the manufacturers to the development costs of the new technology, which will have a strong focus on sustainability, safety and cost management.

The introduction of hybrid technology was announced in 2019 and close collaboration between the manufacturers, WRC Promoter and FIA led to technical regulations receiving a green light at the recent World Motor Sport Council.

Hyundai Motorsport's new challenger

will be based on the i20 N road car, a hot hatch inspired by the current i20 World Rally Car. Neither M-Sport Ford nor Toyota Gazoo Racing has confirmed which model they will use, though Ford's choice is believed to be the Puma.

In recent years the WRC has been rocked by the withdrawal of long-term supporters VW and Citroen, as the direction of the automotive industry changed. The existing trio's commitment – each for three years – is therefore a landmark step.

"It's no exaggeration to say the introduction of sustainable hybrid technology for the WRC's headline category marks one of the biggest milestones in the sport's history," said WRC Promoter managing director Jona Siebel. "It's fitting such a major progression will be welcomed in the championship's 50th anniversary season.

"Along with the FIA and the manufacturers, WRC Promoter is fully committed to the introduction of greener cars. The hybrid powertrain forms an integral part of the automotive industry as the world moves towards a more sustainable future, and it's essential the WRC is aligned with this evolution.

"This is rallying with a purpose – providing a perfect R&D platform for the automotive industry to communicate its new technology.

"WRC remains motorsport's toughest championship for production-based cars and the leadership from these teams sends a positive message about its future to other manufacturers considering joining the series," Siebel added.

To ensure increased stability and better long-term planning opportunities, the FIA is introducing a three-year championship commitment for manufacturers in place of single-year agreements. From 2022, a new system will be introduced to the series, with the three current manufacturers and the FIA each owning one of four licences.

The hybrid announcement follows confirmation of the WRC's plans for more sustainable fuel for competing cars and greener energy sources in the service park. Requests for tenders have been invited for: sustainable fuel across all classes; branding of the plug-in hybrid charging stations in service parks; and sustainable energy generation and supply in the service park to cover the needs of the plug-in charging elements of the World Rally Cars and general service park power requirements.



LEFT The new hybrid ruleset commences next season

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Hyundai turns to Ricardo for WRC hybrid push

HYUNDAI Motorsport GmbH (HMSG) has selected world-leading motorsport transmission specialist Ricardo Performance Products as technical partner in the development of the all-new hybrid four-wheel drive transmission for its next generation World Rally Championship contender.

The WRC's hybrid era commences in 2022. Ricardo will draw upon its extensive experience in traditional, hybrid and fully electric motorsport, together with its longstanding pedigree in WRC transmissions and drivelines. But it is the success of its collaboration with Hyundai in rallying's second tier that underpins the new deal.

The two companies have enjoyed a five-year partnership on the Hyundai i20 R5, which featured a 5-speed sequential gearbox and differential units designed and manufactured by Ricardo. That existing agreement, under which Ricardo supplies drivelines for the i20 N Rally2 car, has also been renewed.

Martin Starkey, Managing Director of Ricardo Performance Products Division, said: "We have made significant investments in our performance manufacturing facilities in terms of both capacity and capabilities. I am confident, therefore, that we will offer HMSG a very strong technical solution to support their bid for the World Rally Championship title in 2022 and beyond, while also building on the proven success of the i20 with the transmission for the next generation Rally2 car."

The new hybrid transmissions will be designed, manufactured and assembled at the Ricardo Performance Products facility in Leamington Spa, UK. ABOVE Ricardo has been appointed as Hyundai Motorsport's 4WD transmission partner after their success in WRC2

RallyX Nordic introduces new biofuel

RALLYX Nordic presented by Cooper Tires will debut a new, sustainablyproduced, high-performing biofuel this season courtesy of a partnership with P1 Racing Fuels.

In a world-first for rallycross, this new P1 biofuel will be mandatory in the Supercar Lites category in 2021 – and optional in all others. In 2022, it will be compulsory across the board as RallyX Nordic aims to make all of its events completely fossil-free.

Jan-Erik Steen, CEO of RallyX Nordic Promoter, RX Promotion, said: "At RallyX Nordic, we've always tried to stay ahead of the curve, and we are hugely proud to confirm the introduction of this sustainablyproduced, high-performance biofuel in conjunction with P1 Racing Fuels.

"Whilst we have only made BIO RACING

100% mandatory in one class for the moment, we are very confident that the performance gains are such that all competitors will soon elect to use it. This is just the first step in a longer-term plan that will see all RallyX Nordic cars running on fossil-free biofuel and – ultimately – an



ABOVE RallyX Nordic is targeting a fossil-free paddock

entirely fossil-free paddock."

Martin Popilka, Chief Executive Officer, P1 Racing Fuels, added: "Here at P1, we are passionate about working towards a more sustainable future for motorsport and have been focusing for some time on developing a completely fossil-free racing fuel for use in competitive environments.

"There is a stigma around biofuels that they don't perform as well as fossil fuels, but the data proves that is completely untrue. What we have produced for RallyX Nordic is the world's first fully renewable fuel that doesn't feature any fossil-based components, without having to make any sacrifices on the performance front – indeed, recent dyno testing has shown that BIO RACING 100% actually generates more power, making it a win-win for everybody."





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EXTREME E Founder and CEO Alejandro Agag hailed the start of the pioneering electric SUV off-road racing series as "beyond my wildest expectations".

The series raced into the heart of the Saudi Arabian desert for its inaugural X Prix. The challenging, high-speed 8.8-km track – laid out in the midst of a breath-taking otherworldly landscape – did not disappoint.

"We've worked so hard on this for many years, and

BELOW Rosberg X Racing triumphed in the Desert X Prix



finally everything came together," said Agag after an event that claimed unprecedented media coverage. "If I had written a script for the perfect weekend, I could not have come up with anything better than what we witnessed – I've never seen such extreme racing in my life. I think it's fair to say we have really made our mark."

The Rosberg X Racing pairing of three-time FIA World Rallycross Champion Johan Kristoffersson and former Australian Rally Champion Molly Taylor conquered the opening day's single-car Time Trials and Sunday's wheel-to-wheel action to lift the Desert X Prix trophy. The duo emerged victorious at the end of an event that yielded more than 4,500 media articles throughout almost 100 countries, attaining a total reach of 1.2 billion.

Prior to the event, the championship signed an agreement with TikTok to bolster its social media offering. Across the race weekend, Extreme E pulled in 18.5 million organic views across TikTok content produced by digital media giant Little Dot Studios, with a reported 17.2 million people checking out #DesertXPrix videos alone.

As part of the ambitious partnership, Extreme E and Little Dot Studios created an exclusive 90-minute production, which aired on Extreme E's TikTok account. More than 386,000 people watched the show, which gave a behind the scenes look at the series and the personalities at the heart of it. One of the most popular videos was 'The Drop'

- a part of the course measuring 100 metres with a 45-degree descent, which left viewers with their hearts in their mouths. The on-board video gave a view from the cockpit and 3.8 million fans tuned in to see exactly what the driver saw as they took on this challenging element of the course.

Prodrive partners with Lewis Hamilton's X44 Extreme E team

PRODRIVE has partnered with X44 to run Lewis Hamilton's team at each round of the five-race Extreme E series.

"Extreme E is such an exciting and unique concept and I have been fascinated by the project ever since Alejandro [Agag] launched it almost two years ago," said Prodrive chairman and founder David Richards. "When Lewis then announced his interest in a team it was a great opportunity for Prodrive to help him realise his personal ambitions from the series."

Prodrive-contracted drivers Sébastien



ABOVE Lewis Hamilton and Prodrive: a formidable combination

Loeb, and fellow Dakar competitor, Cristina Gutiérrez, will compete in the X44 ODYSSEY 21. The bespoke E-SUV produces 400 kW (550 bhp) and is capable of reaching 100 kph in 4.5 seconds.

Prodrive is one of the most successful motorsport businesses in the world. The company has won: six World Rally Championship titles; six Le Mans titles; five British Touring Car Championships; and is the reigning FIA World Endurance Championship GT Manufacturers' and Drivers' champions with Aston Martin Racing.





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OPEL has grasped the nettle encountered by all manufacturers producing electric vehicles for competition: the lack of noise that impacts both on safety and excitement. It is equipping its batteryelectric Corsa-e Rally car with a special sound system that makes the car audible during rallies.

Spectators and marshals on the special stages must be able to hear when a car is approaching. The Corsa-e Rally with its unique sound system will make its debut on May 7-8 in the opening round of the ADAC Opel e-Rally Cup, the world's first one-make cup for electric rally cars.

It was clear from the start of development that the Opel Corsa-e Rally would need a sound system. The German motorsport federation requires that rally cars must be audible for the safety of officials and spectators. However, as in other areas of the revolutionary electric rally concept, no-one had any experience of sound systems.

First there was the question of the hardware. It must be powerful and robust. Commercially available loudspeakers are usually installed inside vehicles or buildings, so they are rarely waterproof. In order for an electric rally car to be heard well by the spectators, however, the loudspeakers must be mounted externally, where they are fully exposed to vibrations, dust and moisture.

The Opel engineers searched for highly durable speakers and found what they were looking for in marine accessories. At the front and rear of the Corsa-e Rally there are now two splash-proof loudspeakers each with a power consumption of up to 400 watts. They are supplied by an amplifier that receives its signals from its own control unit. This black box operates with specially written software that converts the vehicle data.

The system is rpm-dependent, which therefore makes spinning wheels audible. The tuning of the final sound pattern took several months. The software was continuously developed and is now based on a stationary "idle sound" that can be adapted to all speed ranges.

The volume can be adjusted in two power levels. When driving on public roads between competitive stages, a quiet mode is used. The volume is turned up fully only on special stages. The regulations require the teams to adjust the volume accordingly.

"We did not want to simply simulate the sound of a combustion engine, but create a unique electric

ABOVE & RIGHT Opel engineers have created a rally sound unlike any other sound that suits the project," said Opel Motorsport Director, Jörg Schrott. "We are pleased with the result and convinced that the sound will also excite the fans along the special stages, even though it is deliberately different from that of a classic rally car with combustion engine."

The sound system will be tested for the first time in competition on May 7-8, at the season-opener of the ADAC Opel e-Rally Cup, the 33rd ADAC ACTRONICS Rally Sulingen.



DTM enlists AVL Racing for GT3 BoP

THE DTM has enlisted the expertise of global automotive service provider AVL to balance the performance of its new GT3 racecars.

The German series switched to GT3 upon the demise of its Class 1 regulations at the end of last season. Its GT3 contenders, currently from Audi, BMW, Mercedes, Ferrari and McLaren, will be categorised by a DTMspecific 'balance of performance' (BoP) in the quest for exciting racing.

This will enable a range of front- and rear-wheel drive cars to compete, as it will different engine formats. BoP will be implemented by the likes of weight, ride height, air intake and boost pressure adjustments.

For its vehicle simulation and BoP calculations, AVL is relying on decades of experience in motorsport, particularly in the areas of drivetrain development, vehicle simulation, testbeds and prototyping. A core element of the BoP calculations is the VSM Race (Vehicle Simulation Model) software, developed by AVL over the years.

For instance, the versatile VSM Race software is giving the AVL engineers the opportunity to simulate up to 100,000 laps in a minimum of time by means of cloud computing between two practice sessions.

