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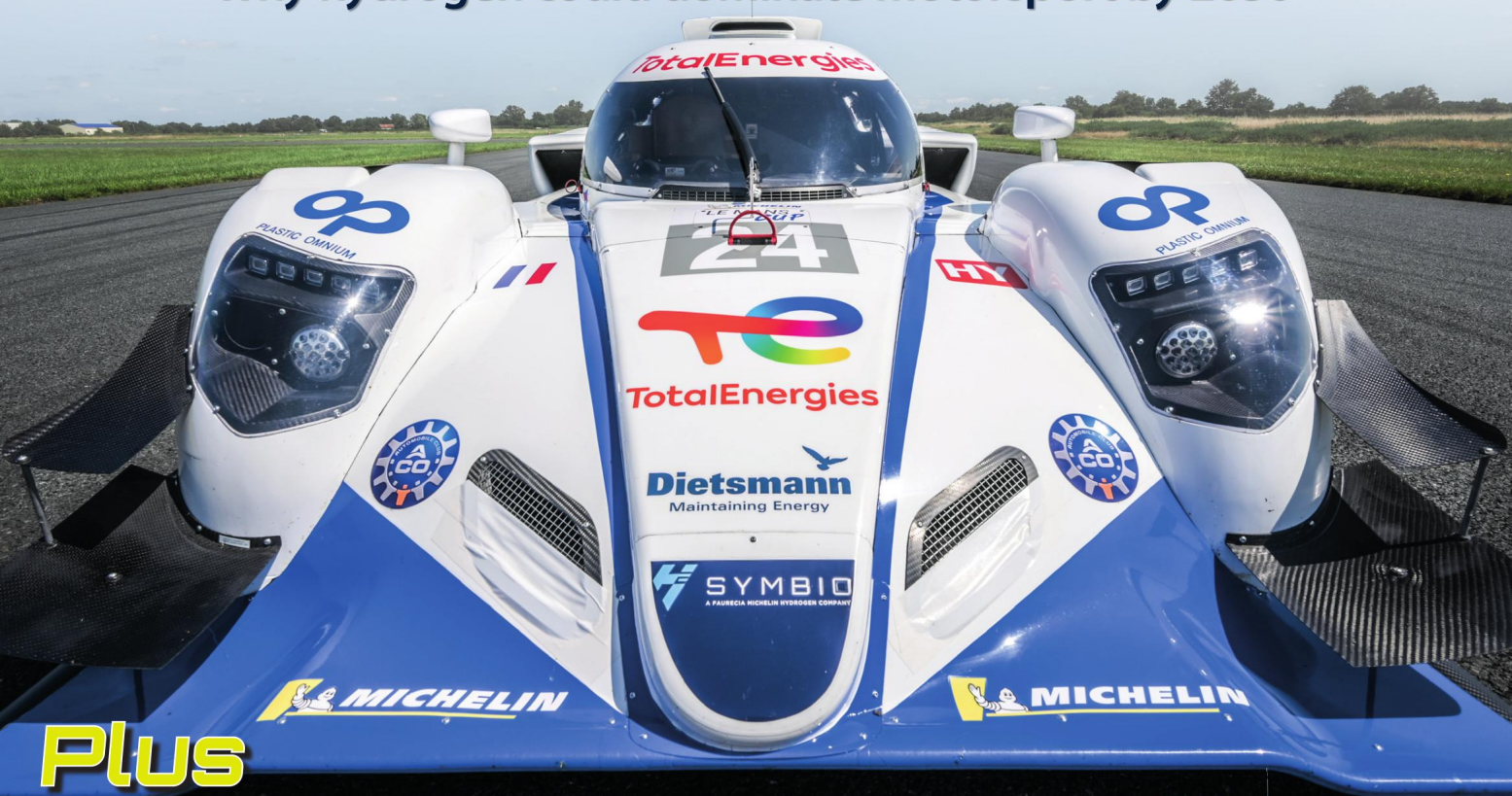