"AVL has been working with the VSM Race software for 20 years to compare different vehicle and drive systems with each other," explained Ellen Lohr. The only female DTM race winner to date took on the position of AVL's motorsport director at the beginning of the year.

"It is our aim to generate an effective BoP with our engineers and together with ITR as a basis for exciting motorsport," she said.

In contrast to other vehicle balancing procedures that, among others, integrate the insights from a real test driver, ITR and AVL RACING, in their close cooperation, are relying on state-of-the-art virtual laboratory conditions, taking into account a huge database as well as specific data sources from test sessions, practice sessions and races throughout the DTM season.

In the process of creating a BoP model in a virtual environment, exclusion of external factors or temperature differences depending on the time of day is elementary. On the other hand, to determine the circuit-specific BoP ratings, weather and track conditions are very much taken into account as temperature and ambient air pressure have a relevant effect on the engine performance, just like the actual grip levels of different cars can be used in disparate ways.

"We have opted for AVL because the company has decades of experience as well as systems that have been optimised over the years and experienced staff, also from GT3 racing," Michael Resl, DTM Director Competition & Technology, said.

"Together, we are breaking the moulds by means of a technically coherent, comprehensive simulation with virtual race cars and virtual drivers that leads to maximum coherency in the performance of the DTM cars."





LEFT & ABOVE The central element of the BoP calculation is the VSM Race software developed by AVL

Porsche Mobil 1 Supercup focuses on renewable fuels

PORSCHE and ExxonMobil are testing advanced biofuels and renewable, lowercarbon eFuels, as part of a new agreement to find pathways toward potential future consumer adoption.

The first iteration of Esso Renewable Racing Fuel is a blend of primarily advanced biofuels and is specially formulated by ExxonMobil's in-house team of scientists and engineers. Analysis indicates the potential to significantly reduce greenhouse gas emissions with a liquid fuel. The fuel will be tested in race conditions with Porsche's highperformance motorsports engines during the 2021 and 2022 Porsche Mobil 1 Supercup race series.

Porsche and ExxonMobil's collaboration will also focus on eFuels, synthetic fuels made from hydrogen and captured carbon dioxide. As early as 2022, the companies plan to test the second iteration of Esso Renewable Racing Fuel, which will contain eFuel components. The eFuel is anticipated to achieve a greenhouse gas emissions reduction of up to 85 per cent, when blended to current market fuel standards for today's passenger vehicles.

"The electrification of our vehicles is of highest priority to us," said Michael Steiner, Member of the Executive Board, Research and Development of Porsche. "eFuels are a good complement to our powertrain strategy. They allow our customers to drive cars with conventional combustion engines as well as plugin hybrids with significantly lower greenhouse gas emissions.

"The collaboration with ExxonMobil enables us to test the eFuels under demanding conditions on the racing track. This is a further step towards making eFuels an affordable and lower greenhouse gas emission substitute to conventional fuels."

The eFuel will be sourced from the Haru Oni pilot plant based in Chile that generates hydrogen, which is then combined with captured carbon dioxide drawn from the atmosphere to produce methanol. ExxonMobil is providing a licence and support for the proprietary technology to convert the methanol to gasoline, which will result in a lowercarbon fuel.

In the pilot phase, around 130,000 litres of eFuels will be produced in 2022. As the fuel's primary user, Porsche will use the eFuels from Chile among others in the Porsche Mobil 1 Supercup starting in the season of 2022.

COMMERCIAL VIABILITY

"Over the past quarter-century, we have worked together with Porsche to develop high-performance products that support Porsche's vehicle performance on the racetrack and on the road," said Andy Madden, vice president of strategy and planning for ExxonMobil Fuels & Lubricants. "Our continued collaboration on renewable and eFuels is a critical step in assessing the technical capability and commercial viability of fuels that can significantly reduce emissions."



Porsche and ExxonMobil carried out initial fuel tests and gleaned information back at the beginning of 2019. Early in 2020, engine tests were conducted on test benches as well as material compatibility experiments with fuel-system components and functional trials under a wide range of driving conditions.

The first on-track testing of Esso Renewable Racing Fuel took place recently at Zandvoort, Netherlands. A software update was applied to co-optimize engine and fuel performance. Thus, the engine output of the new 911 GT3 Cup racing car remained unaffected.

"The testing of new technologies in racing has a decades-long tradition at Porsche. We're proud to be able to assume a pioneering role for Porsche on the critical topic of eFuels," affirmed Oliver Schwab, Project Manager Porsche Mobil 1 Supercup.

In January, ExxonMobil announced the creation of a new business, ExxonMobil Low Carbon Solutions, to commercialize its extensive low-carbon technology portfolio and plans to invest \$3 billion on lower emission energy solutions through 2025. Last year, ExxonMobil announced plans to distribute renewable diesel within California and potentially other domestic and international markets as soon as 2022.

Over the past two decades, ExxonMobil has invested more than \$10 billion to research, develop and deploy loweremission energy solutions.

Porsche is committed to invest 15 billion euros in electromobility and digitalization by 2025. In 2030 the sports car manufacturer will offer more than 80 per cent of its vehicles with electric engines. The company seeks carbon neutrality in its products and operations by 2030, investing around 1 billion euros in sustainable mobility.

> **LEFT** The first iteration of Esso Renewable Racing Fuel is being tested in the Supercup



Engine for \$1m autonomous Indy shoot-out revealed

THE engine has been selected for the Indy Autonomous Challenge, a high-profile race for full-size autonomous-enabled Indy Lights cars around Indianapolis Motor Speedway this October.

Featuring a \$1 million prize for the winners, the event – aimed at student teams – has been conceived to drive the next generation of software innovations that could kick-start the Autonomous Vehicle industry.

Dallara's AV-21 Indy Lights machine, dubbed the most advanced, fastest autonomous vehicle ever developed, will be powered by a 2.0-litre turbocharged 4-cylinder engine built by 4Piston Racing. The Indianapolis-based company is best known for supplying the hot rod market.

The engine will feature direct fuel injection and variable valve timing.

It produces approximately 385 horsepower at 6,800 RPM.

"It is a stressed member of the chassis, so we had to design an appropriate dry sump oil system and upper engine load paths to ensure structural integrity of the vehicle," said Dr Robert Prucka, Department of Automotive Engineering, UC-ICAR (Clemson University, International Center for Automotive Research).

"One special consideration we made for autonomous racing was requiring a low idle speed so that the car could go as slowly as possible in first gear," he explained. "This allows the car to perform a 'track walk' at low ground speed to collect track mapping information from the radars, lidars, cameras and GNSS systems. We also utilized an antistall centrifugal clutch to allow for significantly simplified launch control. "Throttle position commands are provided by the on-board Al computer. Signals from the Al computer pass through a supervisory control system that is continuously monitoring heartbeats from all electronic devices (for safety) as well as critical engine parameters like oil pressure."

Through Clemson University's long-running vehicle prototype programme, Deep Orange, Clemson graduate automotive engineering students are leading a collaborative process that includes all IACregistered teams to engineer the autonomous-capable Dallara race car. It is being equipped with industrystandard computers and sensors.

The use of an ICE, rather than electric motors, is seen as central to the organisers' plans to engage traditional race fans in an event aimed at widening awareness of AV technology.



BTCC turbo contract extended

LEADING forced induction specialist Owen Developments (UK) Ltd has been awarded an extension to its existing contract with TOCA to supply the control-specification motorsport turbochargers and wastegates to the British Touring Car Championship.

The contract – first awarded in 2011 and now extended through until the end of the 2026 season – entails the supply and support of turbochargers and wastegates to the entire BTCC grid.

Owen Developments turbocharger units have delivered prodigious performance and reliability throughout all BTCC racing and testing activity over the last decade. This latest extension will see the company contracted through the new Hybrid technology phase in the UK's premier motorsport series.

Commenting on the contract renewal

announcement, Owen Developments' MD Lee Owen said, "Myself and everyone here at Owen Developments are extremely proud that we have retained our contract as the supplier of turbochargers and wastegates to a championship as prestigious and as high-profile as the BTCC for a further five years.

"This new appointment sees us move forward into the new and exciting Hybrid era of the BTCC. This success is clear recognition of Owen Developments' technical expertise and commitment to providing quality products and service to the BTCC. We look forward to this new chapter of our relationship with the BTCC."



LEFT The BTCC has extended the contract for turbos



THE MOST EXTREME ROAD CARBASED BENTLEY IN HISTORY

Pikes Peak project to spearhead launch of new sustainability initiative

B ENTLEY has launched a major new sustainability initiative, with the announcement of a renewable fuels research and development programme spearheaded by the most extreme road car-based Bentley in its 101-year history.

The Continental GT3 Pikes Peak, designed and built to compete for the Time Attack 1 record at this June's Pikes Peak International Hill Climb, will be the first competition Bentley to run on renewable fuel, ahead of a goal to offer sustainable fuels to Bentley's customers around the world.

The modified Continental GT3 racer, based on Bentley's race- and championship-winning car, will power its way through the 12.42-mile course running on a biofuel-based gasoline. Various blends of fuels are currently being tested and evaluated, with possible Greenhouse Gas (GHG) reductions of up to 85 per cent over standard fossil fuel. This first step marks the start of a longer programme that will investigate both biofuels and e-fuels for their potential to power the Bentleys of past and present in a sustainable way.

Bentley's ambitious and transformational 'Beyond100' programme will see the brand become the world's

leading sustainable luxury mobility company, with the entire Bentley model range offered with Hybrid variants by 2023 ahead of Bentley being BEV-only by 2030. The adoption of renewable fuel for this project signals the start of a long-term ambition for Bentley, initiating a research and development programme that aims to offer renewable fuels to Bentley customers in parallel to Bentley's electrification programme. This twostrand strategy is set to maximise the pace of Bentley's progress towards outright carbon neutrality, as part of its Beyond100 journey.

Combustion-engine Bentleys will still be produced for the next nine years – and Bentley's new project aims to make those cars as sustainable as possible through the use of innovative fuel technologies. With more than 80 per cent of all Bentleys ever built still on the road, a genuinely sustainable and customerfacing renewable fuel offering will also allow customers to enjoy their current and classic Bentleys responsibly for years to come.

Bentley currently holds two Pikes Peak titles – the Production SUV record attained in 2018 with a Bentayga W12, and the outright Production Car ABOVE & RIGHT The Continental GT3 Pikes Peak Bentley will run on renewable fuel



record secured in 2019 with a Continental GT.

Bentley's Member of the Board for Engineering, Dr Matthias Rabe, commented: "We are delighted to be returning to Pikes Peak for a third time – now powered by renewable fuel, as the launch project for another new element of our Beyond100 programme. Our powertrain engineers are already researching both biofuels and e-fuels for use by our customers alongside our electrification programme – with intermediate steps of adopting renewable fuels at the factory in Crewe and for our company fleet. In the meantime, the Continental GT3 Pikes Peak will show that

The potential to power the Bentleys of past and present in a sustainable way"

renewable fuels can allow motorsport to continue in a responsible way, and hopefully it will capture the third and final record in our triple crown."

Bentley's pinnacle Pikes Peak project is being run in conjunction with British Continental GT3 customer team Fastr, which has successfully campaigned its Bentley race car in time attack competitions across the country. Technical teams from Bentley and Fastr are working together with specialists from M-Sport





ABOVE Bentley's Continental GT broke the outright production car record at Pikes Peak by eight seconds in 2019 in Cumbria to extract the maximum possible performance from the Continental GT3 package, which will be run in Colorado by the same team and with assistance from K-PAX Racing.

To break the record, the car will have to complete the nearly 5,000 ft climb, which includes 156 corners, at an average speed of more than 78 mph to cross the finish line in less than nine minutes and 36 seconds. To help achieve this ambitious target, Bentley has once again turned to three-time Pikes Peak champion and former "King of the Mountain' Rhys Millen (NZ) – who holds individual class records. It was with Millen that Bentley captured its two existing Pikes Peak records.

BIGGEST REAR WING EVER

With the start line at 9,300 ft, the course climbs to 14,100 ft – where the air is a third less dense than at sea level. This environment means that the Continental GT3 Pikes Peak features modifications both to its aerodynamics package and its engine, turning it into the most extreme iteration of a Continental GT – or indeed any Bentley road car – ever.

The biggest rear wing ever fitted to a Bentley dominates the rear of the car, sitting above a highly efficient rear diffuser that surrounds the transaxle gearbox. This rear aerodynamic package is balanced by a two-plane splitter at the front, flanked by separate dive planes.

The engine is Bentley's proven racing power unit, developed from the 4.0-litre turbo V8 fitted to the Continental GT V8. For the Continental GT3 Pikes Peak, engine modifications together with the use of carefully-selected biofuel will ensure the engine develops significant horsepower despite the rarefied conditions it will operate in. Short side-exit exhausts will ensure the car sounds as dramatic as it looks.

Further modifications include cooling air scoops in place of the rear windows, and the obligatory stopwatch mounted to the roll cage next to the steering wheel, to allow Millen to keep track of his sector times up the mountain.

The Continental GT3 Pikes Peak now enters a major test and development phase, based initially in the UK before being shipped to the USA for altitude testing.

Wolf Lubricants partnership extended

WRC Promoter has signed a multiyear extension with European lubricant manufacturer Wolf to continue as a premium partner of the FIA World Rally Championship.

The extension beyond the previously agreed end-date of 2022 means the live TV Wolf Power Stage will continue as the exciting finale to every WRC round over the coming seasons, as drivers fight for vital bonus points through the Sunday lunchtime speed test.

"It's a huge vote of confidence in the championship from Wolf," said WRC Promoter marketing and sales director Thomas Tap. "This extension comes against the backdrop of COVID-19, which has had, and continues to have, a significant effect on the global economy.

"Despite these difficulties and this period of uncertainty, Wolf Lubricants has proved to be a strong partner, remains totally committed to the series and supports the WRC into the future."

The Belgium-based company was founded in 1955. It became the WRC's Official Lubricant Partner in 2019. It specialises in tailored, technology-enhanced lubricants. Wolf produces oils and fluids for engines, transmission, brakes and steering. It has a

RIGHT The rally-closing Wolf Power Stage has become synonymous with drama

HEHIS

wide product range, including cars, heavy duty vehicles, motorcycles, marine and agricultural machinery.

Yves Decat, Global Brand & Experience Manager at Wolf Lubricants, expressed his excitement over the extended agreements. "With our partnership with such a prestigious motorsport as WRC, we do not only build on our brand's continuous growth of the last years, but we also enjoy our technical collaboration with Junior WRC, which provides us with the perfect platform to develop cutting-edge lubricants to be later introduced to our product ranges," Decat said.



Retrac Group creates employeeownership structure and appoints new CEO

RETRAC Group, one of the UK's leading advanced manufacturing specialists in the Formula 1, automotive and aerospace sectors, has announced a structural change to increase growth and enhance the security and prospects of its employees.

Following five decades of being owned by the Carter family, the Swindon-based company's ownership has been transferred to an Employee Ownership Trust (EOT) structure, which makes the 115-strong workforce the beneficiaries of the company's future success.

Experienced automotive and motorsport executive Dan Walmsley has been appointed as CEO to lead the Group's two divisions, Retrac Productions Ltd and Retrac Composites Ltd. In tandem, longstanding co-owner and Retrac Productions managing director, Andy Carter, is to step into the role of Chairman of Retrac Group. With a long history of innovative

manufacturing excellence, Retrac Group

has been a key supplier to more than half of the Formula 1 World Champions in the past 25 years. It has also diversified its blue-chip client portfolio across multiple sectors, providing engineering solutions in advanced materials, tooling and component manufacture.

"We firmly believe that the EOT mechanism is the correct succession plan for the business," said Andy Carter. "Since my father founded Retrac in 1972, the



ABOVE Walmsley: new CEO

most important aspect of the business is the employees. The average service record of more than a decade stands as testament to the loyalty and commitment of the Retrac workforce."

Dan Walmsley arrives at Retrac having last year been a co-ordinating lynchpin for the Ventilator Challenge UK Consortium. As part of the Cabinet Office response to the COVID-19 pandemic, Walmsley helped co-ordinate multi-site production activities for Airbus, Ford, Siemens, McLaren, Penlon and GKN Automotive. Prior to that he was Motorsport Director at McLaren Automotive from 2016-20, having been Team Principal at FIA World Sportscar Championship entrant Strakka Racing. As CEO, Walmsley will oversee the day-to-day running of the Group. "The Carter family and the Retrac staff have created a company that has long excelled at delivering into some of the most demanding industries through hard work, innovation and re-investment," he said.

"Yet the breadth of applications for innovative, lightweight materials and skilled yet rapid manufacturing is growing exponentially across many sectors, and we see a bright next chapter in the Retrac story."





Darrick Dong 1952-2021

MOTORSPORT lost one of its most respected figures last month when Darrick Dong, long-time director of motorsports at PFC Brakes, lost his long battle with illness.

Dong was a cornerstone at PFC for some 25 years, joining in June 1996, where his knowledge and experience made him one of the industry's most insightful, accessible, and trusted authorities on motorsports and braking technology.

"Steadfast, passionate and a true professional, Darrick's knowledge of the total braking system has been pivotal to the success of PFC," a company statement acknowledged. "Darrick's ability to educate PFC's customers on how they properly install, tune and personalize their brake packages was truly a gift and something to be cherished.

"His time and know-how gained at Tilton Engineering, along with the years of experience of working with professional race teams, are the catalysts of what has elevated the PFC Brakes Motorsports department to what it is today," the statement continued.

"Darrick strived to embody every principle that makes the racing industry great with his stubborn 'no stone left unturned' demeanour toward troubleshooting a brake system for a customer in need. Darrick was a fierce competitor and always put his customers and racers first.

"His dedication to PFC and the motorsports industry cannot be rivalled and we will continue to push the NO COMPROMISES attitude that he so greatly brought to light in the racing world.

"Darrick's legacy will forever be remembered and ingrained into the culture of PFC."

Dong oversaw a number of major developments at Clover, South Carolinabased PFC throughout his decades-long career there. They included PFC's release of its ground-breaking ZR43 Zero Drag caliper in 2010, which earned success in NASCAR, including victory at the prestigious Daytona 500. The product went on to win the Most Innovative New Motorsport Product of the Year Award at RACE TECH's World Motorsport Symposium.

Later, Dong was instrumental in IndyCar's move to PFC hardware in 2017, followed by its transition to the full package in 2018.

"It's hard to find anyone who was more dedicated to his craft and his love

Darrick strived to embody every principle that makes the racing industry great"

of IndyCar was second to none," said IndyCar Series president Jay Frye. "We are incredibly fortunate to have worked with Darrick. There is no question that our paddock was a benefactor of his lifelong passion. He will be missed."

"Darrick was truly a legend in our industry and will be greatly missed," said Soheila Kimberley, RACE TECH's publishing director. "We have lost not only a great man but also a very good friend."

"Beyond his vast technical abilities, he was also a great person," said John McCrory, racecar product manager at Aurora Bearing Company.

Recalling an anecdote from the NASCAR paddock, in which Dong won huge respect, McCrory said: "It would not surprise anyone that when he first worked in the NASCAR garages, he stood out. Rather than be combative when subjected to rude comments, he turned his uniqueness into an asset.

"Mechanics faced with a brake problem would say 'Get me the China boy'. Darrick did his job, fixed people's problems, made their cars faster. Soon enough it was, 'Get me Darrick'". He became 'The Man'.

"What many of us in motorsports often did not grasp was that brakes were his specialty: not just racecar brakes," said McCrory. "I was fortunate to listen in when he would talk about military, commercial and other applications.

"Darrick was rightly proud when PFC became a Porsche OE supplier. His comment was, 'You don't know how many years I've worked to make this happen'. It was not only a source of pride for him, but an inspiration to many of us in the motorsports field."

IMSA president John Doonan chose PFC to outfit some of his racecars – including the race-winning RT24-P DPi – during his spell as Mazda's motorsports director. "The example Darrick set when it came to his professionalism is something we should all learn from and emulate," Doonan said. "Our sport has lost another 'all-star'."



LEFT Dong was part of the PFC team honoured with the Louis Schwitzer Award for Engineering Innovation and Excellence at the Indianapolis Motor Speedway during the 2017 Indy 500 26



RIGHT The use of screaming Internal Combustion Engines in the cars is part of the plan to get the existing motorsport fanbase onside with AV technology

Can a \$1 million shootout for autonomous cars at Indianapolis Motor Speedway transform both the AV industry and our perception of it? **Mark Skewis** talks to one of the key movers behind the Indy Autonomous Challenge

AUTONOMOUS racecars competing wheel-to-wheel, engines screaming, at speeds touching 200 miles per hour around Indianapolis Motor Speedway. A \$1 million dollar purse awaits the victor. It's a tantalising glimpse of the future, isn't it?

Except that future isn't 2050. Not even 2030. It's this October.

Autonomous vehicles (AVs) represent the future state of mobility. An anticipated \$75 billion investment in the technology between 2019 and 2023 underlines that belief. Indeed, the majority of the big automotive manufacturers were so certain that they forecast self-driving cars would hit the highway by 2021. But, one by one, those over-optimistic predictions have fallen by the wayside.

A global pandemic that has sapped the OEMs' finances has done nothing to improve that timeline. Even before the advent of COVID-19, however, there were three prominent barriers to the commercialization of AV technology.

The first is the solving of 'edge case' scenarios – problems or situations that occur only at an extreme operating parameter, such as avoiding unanticipated obstacles at high speeds while maintaining control.

If edge case issues represent the biggest and ugliest issue lurking in the AV 'in-tray' to deal with, other dark clouds lurk on the autonomous horizon.

At present, automated vehicles are too expensive for scaled commercial deployment. Automakers and tech companies are seeking sources of new intellectual property (IP) and qualified engineers and software developers.

Last, but not necessarily least, there is a need for the public to be engaged if the technology is to become accepted. A sizeable fear factor remains.

Three weighty problems, then. But where to start searching for the answers? Enter, stage left, the Indy Autonomous Challenge. ►



Why screaming ICE engine was vital

WITH the path to Autonomous Vehicles seemingly inextricably linked with the automotive industry's stampede towards electrification, it might surprise some people that the Dallara AV-21 will be powered by an Internal Combustion Engine.

In fact, says Matt Peak, MD of Energy Systems Network, the choice of an ICE unit was a crucial one if the Indy Autonomous Challenge was to achieve its lofty goals. "We wanted to tap into what is familiar at Indianapolis Motor Speedway: open-wheel Indycars with loud, shrieking engines," he explains. "The hypothesis is that by using that approach, we are going to engage fans that otherwise couldn't care less about autonomous."