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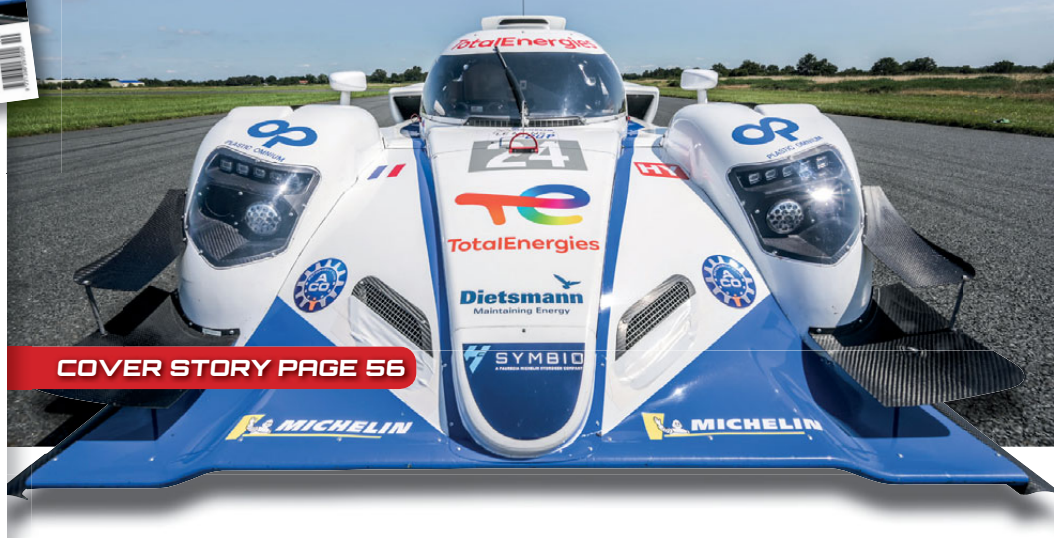
# HYDROGEN
## The final frontier
### Why hydrogen could dominate motorsport by 2030

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# ENERGY OF THE FUTURE?

**I**T was impossible to ignore the theme of sustainability that underpinned almost everything that happened at this year's Le Mans 24 Hours.

The Automobile Club de l'Ouest, founder and organiser of the event, unveiled its Corporate Social Responsibility (CSR) strategy. It also announced its new Sustainable Endurance Award, presented by DHL. The award will recognise a competitor's CSR approach, with emphasis on the progress made from one year to the next.

There was a prominent role for the ACO's 'poster boy', the H24, the hydrogen-electric prototype featured on the cover of this issue. The H24 is paving the way for the cars that will compete in the 24 Hours in 2025. That target was originally 2024, but has understandably been delayed by the impact of the COVID pandemic.

Cynics might suggest it is apt that the timescale for the introduction of the hydrogen class at Le Mans is slipping. After all, hydrogen has been the 'fuel of the future' for as long as most of us can remember. But always the timescale for its true arrival recedes away from us.

That's why it took Chris Ellis, the author of our cover article, so long to convince me that we should run his feature. His claim that hydrogen would be a major player in much of motorsport by 2030, was, I suggested, preposterous.

But then a strange sequence of events unfolded as the article was put together.

First, F1 MD of motorsports Ross Brawn acknowledged to the BBC that hydrogen could be a genuine contender for Formula 1's next-generation powertrain. Then, the UK government published its much-anticipated Hydrogen Strategy, which sets out how it will meet its ambitious target of 5 GW of low carbon hydrogen production capacity by 2030.

The hydrogen economy, it claims, could be worth £900 million, creating over 100,000 jobs by 2050. Government analysis suggests that 20-35% of the UK's energy consumption could be hydrogen-based by 2050.

Just before we went to press, ACO president Pierre Fillon revealed that the hydrogen class has been devised to fight for overall victory at Le Mans. It could, he suggested, even win the 24 Hours by 2026 if the right manufacturer decides to invest its effort in developing the fuel-cell technology.

When journalists raised their eyebrows at this, he reminded them that people thought Audi was crazy when it proposed developing a diesel engine for the race.