Although the Indy Lights cars are usually powered by a two-litre, fourcylinder engine built by UK-based AER, such high-performance powerplants were deemed to be outside of the cost and maintenance parameters of a student competition.

Instead, Indianapolis-based 4Piston Racing – which has carved a reputation for itself supplying the hot rod/drag racing market – has produced a 4-cylinder turbocharged unit that Peak maintains is, "a beast of an engine".

Based on the trusty Honda K20 block, a staple for so many of 4Piston Racing's usual customers, the intention is that the engine is affordable, reliable and can be serviced pretty much anywhere in the country.

WHAT IS THE CHALLENGE?

To be clear, we're not talking boys playing with radio-controlled cars in a car park. The IAC is a 20-lap race around Indianapolis Motor Speedway for fullsize Indy Lights racecars, modified for autonomous use. The cars must average 120 mph to qualify as a finisher.

The initiative is led by Energy Systems Network (ESN), an Indianapolis-based non-profit and a branded initiative of the Central Indiana Corporate Partnership

HAN NUT

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price Cheap constant access to piping hot media Protect your downloadings from Big brother Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages Brand new content One site



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(CICP) and CICP Foundation Inc (CICP Foundation). Working in close collaboration with the Indianapolis Motor Speedway (IMS), the Indy Autonomous Challenge is a broadly collaborative effort that brings together public, private and academic institutions to challenge university students around the world to imagine, invent and prove a new generation of automated vehicle software. The dream is to inspire the next generation of STEM (Science, Technology, Engineering and Mathematics) talent.



LEFT & ABOVE Developing software to make decisions at 200 mph, in the vicinity of other cars, could be the catalyst to take autonomous tech in the real world to the next level

A racing context will stretch self-driving cars to the absolute limit"

The primary goal of the IAC is to advance technologies that can speed the commercialization of fully autonomous vehicles and advanced driver-assistance systems (ADAS), leading to increased safety and performance. In addition, the IAC has been devised as a challenging competition to excite the best and brightest university students from around the world to engage in hands-on engineering firsts.

The concept has been taking shape for more than three years. It gathered momentum with a development workshop at Indianapolis in 2019, attended by industry figures and university representatives.

"It became clear that a motor race would show up the edge cases, because the software trying to mimic human drivers and overtaking at 200 miles per hour would give us some ridiculously complex scenarios to solve," recalls Matt Peak, MD of Energy Systems Network. "It was exciting because we could bring together some of the brightest AI minds from around the world. The question we were asking was, 'If we hold the party, will anybody show up?'"

The answer, it transpired, was an emphatic 'yes': more than 500 undergraduate and graduate students, PhDs and mentors who excel in artificial intelligence software, have responded to the challenge. They represent 39 universities in 11 countries on four continents.

AUTONOMOUS ROADMAP

If the AV movement has stalled somewhat, where is the technology roadmap for this sector headed?

"Ask 10 different people and you will get 10 different answers," admits Peak, one of the driving forces behind the IAC. ► 30

"There are five levels. They range from Level 1, being human-engaged autonomy, through to Level 5, which is 'go anywhere, any time, any place' completely robot control. Usually when people talk about autonomy, they are talking about the latter.

"About five years ago, that vision generated a lot of excitement as we started seeing a commercial application for this technology. But that quest for the higher levels is technologically very difficult.

"The approach emerging amongst companies we are seeing today is focused market applications, whether these are very slow people movers around corporate venues, or on-highway autonomous trucking."

Understandably, most companies investing in autonomous technology are seeking a bang for their buck. Refreshingly, the IAC has a higher purpose. There are 40,000 deaths on US roads each year, with research suggesting that 94 per cent of them are caused by "human factors". Advancements in vehicle automation have the potential to save thousands of lives.

"Igniting passion in the academic world can make a difference to the applicability of autonomous tech in the real world," stresses Peak. "Those robot taxis might be some way off at the moment, but there is plenty of potential for autonomous tech on the road today – the simple ADAS system, for instance, to help you avoid obstacles and debris in the road – but how reliable are these? How much do we trust them? But what if the technology developed on the racetrack, for a car to avoid another car at 200 mph, could be

Why Indianapolis?

IF you are creating an event to fire people's imagination, where better to host it than the Indianapolis Motor Speedway?

The Brickyard, which holds an iconic position in US automotive history, is still viewed as the jewel in IndyCar's crown. As such, it offers the perfect 'calling card' for the IAC.

As well as a prestige venue, it is a fitting one: IMS was built in 1909 as a proving ground for innovation. Although renowned for its motorsport feats, Indianapolis did also originally host a range of innovation, from hot air balloons to altitude record attempts for aircraft. Back on the ground the Marmon Wasp, the first car to win the Indianapolis 500, in 1911, was also the first racecar to feature a rear-view mirror.

"The IAC is going to bring the best minds from around the world to solve a very complex problem, right here at the Racing Capital of the World," says IMS President J. Douglas Boles. "As the birthplace of motorsports innovation, the Indianapolis Motor Speedway is a fitting setting for this event, and we can't wait to see the winning entry cross the Yard of Bricks into history."

BELOW The Indianapolis Motor Speedway, home of the Indy 500, the world's largest singleday sporting event, provides a wonderful backdrop for the IAC





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INSPIRATION

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The inspiration for the Indy Autonomous Challenge can be traced back to the Defense Advanced Research Projects Agency (DARPA) Grand Challenge in 2004, which put forth a \$1 million award and did much to create the modern automated vehicle industry. Moreover, given its heavy presence of universityaffiliated teams, the DARPA Grand Challenge inspired an entire generation of students to pursue STEM. It seems ironic, looking back, that the first DARPA

event had no finishers, yet is still credited as the catalyst for a transformation of the industry.

ABOVE The DARPA Grand Challenge led to tremendous advances in the AV industry

BELOW The most advanced autonomous car ever? Dallara's AV-21 at Indianapolis Motor Speedway "A competition like ours introduces the uncertainty and the impossibility of it all!" smiles Peak. "Reflect on where DARPA was at and where AVs were at when DARPA was announced. Asking a robot car to go through a desert for almost 20 miles, at a time when the only things that existed were these little Mars Rovers, was remarkable.

"Yes, in 2004 nobody finished and the furthest distance travelled was seven miles. Jump ahead just one year, to 2005, and a number of teams finished.

"Our competition could push the needle on when you see those higher levels of automation really emerge and introduce that excitement to the industry."



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Sebastian Thrun, a member of the victorious Stanford University team in 2005, played a key role in firing the imagination of the IAC's creators.

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"The DARPA Grand Challenge proved that robots can drive themselves in very confined environments, but that they don't have the agility and skill of a really well-trained human racecar driver to act in extreme situations," he says. "IMS is the best place in the world to challenge the robotics community to test self-driving cars. By going into a racing context, we will stretch self-driving cars to the absolute limit.

"These robots have to have an intelligence that lets them predict, in advance, what is going to happen. It is even more intense when robots race in the same race because now you don't just have to worry about your own dynamics; now you have to worry about what the others are doing. In real time. Really fast. With enormous competency.

"The reason to compete is to be part of the next generation of self-driving experts. Competitions are a great place to do this because once you get competitive, you will most likely stop sleeping, and work weekends to make sure you win!"





"Competitions that demand the highest performance thresholds have shown the ability to reveal new thinking, new collaborations and new talent," agrees Reilly Brennan, a lecturer at Stanford's Center for Automotive Research, partner at Trucks Venture Capital and another competition advisor. **LEFT** Autonomous technology is already playing a role in our everyday lives. Top, Bosch Rexroth's ActiveShuttle is used to transport goods from stockrooms directly to production lines; below, the first public test of the R&D project HEAT (Hamburg Electric Autonomous Transportation), a five-metre-long autonomous minibus

BELOW Through Ansys' virtual environment, student teams can quickly design, test, iterate and validate their software with high fidelity

"The DARPA Grand Challenge kickstarted an important wave of innovation in automated vehicles that spilled over into the private sector and reinvigorated the research community. I believe a new competition focused on high-speed automated vehicles has the potential to do the same." ►



Giorgio Piola FORMULA 1 2016-2018 Technical Analysis (with 2019 preview)











EAN: 978-88-7911-684-8 / Text: English - Pages: 208 -Pictures: over 600 technical drawings in colour - Hardbound - £ 49.00

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PERFECT PLATFORM

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In order to give the students the perfect platform from which to develop the software and control algorithms, the rest of the package needs to be bullet-proof. It was for that reason that the IAC organisers approached Dallara, the sole racecar supplier of the Indy Lights series since 2002.

The Italian constructor worked with some of the suppliers it knew and trusted, like ZF and Ricardo (see Race Tech 246), to modify the existing chassis.

Juncos Racing, a championship-winning racing team, will work closely with the university teams throughout the racecar assembly process. It will also take care of the service and maintenance of the AV-21s.

"The Dallara-built IAC racecar is the most advanced, fastest autonomous vehicle ever developed," says Paul Mitchell, president and CEO of ESN, and co-organizer of the IAC. "Our sponsors are providing radar, lidar, optical cameras and advanced computers, bringing the value of each vehicle to \$1 million."

The modified Dallara – the changes are sufficient to warrant a new chassis designation: AV-21 – is retrofitted with hardware and controls to enable automation to enhance safety, control and performance. Components include rugged-edge on-board computing, vehicle-to-vehicle communications, perception systems, high-end graphics processing units (GPU99s), drive-by-wire, and artificial intelligence acceleration and powerful central processing units to run IAC teams' software and algorithms in the racecar.

"Designing the chassis for autonomous racing was really challenging," admits Stefano dePonti, CEO and general manager of Dallara USA. "We know how the world's best racecar drivers react in the Dallara, in high-speed scenarios, but now we have to anticipate the actions of a robot..." Addressing the rise of autonomous vehicles, Cosworth CEO Hal Reisiger once opined: "It's all about artificial intelligence and machine learning. How quickly can we get a car to work like a human? And this is a big challenge because sensors aren't eyes and processors are not brains."

That's why the focus of the IAC targets software development, the premise being that the hardware is largely already mature. Teams will not be asked to develop and produce automated vehicle computers, sensors or other hardware. Instead, the focus is on developing new generations of software that can ensure precision control of vehicles at high speeds. The ambition is to innovate the software that takes the control algorithms to the next level.

Many billions have already been invested in preparing for autonomous technology. So why might students achieve the breakthroughs that existing companies haven't already discovered?

WHY STUDENTS CAN SUCCEED

Peak points to the DARPA Grand Challenge by way of justification. "Historically, a lot of competitions have failed to generate that kind of impact because they were open to anybody and everybody," he reasons. "We came to the table thinking, 'Let's not limit this', but then Sebastian explained that DARPA generated the impact it did because it's the universities who have the pre-established fan base, laboratories, the institutional infrastructure to







ABOVE & LEFT The

software on the autonomous Dallara AV-21 (above) will have to replicate the split-second decisions taken by the top human racers (left) compete for something like this."

The IAC has attracted a stellar list of sponsors. Some, such as global engineering simulation leader Ansys, cooling solution expert PWR, Valvoline, Bridgestone and Schaeffler, are familiar to the motorsport industry. So too Microsoft, which adorns the flanks of the Toyotas in the World Rally Championship. Others, like Luminar (software and sensors) and Real-Time Innovations (the largest software framework provider for smart machines) are better known in the autonomous sector.