There are, divulged Fillon, eight manufacturers sitting around the table in the hydrogen discussions.

As experts point out, the physics, chemistry, and engineering challenges of hydrogen have not changed, but the context for its use has. The need to meet the target of limiting global average temperature rise to 1.5 degrees Celsius will force industries into aggressive decarbonisation.

Hydrogen could have a big role to play. So could motorsport…

William Kimberley
**EDITOR**

# FUTURE OF POWERTRAIN TECHNOLOGIES IN THE SPOTLIGHT

Experts suggest that in the quest for a more sustainable future, powertrain choice must avoid short-term thinking. **By Mark Skewis**

**BOMBARDED** by batteries? Rejuvenated by renewable fuels? Hyped up by hybrids? Or handed a lifeline by hydrogen?

Where being spoilt for choice once referred only to the number of cylinders you opted for in your engine, motorsport now finds itself with more options for propulsion than ever before. And with more danger of chasing the wrong solution.

With the sport at a crossroads, which direction should we head? A recent FIA conference offered a few clues.

A fascinating and detailed discussion joint plenary on 'The Future of Powertrain Technologies: Towards Sustainable Motor Sport and Mobility' pointed to a balanced approach to energy sources being the key to building a cleaner future.

Speaking first, Motorsport UK Chairman David Richards said that in the pursuit of sustainable motorsport it is important not to disenfranchise existing competitors and that outside top-level motorsport sustainable powertrains are best introduced at junior level.

"We have to achieve a balance," he said. "We have 30,000 members, licence holders, who have existing cars and want to participate and we also have a demand from the general public who wants us to move towards sustainability. We cannot disenfranchise existing licence holders but we have to show leadership. We should introduce it at junior levels. For example, cadet Karting is an easy level to introduce it at.

**BELOW LEFT** The ERA, the world's first all-electric junior race series, identified the need for young drivers to prepare for life in the EV racing ranks

"We have governments that are focusing on electric to the exclusion of everything else and we have to educate them that motorsport is a great platform for transforming transport very quickly."

In Mobility, Royal Automobile Club of Western Australia (RAC WA) Group CEO Rob Slocombe explained how the Club had been concerned by the lack of infrastructure in his region. In the absence of action at state level, the Club undertook the construction of 12 charging stations covering some 500 km of road. He explained that the government followed the action by committing AUS$21 million to infrastructure programmes.

However, he added that uptake of sustainable technologies in Australia will be slow as a result of the increasing popularity of diesel vehicles, coupled with the country's poor fuel quality.

"Average emissions intensity for passenger vehicles in Australia is 45% higher than in Europe," he ▶

**ABOVE** The session provoked a fascinating range of opinions

said. "According to our statistics, some 2,500 people die each year as a result of emissions, higher than the number dying in crashes. The government has said it will bring in new fuel standards in 2027. That's way too long and the longer it is delayed, the longer we will stay out of step with the world. We need to get more aggressive with our timeframes."

Motorsport Industry Association CEO Chris Aylett insisted that consumers are being dictated to by governments in a switch to electric. According to him, this is founded on the short-term view of politicians who will not be in power over the decades needed for the future of powertrains to be played out.

"The challenge is: what is the future? Is it 10 years? That's nonsense in technology terms. Is it 20 or 30?" he asked. "It's fascinating to see politicians who are in power for five years having to talk about 10-year timeframes because they want the votes. We are going to make mistakes if we put speed before common sense. Is the future all-electric? Not a hope. Too many nations can't adapt; can't afford it. Electric won't work everywhere.

"The internal combustion engine is a very efficient mode of mobility and has been so for 100 years. There is plenty of potential there if we weren't in such a hurry to go electric. With regard to sustainable fuels, I am quite sure we will go forward into the future with an urban electric solution and a non-urban solution. It is a great opportunity for the FIA to work with the supply chain in motorsport to rise to these challenges."

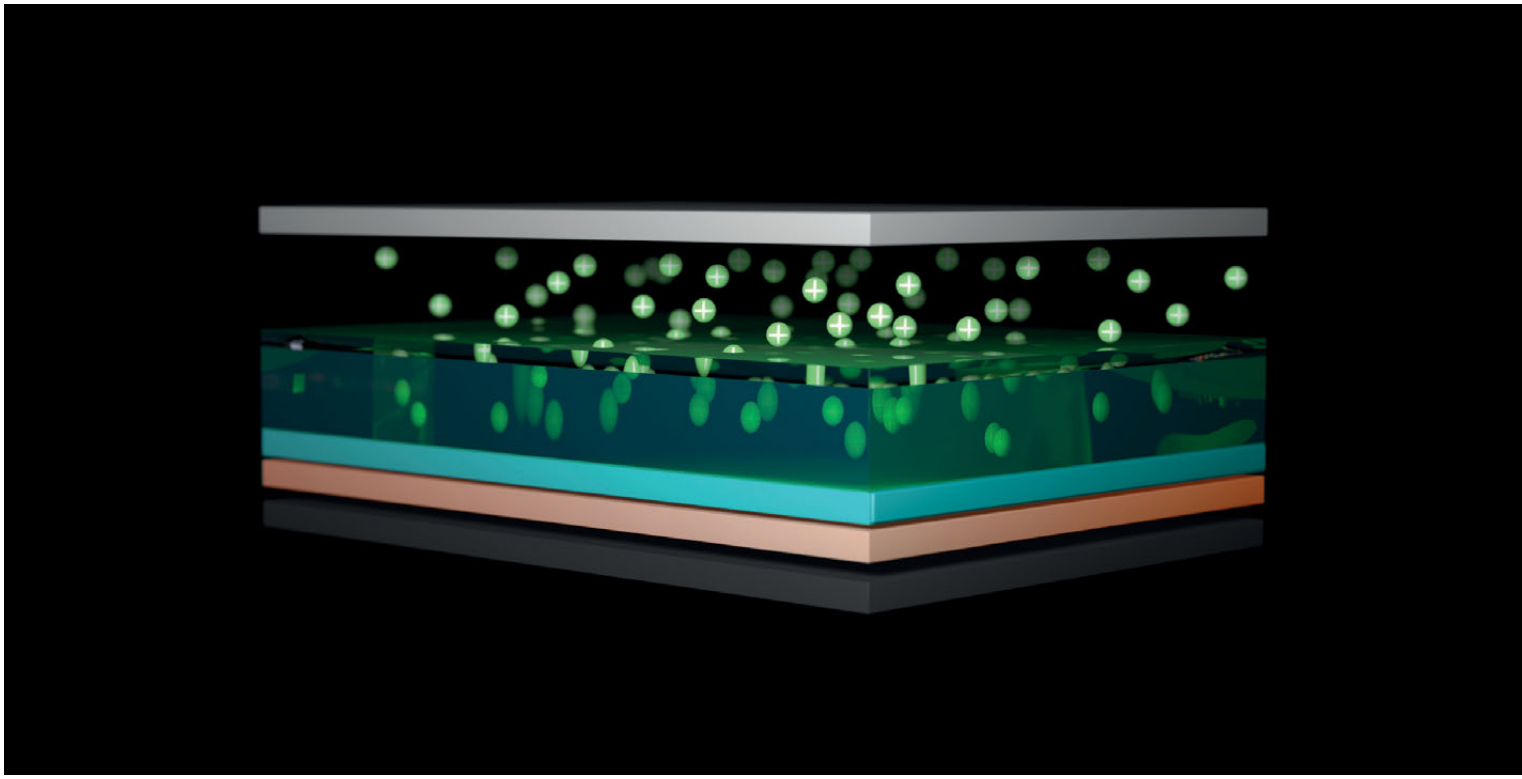
**RIGHT** Coryton is one of the pioneers supplying advanced fuels solutions


FIA Environment and Sustainability Commission President Felipe Calderón then raised the point that some forecasts suggest that as battery development improves, electric vehicles (EVs) could be "equal or even cheaper than combustion-engine vehicles. If that happens, there will be a huge change in the market. It will happen because of a rational decision by consumers to switch."