Many of the firms involved have worked behind the scenes to offer students connections to people within the company, some of whom are working to tackle the same problems the teams will encounter. Others are offering a deep dive into their technology or products. Some, mindful that these are the engineers of the future, are teeing up job opportunities.

The one thing the sponsors all have in common is that they are having to navigate their way through the twists and turns of a global pandemic.

The IAC was an ambitious project to start with. The path of Coronavirus has done nothing to improve matters.

The saving grace, perhaps, is that if any generation is equipped to overcome the barriers raised by COVID-19,

it is the students the competition is aimed at. Brought up with social media, skilled in the virtual domain, they have taken things in their stride.

"If you are going to host a competition that has a virtual online element [teams have to navigate a number of rounds, some of them simulations, to qualify for the final race], you could do worse than have that aligned with a pandemic!" suggests Peak with a wry smile.

So what, in his finest daydreams, does Peak believe the Indy Autonomous Challenge will achieve?

"My dream is that five, 10 years from now, the transportation industry has a material benefit generated by those that came out of the IAC," he reflects. "I want to flip open *The Wall Street Journal* 10 years from now and see that so-and-so's new company is making a material difference in the world."

And in his nightmares? "We're not even going there!" comes the quick riposte.

"It's a big, open question whether we will ever get to that 'any time, anywhere, any place' level," concludes Peak. "We'll get to the Robo Taxi some day, but right now there are 40,000 deaths on the highway each year and we can make a difference. Let's not let the perfect be the enemy of the good." www.racetechmag.com GREEN TECH Mobile hydrogen refuelling station

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TOTAL COMMITMENT

Chris Pickering talks to Romain Aubry, TOTAL's Motorsport Technical Manager, about the implications of the world's first portable hydrogen refuelling station for motorsport

OR almost all of the last 100 years or so, motorsport powertrain development followed a nice stable trajectory. Sure, there were improvements in combustion and gas flow, there was forced induction, and occasionally there was even compression ignition (although we don't talk about that now). But as a general rule, most of this was evolutionary development of proven technology.

Well, not anymore. We already have two major electric racing series, there's talk of carbon-neutral synthetic fuels coming to Formula 1, and by 2024 there will be a class at the Le Mans 24 Hours specifically for hydrogen fuel cell vehicles. The potential for change over the next decade is staggering. That change is all-encompassing too. Switch to hydrogen fuel cells, for instance, and you don't just have a whole new type of propulsion system on the vehicle itself, but utterly new challenges in terms of refuelling, safety and logistics. No aspect of designing, building and running a racing car could be taken for granted anymore.

That's where organisations like TOTAL come in. The French energy company has partnered with the ACO and GreenGT on the Mission H24 project that aims to bring hydrogen fuel cells to Le Mans in just three years' time.

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As part of that project, the company has developed the world's first portable hydrogen refuelling station for motorsport use. The initial designs were produced in 2018, and the portable filling station made its debut when the GreenGT team participated in the free practice sessions for the Michelin Le Mans Cup event at Spa in 2019.

"As an engineer, hydrogen is a very exciting area to be working on. We're among the first to look at hydrogen for motorsport and it's a big challenge, so we're learning a lot," explains Romain Aubry, TOTAL's Motorsport Technical Manager. The refuelling station idea came from the ACO, who'd acknowledged that it wouldn't be realistic to expect circuits to invest their own money in hydrogen facilities while the concept is still in its infancy. Instead, they decided to commission a portable version that could follow the cars around.

TOTAL already operates a number of hydrogen filling stations in Germany, Belgium and France, but downsizing this technology into a portable package presented a formidable challenge. To do this, engineers from TOTAL Gas Mobility – an affiliate from the TOTAL group – broke down the elements that make up a hydrogen filling station and looked at each area in turn.

BELOW Development of the first mobile hydrogen filling station is a central part of the ACO's plans for hydrogen cars to race at Le Mans 39

www.racetechmag.com GREEN TECH *Mobile hydrogen refuelling station*

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LEFT With the hydrogen stored separately, the filling station itself is small enough to fit into a standard 20-foot shipping container

"The first thing to consider is the storage," explains Aubry. "The hydrogen is stored separately, which means the filling station itself is small enough to fit into a standard 20-foot shipping container. Inside there is a compressor, which compresses the gas inside a pair of small buffer tanks that act as a highpressure reservoir. This heats up the hydrogen, so it is passed through a cooling system before going on to the dispenser. These three main parts of the station are linked to a central control system, and there is also a small room within the container where two engineers monitor the filling process."

In theory, the process is quite straightforward. Once a valve is opened, the high-pressure hydrogen in the buffer tanks naturally flows into the onboard tanks. However, there are a number of practical challenges. Chief among these is that pressurising the gas inside the onboard tanks – which may be

BELOW The first refuelling, in the midst of a competitive session, took place at Spa



virtually empty when the process begins – causes their temperature to rise.

The tanks are subject to a safety limit of 80 deg C, which effectively limits how fast they can be filled. Consequently, there's an infrared data connection integrated into the refuelling nozzle, which communicates with the car's electronics to monitor the temperature and pressure in each of the three tanks onboard the H24.

"When you fill a hydrogen road car, the first minute is spent communicating and exchanging data. After that, there's a standard ISO protocol for the filling and you can't go above 1 kg per minute. For racing, we want to fill the car as quickly as we can," notes Aubry.

The buffer tanks in the final version of the system may have to operate at 900 or 1,000 bar"

Currently, the TOTAL mobile station can work at rates of up to 2 kg per minute, but the engineers are looking to improve this further. Part of that will include operating at higher pressures – for now, there is a maximum of 350 bar due to the tank construction, but the plan is to bring this in-line with state of the art road car systems that run at 700 bar.

One of the tricky aspects of doing this with a downsized mobile filling station is that the buffer tanks have to be capable of operating significantly above the onboard tank pressure. At the moment that equates to 450 bar (for a 300 bar onboard pressure) but the buffer tanks in the final version of the system may have to operate at 900 or 1,000 bar.

"If we want the hydrogen cars to race against the internal combustion engined cars in 2024, they will need to be able to refuel in less than two minutes,"



ABOVE & BELOW A compressor is used to compress the gas inside a pair of small buffer tanks that act as a highpressure reservoir comments Aubry. "We have basically three race seasons until 2024, so we will use those to learn about the filling protocol."

The details of the deployment have yet to be finalised. It's undecided at the moment whether there will be a filling station in every pit box – as there is now for ICE cars – or whether the competitors will have to share a central filling station. Another issue is the potentially conflicting EU safety regulations that govern internal combustion engined cars and fuel cell vehicles. These could make it difficult – at least from a legislative perspective – if the two groups were to share the same paddock area.

THE FUTURE

There's a lot of work to be done before 2024, and the TOTAL engineers are keen to get out to race events with the experimental GreenGT H24 prototype.

"It's going to be interesting to test the refuelling process in different situations. For instance, coming back to the pits at different tank pressures and temperatures," comments Aubry. "It's going to be a big challenge, but we've got great engineers here at TOTAL and among our technical partners. We've done some private tests with the team, so we have a lot of **>**



data already, but we need to improve our models and optimise the process."

Once the engineers have got a handle on refuelling the current prototype they will have to start looking at how to deal with a whole category of different entries. The hydrogen tanks themselves will be part of a spec package on the 2024 cars, but other aspects of the design, including the fuel cell stacks, will be open to the teams. "We will have to work with the different manufacturers. The fuel cells will certainly have an impact on the tanks' behaviour," notes Aubry.

SCRATCHING THE SURFACE

In a sense, though, this is just scratching the surface. As it stands, the refuelling station is completely portable with no real input required from the circuit operator. But an even bigger challenge might be encountered in the future if hydrogen racing were to become a mainstream discipline, with permanent venues hosting dozens of different cars **RIGHT** The project is breaking new territory

BELOW TOTAL believes the pioneering hydrogen work offers the potential for genuine technology transfer from motorsport to mainstream applications



"It's a chicken and egg situation," comments Aubry. "We need to get hydrogen cars on track to develop the technology. And that needs to be proven before I think there's any chance of the circuits investing in infrastructure. It's probably too early to say what would be needed to support a permanent refuelling infrastructure at a track. It would certainly be a huge challenge." The lessons learned from this on-track experience could have far-reaching consequences, with the potential for genuine technology transfer from motorsport to mainstream applications, he points out: "The way things are going at the moment, it looks like passenger cars will focus on battery electric propulsion for the next few years, whereas hydrogen will mainly be used in long-haul applications to start with. A train, for instance, might ►

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THE LAST GREAT ADVENTUR The quest for the ultimate Dakar Rally of

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LEFT France's first hydrogen train, the Coradia Polyvalent range for Régiolis, developed by Alstom. With trains holding more than 30 kg of hydrogen, this is just one example where experience gained in motorsport could be passed on

hold more than 30 kg of hydrogen, so the refuelling time is significant. Work on the motorsport side could help us to reduce that."

Heavy transport might sound like an unlikely comparison to motorsport, but there's a clear parallel with long-distance endurance events, where it's hard to see battery electric vehicles ever playing a major role. Hydrogen has already made an impact in these competitions, with the Dutch university team Forze Delft competing in a round of the Supercar Challenge in 2019.

PART OF THE GAME

Elsewhere, French team GCK is preparing a hydrogen fuel cell vehicle for the Dakar Rally. So too is the Gen Z team run by explorer Mike Horn and five-time Dakar winner Cyril Despres.

That's not to say hydrogen will be restricted to long-distance events. In Germany, a consortium of heavyweight motorsport names, including HWA and

Hydrogen propulsion is one of the pillars of TOTAL's plans to go carbon neutral by 2050"

the ADAC, is developing the HYRAZE League, which is understood to be based around sprint races (with the option of longer endurance races featuring refuelling). Aubry describes hydrogen propulsion as "one of the pillars" of TOTAL's plans to go carbon neutral by 2050. "It's part of the game, but our idea is not to dictate the technology that people use. We're investing in electricity, green hydrogen and biofuel," he comments.

Arguably the most important factor with fuel cells, hydrogen combustion or hydrogen-derived synthetic fuels is how the gas is captured in the first place. Hydrogen that's produced using fossil-

BELOW TOTAL is collaborating with electricity company Engie on France's largest green hydrogen production facility



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LEFT An infrared data connection integrated into the refuelling nozzle monitors the temperature and pressure in each of the three tanks onboard the car

BELOW Testing with the experimental GreenGT prototype will need to trial the car returning to the pits at different tank pressures and temperatures

PLASTIC OMNIUM

fuel techniques is referred to as 'grey hydrogen' (or blue hydrogen if the resulting CO2 is captured before it reaches the atmosphere). This is how the vast majority of hydrogen is currently produced (in the United States, for example, 95 per cent comes from a process known as steam methane reforming) but there are cleaner alternatives.

Currently, the most talked about option is green hydrogen. This term can be applied to any process based on renewable energy sources, but it most commonly refers to the use of renewable electricity to split water into hydrogen and oxygen.

Another option is so-called turquoise hydrogen, where the carbon is removed from natural gas and stored as a solid, leaving pure hydrogen behind. This approach is in its infancy at present and



there are practical challenges surrounding the lifespan of the catalyst materials and what to do with the remaining carbon. Earlier this year, TOTAL announced that it was collaborating with electricity company Engie on France's largest green hydrogen production facility. The plant in Châteauneuf-les-Martigues near Marseille will have a 40 MW electrolyser connected to a 100 MW solar farm, enabling it to produce five tonnes of green hydrogen per day. "Electrolysing water is the first green hydrogen production process that's been applied on an industrial scale," comments Aubry. "It requires a lot of energy input, but that's not a problem if you have access to green electricity, and it's easier to store that energy as hydrogen than it is to put it in a battery."

Most of its advocates accept that hydrogen won't be a universal solution for all areas of transport (or indeed all areas of motorsport). Nonetheless, its status as an energy-dense liquid fuel makes it a genuine contender for applications where batteries are unlikely to be feasible, such as endurance racing.

The best way to put this to the test is to try it. And the only way to do that is to have a system in place to support refuelling at the track.

1810

"Fossil petroleum is a bad thing for the future. But petroleum itself is a fantastic set of chemicals"

The architect of so much success in Formula 1, Paddy Lowe is now bringing that same demanding mindset to a far more important challenge. **Chris Pickering** finds out more

ADDY Lowe is a man on a mission. His Formula 1 career spanned more than three decades, during which time he oversaw the development of no less than seven world championship-winning cars. At Williams, he masterminded the active suspension system that allowed the FW14B to blitz the competition in 1992; at McLaren he helped to tip the balance in Mika Häkkinen's favour during his epic World Championship battles with Michael Schumacher in 1998 and 1999 and was engineering director for the first of Lewis Hamilton's world titles in 2008; and as executive director at Mercedes from 2013 to 2017, he laid the foundations for the team's crushing dominance of the V6 turbo era.

But his latest quest is bigger than any of

those feats. As the world faces up to the threat of catastrophic climate change, the former F1 technical boss has set out to break society's dependence on fossil fuels. And he's going to do it with the combustion engine. Or to be more precise, he's going to do it with petroleum (the collective term for fuels and petrochemicals based on hydrocarbons).

"We're all hardwired to consider petroleum and fossil fuels as one and the same thing, but they're not," he comments. "Fossil petroleum is a bad thing for the future, and it's becoming abundantly clear that we need to move



away from it. But petroleum itself is a fantastic set of chemicals, both for energy and as the basis **ABOVE** The drive and winning mindset that earned Lowe such phenomenal success in F1 is now being applied to issues that are bigger still

LEFT Formula 1's ambition to showcase synthetic fuels and retain the Internal Combustion Engine could act as a template for the rest of the motorsport pyramid industry that is already having to work very hard to retain sponsorship money in an increasingly environmentally-aware world. Big brands simply can't afford to be associated with anything that's perceived as polluting.

There's also a practical problem when it comes to decarbonising motorsport, as Lowe explains: "There are basically three types of process that you can use to store energy. Atomic processes where you split or fuse atoms; molecular processes where you burn a fuel; and then there are electrochemical processes like batteries. There is a practical limit to how far you can go with each of those.

ENERGY DENSITY

"Electric powertrains are not an appropriate answer in high-end motorsport. Formula E does a very good job under the circumstances, but those are not cars that would look at all interesting on a proper racetrack. And they won't get there either, because the energy density isn't possible with electrochemistry. Plus, for motorsport to be exciting we need a visceral experience, and that includes noise."

This brings us back to the concept of liquid fuels. With around 50 times the energy density of battery storage and steeped in over a century of automotive tradition, they remain pretty much the ideal solution if you can overcome the environmental concerns. ►

away from it. But petroleum itself is a fantastic set of chemicals, both for energy and as the basis of everything from plastics to pharmaceuticals. It simply isn't feasible to move away from petroleum, so the question is how do we make it synthetically?"

This is a question that comes back to motorsport, as well as the wider world. Although the actual carbon footprint of motorsport is tiny – certainly when you look at the cars themselves – it's an



Chief among these is CO2 production. But if your fuel is based on CO2 that's been extracted from the atmosphere, you can burn it without any net increase. Instead, your engine - be it a thumping NASCAR V8 or a screaming naturally aspirated V12 – is purely recycling that which already exists. Not only does that make the fuel carbon-neutral, but it raises the very real prospect that the powertrain could have less environmental impact than a battery electric

system with rare metals extracted from opposite ends of the globe.

That's not to say that synthetic fuels are a straightforward solution, but that's where Zero Petroleum comes in - Lowe's new venture with Nilay Shah, Professor and Head of Chemical Engineering at Imperial College London. Founded in 2020, the company aims to upscale the production of synthetic petroleum and establish its own production facility.

Energy Density: the Unbeatable Advantage of Hydrocarbons

Specific energy and energy density of a range of fue options, taking into account typical tank weights (lower heating value).



High Performance Vehicles: Energy Density is Critical

ABOVE First time around at Williams, Lowe oversaw the development of the active suspension that was responsible for the team becoming such a dominant force and Nigel Mansell winning the 1992 World Championship

COMPACTION, WORK TIME Emirates RANGE, PAYLOAD ENTERTAINMENT ULTIMATE PERFORMANCE RANGE, PAYLOAD RANGE, PAYLOAD





LEFT The politicians might love them, but the issue of energy density ensures that batteries cannot always be the go-to answer

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CARBON CAPTURE

This isn't the first time that someone has looked at producing synthetic fuel on a commercial scale. Nearly a century ago, German chemists Franz Fischer and Hans Tropsch developed a process for creating liquid hydrocarbons from carbon monoxide and hydrogen. This was used extensively in Germany during World War II to produce synthetic fuels from the country's vast coal reserves, with production peaking at 124,000 barrels per day in 1944. The same process was later used in South Africa when sanctions on the apartheid regime made natural oil hard to come by.

Zero Petroleum is one of a number of organisations that now plan to harness the Fischer-Tropsch process to produce sustainable hydrocarbons. Instead of getting carbon monoxide and hydrogen from the gasification of coal, they use electrolysis (for the hydrogen) and direct air capture (for carbon dioxide, which is then put through a reverse water-gas shift reactor to create carbon monoxide).

The end result, according to Zero Petroleum's calculations, is that 1.46 kg of water and 3.07 kg of carbon dioxide can be used to create 1 kg of hydrocarbon (and 3.53 kg of oxygen). Both the electrolysis and the direct air capture require significant amounts of energy, but this is taken from renewable sources, which would most likely be located on-site Talk to people about making clean gasoline from air and water and they look at you like it's alchemy"

with the facility itself.

Initially, the company is targeting relatively small volumes, but the intention is still to function as a commercial supplier rather than simply a technology developer, Lowe explains: "Our priority is to produce actual fuel and start to give industries non-fossil alternatives that aren't available today. It's very much not about spending 10 years in the lab."

FAST-TRACKING CONCEPTS

This philosophy of fast-tracking concepts through to production is part of the F1 mindset he says: "Engineering in Formula 1 is all about making the car faster and bringing out those improvements as quickly as you can. You can't sit on your great ideas and wait for them to be perfect, because the other teams will be out there winning races. If your analysis says a new idea will deliver lap time, you get it on the car, and then perhaps you can get another 10 per cent of that improvement by refining the concept once it's out there. And that's what we want to do with Zero Petroleum – get out there and start developing the market."

The company has a number of live R&D projects currently. The scale of the operation will depend on how those pan out and how the enterprise is funded, Lowe notes, but the scenarios range from two or three barrels a day up to maybe 100 barrels a day [roughly 500 litres to 16,000 litres per day]. That's minute by oil company standards, but even at the lower end of that spectrum it could theoretically supply a whole motorsport series.

In terms of chemical processes, the weakest link in the chain at present is the direct air capture of CO2. There are already commercially available technologies that will do exactly that, but they tend to be expensive and inefficient. Earlier this year, Tesla and SpaceX

founder Elon Musk announced a \$100 million prize for carbon capture solutions. The Carbon Removal X Prize will run until April 2025. It's believed to be the richest prize incentive in history and it's aimed at systems that can be scaled to the gigaton level.

"Direct air capture of carbon dioxide is the biggest gap in our current technological repertoire on this planet," comments Lowe. "Over the next decade we expect to see these systems start to become much more practical and economically viable at scale. And synthetic fuels will be one of the drivers for that **>**



It will be quite easy to overcome this growing concept that combustion engines are bad"

because you need more than prizes; you need actual use-cases to drive the technology and the investment."

While direct air capture remains in its infancy, Zero Petroleum is also looking at CO2 captured from industrial sources. In most cases this would normally be vented to the atmosphere, so it still has the same net effect, the company points out.

MORE POWER

6

The other challenge is the sheer amount of energy that's required, especially with the renewable electricity infrastructure remaining quite limited in much of the world. Consequently, Zero Petroleum's plans chiefly focus on small-scale plants that are matched to relatively small-scale distributed power generation. As such, the hydrogen and carbon dioxide could







be captured, combined into hydrocarbons and distributed as a fuel, all from the same site. That's not to say it couldn't be upscaled, however, notes Lowe: "In some respects, it's actually harder to do this sort of thing on a small scale because the economics aren't in your favour. I think there's a model for renewable power generation on the sort of scale we now see with coal or gas, but it will be deployed in more remote locations that aren't suitable for other purposes – perhaps where heat or desertification has rendered the area inhospitable. We're already seeing huge solar farms spanning many, many square kilometres in India, China and the Middle East."

The MBR Solar Park in Dubai's southern desert, for instance, covers a total site area of 77 km² and plans to ramp up to a capacity of **>**

FF Direct air capture of carbon dioxide is the biggest gap in our current technological repertoire on this planet"

5,000 MW by 2030. This would put it at a similar level to the world's largest gasfired power stations.

Of course, having all that electricity at your disposal begs the question of why you wouldn't simply use it in its existing form. By Lowe's own estimates, only around 15 per cent of the energy generated by the renewables plant will actually reach the wheels of a vehicle running on synthetic fuel, once all the various losses have been cascaded. In contrast, that figure for a battery electric powertrain might be 70 per cent.

"It's what I call the displacement argument," he says. "And for some applications it makes a lot of sense. For normal everyday road cars, I think electrification will be a much better route, if we can make it work. But there are some applications where I simply can't see it happening. The obvious one is air travel, but there are also lots of others. A combine harvester, for example, is a machine with very high power demands that works for long periods without a break [which means it needs dense energy storage]. On top of that, it has to drive on loose ground where soil compaction is a problem, so you can't just keep adding weight. There's no real alternative to a petroleum-based fuel in that sort of application."

SYNTHETIC FUELS ADVOCATE

The same very much applies to motorsport. At an estimated 650 kg, the 93.4 kWh battery pack in the Porsche Taycan Turbo weighs more than an entire V8-era F1 car. It's hard to imagine such technology ever completing an hour-long grand prix, let alone a 24-hour endurance race in the format that we know today. Ironically, Porsche is another keen advocate of synthetic fuels. Last year, the company announced it was investing €20 million in a joint project with Siemens Energy to produce synthetic fuels in a new plant in South America. The facility, which is set to open in 2022, hopes to produce 55 million litres of

synthetic fuel per year by 2024, and roughly ten times that amount by 2026. Motorsport has been cited as one of the first uses of the fuel, along with the vehicles at Porsche's Experience Centres, with road-going applications to follow. In a recent interview with BBC Sport, Porsche Motorsport vice-president Fritz Enzinger mentioned that a return to Formula 1 would "be of great interest" if the implementation of synthetic fuels was to be included in the new engine regulations due to be introduced in 2025.