Rob Slocombe said that such an evolution was unlikely in his home country: "In Australia the average age of a vehicle is 11 years. It will take a long time for electric vehicles to come through. EVs are very, very expensive, about 60% more expensive. Yes, economics will drive change but it will take quite a while."

David Richards added that infrastructural change would also cause delay: "Many people's houses will only accommodate

**BELOW** Research into solid-state batteries, ideal for EVs and energy storage applications, could change the game




trickle charging and the national grid in the UK certainly is not equipped to deal with large numbers of cars charging overnight.

"For governments it is a simple message to give – let's go electric. Our role as Members of the FIA is to educate politicians and the public at large that there are alternatives. Our role is to be more agnostic on these technologies."

FIA Deputy President for Automobile Mobility and Tourism Thierry Willemarck agreed, adding: "We have to educate our members on the ways in which we get mobile. The one major reduction on C02 we have immediate access to is to not produce it. When you take the car, is it really necessary? Is it better to take a bike or the bus? We have to educate the population."

Austria's ÖAMTC CEO Oliver Schmerold said that powertrain choice had to be viewed in light of the energy production as a whole. He took delegates through his Club's analysis of the impact switching to either battery electric vehicles or e-fuels would have on energy production in light of his country's stated aim of carbon neutrality by 2040.

"When we talk about the future of powertrains – it is a discussion about the future of our energy system," he said. "More than 75% of primary energy demand comes from fossil fuel sources or nuclear power and only one quarter from renewable sources. We have to transform the energy system. The question of which powertrain we use is only a subsequent discussion of that change."

He then illustrated how reliance on sustainable fuels to meet emissions targets would result in a significant spike in the amount of renewable energy needed to create those fuels, whereas battery-powered vehicle use would result in a more benign increase.

**ABOVE** The Le Mans 24 Hours switches to a 100% renewable fuel next year, with hydrogen also poised to play a big role in the future

FIA Manufacturers' Commission President Prof Burkhard Göschel added that, in his opinion, battery electric vehicles in their current form are not totally sustainable and that the decisions of the EU have not been based on life cycle assessment and the demands being made on materials. Better electric sources are needed, he said.

"We have a lot of electric motorsport series and we should put a lot of purpose on pushing battery technology," he suggested. "I know the costs could ramp up but we have to push. If we go to solid state batteries and it fulfils the performance which has been discussed, it could outperform hydrogen fuel cells.

"The other area is sustainable e-fuels," he said. "We have existing infrastructure for liquid fuels and we have a very weak infrastructure for electric vehicles. We cannot neglect that."

The discussion concluded with a video Q&A with Automobile Club de l'Ouest (ACO) President Pierre Fillon who spoke about the future of hydrogen fuel cell powertrains in endurance racing and at the 24 Hours of Le Mans. "We believe that hydrogen is one of the best energies for future mobility," he said. "Hydrogen will play a key role in Le Mans in 10 years.

"We will have zero C02 emissions, with hydrogen as the top class, and e-fuels in the lower classes and we will stage an exemplary event in terms of social responsibility. Le Mans must remain an outstanding human adventure, a testing ground for mobility and a unique fan experience." RT


# Mercedes FE exit strengthens F1's hand in battle with Formula E

**FORMULA 1**'s plans to fend off the threat posed by Formula E were given a tacit vote of confidence by Mercedes-Benz last month. Just days after winning the first Formula E World Championship Drivers' and Teams' titles, the German manufacturer revealed that it will quit the series at the end of Season 8, in August 2022.

Some will be surprised by the move, given that the manufacturer announced only in late July that it will be ready to go all-electric at the end of the decade, where market conditions allow. But far from securing the Formula E programme, this accelerated ramp-up of electrification – including the development of three electric-only architectures to be launched in 2025 – actually signalled the project's death knell.

Mercedes acknowledged that it is applying the lessons learned in Formula E to product development in series, but insisted it needed to reallocate its resources.