As with Porsche's project in South America, Zero Petroleum's aim is to produce drop-in fuels that don't require any modifications to the engine itself. However, there is scope to tailor their formulation to provide specific attributes, such as increasing knock resistance to enable higher compression ratios.

Although these fuels can be completely







ABOVE Toto Wolff, Niki Lauda, Lewis Hamilton, Paddy Lowe, Andy Cowell and Nico Rosberg celebrate the third consecutive Drivers' and Constructors' Championship for Mercedes-AMG Petronas Motorsport at the end of the 2016 season carbon neutral, careful attention would still need to be paid to other emissions such as nitrogen oxides (NOx). However, synthetic fuels are inherently free of contaminants such as sulphur, which are involved in the formation of many of these pollutants. As such, they are inherently clean-burning and unlikely to cause issues with air quality – particularly if they're used away from towns and cities.

"When you talk to people about making clean gasoline from air and water they look at you like it's alchemy," comments Lowe. "But once you break it down, it's actually quite easy to understand, and the next question they ask is 'when can I have some?' So I think it will be quite easy to overcome this growing concept that combustion engines are bad.

"We need to start by getting synthetic fuels out into the market and putting up the message that petroleum isn't actually bad; it's the sources of the petroleum that we're using currently that cause all these unwanted problems. In fact, there's nothing wrong with noise, with a visible display of energy or even with what we currently think of as waste energy [such as heat] if it's going back into a circular system." He's clearly lost none of his enthusiasm for the visceral world of motorsport, so could Lowe be tempted back to F1? "Not really, no," he replies. "I spent more than 30 years in Formula 1 and achieved a lot, but I've been very busy doing this work, which I really enjoy.

"It's great to actually embark on some new ventures. I still love motorsport, though. And I still love cars, engines and horsepower. So to find a way to bring the two together is very interesting."

If his F1 career is anything to go by, you can expect this latest project to be pursued with the same zeal and determination. It may not scoop any world championship accolades, but there's a possibility that this work could be more important still – particularly for those of us who look forward to enjoying combustion engines for many decades to come. THAT SYACING EEELCG

The ability of Cosworth's ground-breaking AliveDrive system to dovetail video and data has ripped up the traditional 'Driver's Book of Excuses' in the British Touring Car Championship. Now it could transform the way we follow motor racing too. **Chris Pickering** explains

CONTEXT is vital in motorsport. A slight change to one of the control inputs at a crucial point on the track can be the difference between pole position and the second or third row. It can also be the difference between a blameless racing incident and a deliberate transgression.

Bringing that additional context to video data is the aim of Cosworth's AliveDrive system. Based around the company's Pi Toolbox analysis suite, it began as the backbone of the Performance Data Recorder (PDR) system fitted to General Motors' high performance road cars. The idea was to give track day enthusiasts a user-friendly environment in which to review their data and get more out of their cars.





ABOVE & LEFT AliveDrive captured the attention of the motorsport world as an unobtrusive 'spy in the cockpit' in the British Touring Car Championship

RIGHT The capability to synchronise video and data over a high-speed internal bus has transformed the stewards' ability to police the ultra-competitive British Touring Car Championship

It wasn't long before AliveDrive went full circle and returned to motorsport as a mandatory incar video logging system for the British Touring Car Championship (BTCC) in 2015. It's also been used in various GT racing applications, including the Porsche Carrera Cup series and the Renault Sport R.S. 01.

"The original system was aimed at track days. The idea was to give people the opportunity to use data with their normal car," explains Gummi Gudmundsson, automotive programme manager at Cosworth. "That soon caught the eye of [BTCC organiser] TOCA because it could be integrated quite easily into the cars."

Replacing the old Fuji digital video cameras with the AliveDrive system was quite straightforward, he recalls. The key distinction is that the video feed is synched directly with data taken from the car's own sensors (just as it is in the PDR).

"If you look at the overlay for AliveDrive on

Our vision is that someone could open the data on their phone and immediately see maybe three opportunities to go faster"

a PDR, the data it gives is things like engine rpm, vehicle speed, throttle, steering input and brakes," comments Gudmundsson. "These are all sensors that were already fitted to the BTCC cars as part of the standard electronics package that we supply. They're already being recorded by the standard data logger that the teams use, and that logger passes the information on to **>**





I must admit I do miss some of the more creative excuses the drivers would come up with before we started using this system" the AliveDrive system."

Power comes from the vehicle's own battery in normal use. A small secondary battery acts as a 'keep alive' system in the event of a cut in power and will continue to record for 30 seconds even after the system is switched off. The data is then recorded to a memory stick that can be taken by the stewards for review.

THE KITCHEN SYNC

On the face of it, the task of marrying up a video feed with data from existing sensors

doesn't sound especially complex. The widely-used MP4 file format that Cosworth employs is even specifically designed to store data along with the video (albeit usually things like captions or subtitles). But synching the two together on a frameby-frame basis is far from straightforward.

The CAN network that's used to transmit the data doesn't work instantaneously – there is a finite amount of time between the data being sent by one device and received by another – so AliveDrive has to actively sync the two together to prevent any lag.



"There are two processors inside the BTCC system. One that acts as a vehicle interface, which takes the data and sorts it, while the second is a dedicated multimedia processor that handles the video. The two talk to each other over a high-speed internal bus," explains Gudmundsson. "The multimedia processor is very powerful. That handles all the calculations, so the vehicle interface processor just handles the CAN traffic."

Needless to say, the system gets plenty of use in the BTCC, with its famously physical driving style. Usually, it's called in to settle disputes where two drivers' accounts of an incident differ.

ARGUMENT-STOPPER

"Of the many technical attributes of the AliveDrive system, the one I appreciate the most is how it hugely reduces the amount of time we spend investigating incidents," says BTCC chief executive Alan Gow.

"When a driver and/or team manager sees the onboard footage combined with the data of the driver inputs, it's usually an argument-stopper; it's plain to see what and how it happened and no amount of blather can overcome the facts put in front of them.

"Although," reflects Gow with a wry smile, "I must admit I do miss some of the more creative excuses the drivers would come up with before we started using this system..."

One of the key benefits of using a fully-synched system is that the recordings from two separate cars can be compared based on distance rather than time. For instance, if a driver normally brakes at the **>**



LEFT & BELOW

The technology was harnessed in the

Performance Data

Recorder used by GM

to differentiate itself in

the high performance

automotive market





LEFT It's now possible to import, sync and analyse PDR (Performance Data Recorder) recordings with the AliveDrive Race app

The system works pre-emptively to pick the most accurate distance channel under any given set of circumstances. For instance, on front-wheel drive touring cars, which have a tendency to lock the rear brakes, it will filter out those channels as soon as the brakes are applied. Likewise, under heavy acceleration it ignores the driven wheels.

One of the Cosworth engineers' jobs at the start of a BTCC race weekend is to set up an infrared timing beacon that's used by the onboard electronics in each car for its own lap measurements. This allows AliveDrive to break up the data into individual laps, as well as looking at elapsed time and distance covered. Alongside that, a MyLaps transponder system is fitted to every car for official timekeeping. ►

> A 'keep alive' system will continue to record for 30 seconds even after the system is switched off"

100-metre board for a particular corner, it's possible to compare this to the lap when an incident has occurred.

"You can spot the trend over a number of laps," points out Gudmundsson. "So if a driver is accused of brake-checking someone on lap 10, for instance, you can take the nine laps beforehand and stack them all together to show what is normal behaviour for that driver in that corner."

Using distance rather than time is said to bring greater precision to the review process, whether it's for stewarding or performance evaluation: "If you did it based purely on time, it would be very difficult to sync two cars accurately. With distance, you know exactly where the two cars are, so you can truly compare like for like. It's less useful if you're just looking at one car over one lap, but distance mode is the way forward if you need to compare something side-by-side."

Cosworth's distance measurement comes from a series of wheel speed sensors. This approach might come as a surprise in an era when GPS can be found in everything from smartwatches to dog collars, but Gudmundsson says it's generally more accurate and more reliable in a racetrack environment.

"GPS tracking can be very useful in some situations, but it's not 100 per cent reliable and the signal sometimes loses its integrity," he notes. "We've used wheel speed sensors to measure distance for more than 20 years and we have developed specific algorithms to help us filter the data."

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FUTURE PLANS

An updated motorsport version of AliveDrive with new hardware and software is planned for sometime after this year. Cosworth has confirmed that it will be made available to anyone who wants it, although it's not yet clear whether the BTCC will switch or what the timeframe might be if it does.

The exact specification has also yet to be confirmed, but it's likely to support more cameras and higher resolution. Up to 4K is possible, although there's a debate going on currently as to whether the large file sizes involved would be a help or a hindrance for jobs like stewarding and driver coaching, where broadcast quality video isn't generally a priority.

Another option that's being considered is to provide a streaming experience to fans. The idea of an app that could supply onboard footage and data from your favourite team or driver has been around for some time, and it's a concept that seems to have gained more traction in some parts of the world than in others.

"We work with IndyCar a lot in the States. Their app uses a different platform at present, but it takes data from our systems that are on their cars. It's the sort of thing we'd love to see AliveDrive used for in the future," comments Gudmundsson. RIGHT A new version of AliveDrive is expected when the BTCC's hybrid system is introduced next season, complete with Cosworth's latest generation in ECU race technology: the Antares 8 Series

BELOW The frantic nature of the tin-top rough and tumble can now be unravelled with AliveDrive, giving drivers nowhere to hide in the event of contact







For the track day market, one of the next steps could be to increase the level of automation applied in the analysis so the app not only presents the data, but actively advises the driver on where and how they can gain time.

"What we want to do is bring our motorsport experience to track days. So, for instance, it might highlight braking into a particular corner as an area where time is currently being lost," comments Gudmundsson. "Our vision is that someone could go around the track in their road car, take the data off the car then open it on their phone and immediately they see maybe three opportunities to go faster."

TARGETING THE RIGHT DATA

AliveDrive provides the ideal platform to draw these sorts of comparisons, but the skill remains targeting the correct data. Within a professional team there's usually another driver facing the same conditions in an identical car, but that's not always the case on a track day. Nonetheless, it's still possible to gain insights from the data. **BELOW** The system has proved popular in the GT ranks, such as the Porsche Carrera Cup series

The wheel speed sensors approach might come as a surprise in an era when GPS can be found in everything from smartwatches to dog collars"

As the driver builds up a series of laps it becomes possible to calculate an 'average' lap and hence identify instances where they've gained and lost time. This algorithm has to apply a certain amount of intelligence to ensure that it is a valid benefit over the whole lap (as opposed to something like a lastminute dive into a corner that improves one sector to the detriment of the next).

"The easiest way to do this is to look at the lap time," notes Gudmundsson. "If that's within a certain percentage then you can say with reasonable confidence that it was a valid lap, whereas it's more likely to be an anomaly if one particular sector was great but the overall lap time was slower."

In an increasingly digital world, the ability to store this data on the cloud, compare different laps and share it between friends has already demonstrated its popularity among track day enthusiasts with the PDR. In professional motorsport, the stewarding process for series like the BTCC has also benefited significantly from its comprehensive yet userfriendly platform.

With processing power, camera technology and connectivity continuing to improve all the time, you can bet there's plenty more to come.



STARTING A *REVOLUTION*

Luke Ramsey examines the rise of the Revolution Race Cars A-One from an audacious idea to the giddy heights of the F1 support bill

N October 25, 2018, the first Revolution A-One had a shakedown at a chilly Snetterton. James Abbott, Formula 4 race winner and son of company founder Phil, took to the track in the camouflaged sports racer. That moment for the family album was a result of months of intense and secret work, the culmination of their vision to create a genuinely – or revolutionary – customer sports racing car.

Fast-forward to October 25, 2020. Nineteen drivers took to the grid in Revolution A-Ones at the Portuguese F1 Grand Prix Sports Prototype Cup support race, just a couple of hours before Lewis Hamilton claimed his 92nd Grand Prix victory to become the most successful driver in Formula 1 history. Whilst Lewis made the headlines around the world, Revolution was also creating a truly impressive British motorsport technology and export story.

In a year when many motorsport businesses stuttered, we take a look at how Revolution went from being a bold idea to an official F1 support race in only two years.

ONE VISION

Revolution may be a new name, but it has an experienced team with a clear vision. Co-founders Romain Rousseaux and Phil Abbott had extensive experience in customer sportscar racing with a long history at Radical. Rousseaux was the distributor for Radicals in France and Abbott was one of the co-founders of the bike-engined race car pioneers back in 1997.

Abbott led a team that produced over 2,000 cars in 20 years. The lightweight spaceframe series of Radicals proved immensely popular, but Phil was thinking ahead to what customers would be looking for as a next step beyond their Radical racing. Research showed that customers had three growing considerations. Firstly, performance should be intense and well beyond a GT-level car but delivered in a way that is friendly, accessible and predictable. Secondly, maintenance costs should be low. Cars such as the Revolution and Radicals are often operated by arriveand-drive teams and minimising downtime is vital for customer satisfaction and operator profitability.

Finally, but most importantly, customers were becoming more demanding on safety. Spaceframe cars are the norm in club racing but at LMP3-level and above, carbon fibre construction, FIA crash test compliance and driver protection had set new expectations for the typical 'bronze' or amateur customer racer. ►

We've created an LMP-type car at half an LMP3 price"

LEFT The Revolution A-One is a prototype sports racer designed to fill the gap between traditional spaceframe chassis cars and LMP machinery

65





"Instead of trying to make a newer Radical, we've created an LMP-type car at half an LMP3 price," explains Abbott. "For owners of older tech spaceframe cars, it's a huge step to move up to something like an LMP chassis, and there are always customers wanting to step into something faster, safer, more progressive."

That's what set Abbott and his team on the path to create a new segment in the racing market. There's no such category as LMP4, but if there were, it would probably look a lot like this. The Revolution A-One is a prototype sports racer designed to fill the gap between traditional spaceframe chassis cars and the costly, full-blooded LMP machinery of the ELMS or IMSA series. LEFT The spacious cockpit was designed with the comfort of amateur racers in mind The A-One in Sports Prototype Cup specification features a carbon tub, carbon floor and bodywork, weighs just 795 kg and boasts a 400 hp 3.7-litre V6 with a six-speed paddle shift gearbox at its heart. The result shatters the 500 hp per tonne barrier. All the Revolutions are powered by RLM Racing-built engines. They are mated to a gearbox that features internals and a bespoke casting by 3MO and use Life electronics.

SAFETY FIRST

BELOW LEFT The carbon tub is created with an infusion process developed by DD-Compound

BELOW Revolution worked in partnership with CFD expert TotalSim, using its Bramble platform to ensure a stable centre of aero pressure for consistent handling The carbon tub is made with an infusion process. This was developed by German company DD-Compound, which is also responsible for chassis production. It is the first FIA-certified carbon monocoque that is infused in one shot, including all layers, core and inserts.

This process creates a tub that is as stiff, light and strong as a pre-preg chassis, but at a significantly lower cost. This was key to Revolution's vision of having LMP-level safety at a price point (\pounds 139,000) where customers were There's no point in having frenzied performance in a fickle package: a customer racecar has to be easy to run"

used to older spaceframe technology. It seems unusual to describe a racecar as spacious, but realising that a typical amateur driver could be perhaps a little less svelte or athletic than a teenage kart racer, Abbott was determined to create a car that had ample space for a burly driver to share with a racing coach or corporate day passenger.

Romain Grosjean's incredible escape at last year's Bahrain GP highlighted the benefits of the Halo head protection structure. Revolution has brought the same technology to the sports car market and claims a worldfirst with its 'double halo' design. The double halo, inspired by the head **>**



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protection structure mandated in Formula 1 at the beginning of 2018, is the first halo-type structure to be developed for a two-seater, open-top, sports prototype.

This new structure bolts to Revolution's advanced carbon-fibre monocoque and both the double halo and the chassis are compliant with the latest FIA Article 277 safety standards. The double halo is manufactured from 50.8 mm diameter ROPT510 seamless tubing, exceeding the FIA minimum diameter requirement by over 12%.

"By introducing the double halo we are giving drivers and their instructors or corporate guests the same level of safety they would expect in a world championship-type racecar," adds Abbott.

The unique double halo gives the Revolution similarly high safety standards to closed-cockpit Le Mans cars but without the complexity of accessibility, door structures and cooling systems that can add unwanted weight – it only adds 2 kg. ABOVE The 'double halo' is hailed as a world-first and will become compulsory in the European Sports Prototype Cup events

LEFT The 3.7-litre Ford V6 has proven reliability, high-end performance and low running costs

RIGHT The upright, which can be used on any of the four corners, is typical of the attention to detail The device has been tested by several drivers, including Sir Chris Hoy. The Olympian, who has experience of racing LMP2 cars at Le Mans, says: "The double halo gives a real sense of security and still has great visibility. I didn't even notice it once up to speed."

To create a car that could thrill and reassure at the same time, Revolution worked in partnership with leading industry expert, TotalSim. Revolution used advanced simulation tools to create a car able to



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Today's technology in yesterday's cars





A new name, but an experienced team with a clear vision"

generate more downforce than any rival, with a stable centre of aero pressure, delivering a dependable, consistent handling and feel.

The Revolution's suspension includes a pushrod and rocker setup, with three-way dampers, and the unique ability to swap several components from one side to the other, greatly reducing the need and cost of spare parts. This means a team only has to carry one upright, which can be used on any of the four corners just by attachment brackets in a different orientation. It's this kind of attention to detail that shows how Abbott and his team know their customer, stating: "There's no point in having frenzied performance in a fickle package: a customer racecar has to be easy to run."

DRIVING FORWARD IN NORTH AMERICA

In the UK and European markets, the Sports Prototype Cup features a dedicated Revolution class. It's set to have eight races at four circuits in 2021, giving the A-One an established place to race. Revolution aims to build on the 17-strong grid peak achieved in the Cup's first full season last year.

Outside of the Cup regulations, the A-One is also available in an unrestricted 427 hp tune. After the success of racing in Europe, another batch of Revolution



ABOVE A race on the Portuguese GP support bill has acted as the perfect callingcard for the company

BELOW The striking looks are matched by the car's performance

A-Ones has been exported to the USA, creating a storm on the track day scene and a North American championship is on the cards next year. With dealers already appointed in the USA, including Esses Racing in Austin, Texas, Revolution is well placed to grow.

"Since our first F1 support race, our customer enquiries have increased four-fold," says Abbott. "Everybody who has ever bought a sports-racing car in America seems to have contacted us recently. The interest has gone global because we've put ourselves on the right stage."

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DOES HISTORY LEAVE US FOUR-WARNED?



All-wheel drive is on the agenda for Formula 1's new era, but do we need it? Sergio Rinland plays devil's advocate

OW! It was some revelation that Formula 1 may go for AWD in 2025. With my designer's hat on, I love it (albeit with some reservations).

This is not the first time we have been in this territory, though.

In 1947, right after WW2, Piero Dusio hired Porsche Studio (as it was known then) to design the Cisitalia Grand Prix car. The idea was to build a modern version of the successful pre-war Auto Union.

The result was a car way ahead of its time. So much so that if it could have raced, it would have left everybody else for dust: mid-engine; 1500 cc; **BELOW** Will the cars on the grid in 2025 be equipped with four-wheel drive? It's one of the options on the table flat 12; supercharged, delivering 327 HP; sequential gearbox between engine and diff and... 4WD, with a caveat – the front differential could be disconnected. A jewel that I admire to this day. We had to wait 12 years to see another attempt, the Ferguson P99 F1 car. This, perhaps, was not to the exquisite detail of the Cisitalia-Porsche 360, but it was also designed with 4WD – this time, permanent. It was not so successful, one of the reasons being that Cooper, taking the mid-engine concept and a pragmatic approach, changed F1 design for ever.

When in 1967 Formula 1 changed its rules and went to 3-litre engines, it was thought, rightly so, that with the tyre technology at the time it would be very difficult to put all that power on the ground, particularly in wet conditions. Hence, after a very wet season in 1968, three F1 teams, McLaren, Matra and Lotus, decided to implement the 4WD concept. Cosworth also built a complete car, designed by Robin Herd. All of them adopted the Ferguson concept and some of them even got Ferguson to build the transmission. Those were ready for 1969, a very dry season!

With the improvement in tyres, however, and subsequent adoption of aerodynamic devices, it transpired that 4WD was no longer the way to go. The concept was abandoned.

When I first started to play with the idea of electric cars, 10 years ago, I designed a concept car with four electric motors, one per wheel, in-board. I thought at **>**





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the time, that if we reduce aerodynamic downforce by banning wings, an AWD car would be ideal. Then we had LMP1 adopt the idea of electric front drive, which we see up to this day.

But – and isn't there always a 'but'? – do we need AWD in Formula 1 today? Do we need the complexity? The cost? The weight? If I put my 'pragmatic' hat on, I would say no.

The explanation for entertaining the return of fourwheel drive is to be able to reduce even further the ICE and to recover the wasted braking energy from the front axle. If we look at the dynamics involved, we will need more than 600 kW (800 HP) to recover all that energy.

If we compromise in recovering half of that, we still need a good 300 kW MGU plus a differential or $2 \times$ 150 kW for each wheel. If we consider a weight of about 20 to 30 kg and a volume of 7 to 8 Lts, it is a huge engineering challenge. Here I am not even considering the cost of such a unit.

What we are witnessing here is the rule-makers being the agents of innovation, not the car designers. They make the rules to 'plant' a technology, to then limit its development to curb costs and spiralling performance. Hence, putting my 'rebel' hat on, I don't like it that much. We will have heavier, bigger cars and very limited room for manoeuvring.

Last month we said in these pages: 'F1's prime objective is to be a good spectacle. Without that, every other discussion is irrelevant'. Will AWD RIGHT We've been here before: fourwheel drive was just one of the weapons in the formidable armoury of the Type 360 Cisitalia, developed by the Porsche Engineering Office after WW2



improve the spectacle? I doubt it. If anything, it will make it more predictable.

If the rule-makers want innovation to attract OEMs (a doubtful strategy), I will repeat my 'cantilena' (singsong in Italian): open the rules, limit energy, power and downforce and let the engineers do the innovation. Then we may learn something.



Putting my 'rebel' hat on, I don't like it"

LEFT With an MGU on the front axle, operating as an electric motor to drive the front wheels, LMP1 cars became all-wheel drive

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