When the brand entered the al-electric race series as a manufacturer in its own right, the inevitable question raised was whether this would hasten the end of its Formula 1 dynasty? Instead, it was noticeable that its exit statement said the company will concentrate its works motorsport activities on Formula 1, reinforcing the sport's status as the fastest laboratory for developing and proving sustainable and scalable future performance technologies.

This learning will be brought to life through future product architectures like the AMG.EA platform, the dedicated performance vehicle electric platform that will be launched in 2025, and projects such as the Vision EQXX.

Chalk this contest up as a victory for F1, which will placate its manufacturers by increasing the level of electrification in its next generation powertrains.

Markus Schäfer, Member of the Board of Management of Daimler AG and Mercedes-Benz AG; responsible for Daimler Group Research and Mercedes-Benz Cars COO, said: "At Mercedes-Benz, we have committed ourselves to fighting climate change at full force in this decade. This demands the accelerated transformation of our company, products and services towards an emission-free and software-driven future, and to achieve this, we must give full focus to our core activities.

"In motorsport, Formula E has been a good driver for proving our expertise and establishing our Mercedes-EQ brand, but in future we will keep pushing technological progress – especially on the electric drive side – focusing on Formula 1. It is the arena where we constantly test our technology in the most intense competition the automotive world has to offer – and the three-pointed star hardly shines brighter anywhere else. F1 offers rich potential for technology transfer, as we can see in ongoing projects such as the Vision EQXX, and our team and the entire series will achieve net-zero status by the end of the decade."

**ABOVE** Mercedes follows BMW and Audi in quitting the all-electric series

## Focus on Formula 1

Bettina Fetzer, Vice President Marketing, Mercedes-Benz AG, added: "Over the last two years, Formula E has enabled us to showcase the Mercedes-EQ brand in a truly innovative format. On a strategic level, however, Mercedes-AMG will be positioned and strengthened as our performance brand through its close alignment to our record-breaking Formula 1 team, and F1 will be our company's works motorsport focus for the years ahead.

"We wish the Formula E championship, its stakeholders and its innovative format only the best for the future as it continues to grow, and we hope the series has a bright future."

While Mercedes-Benz will depart Formula E at the end of Season 8, the team's leadership group has begun exploring options for the squad to continue competing in the series during the Gen3 era, including a potential sale to new owners.

"We entered Formula E with an open mind about the series and its innovative approach to motorsport," admitted Toto Wolff, Head of Mercedes-Benz Motorsport & CEO, Mercedes-EQ Formula E Team.

"A lot of hard work went into building the team and making it competitive – and we have seen an incredible group of talented women and men deliver at the highest level… We will be giving everything to make sure that we finish our Formula E adventure in style in Season 8."

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# McLaren sells one of its jewels

**THE** McLaren Group has agreed to sell its Applied business division, once one of the brightest jewels in the group's crown, to Greybull Capital.

Formed originally by a merger of McLaren Composites and TAG Electronics, the division was intended to leverage the group's F1 technology. From the Beagle Mars Lander, to North Sea drilling rigs, and from supply deals with F1, NASCAR, IndyCar and MotoGP, to a haul of Olympic medals, its expertise has reached far and wide. In the process, it moved from a clearing house for Formula 1 IP into a pioneering technical enterprise in its own right.

The divestment of Applied further enhances McLaren Group's strategic focus on supercar manufacturing and elite motorsport, with Automotive as the core profit driver. It builds on the Group's recent equity raise and launch of a comprehensive debt refinancing, as well as the successful introduction of minority investment into McLaren Racing last year.

McLaren Applied will continue to operate its technology business focused around transformative and innovative products in electrification and telemetry, control and analytics. Greybull's investment will support the company's strategy to exploit new market opportunities while continuing to build on its history in motorsport and automotive applications.

Paul Walsh, McLaren Group Executive Chairman, said the deal was "the latest in a series of proactive steps to build a more focused and profitable group."

"McLaren now has the right strategy and focus to achieve our ambitions as a global luxury supercar and elite motorsport business, underpinned by a more sustainable capital structure," he continued. "At the same time, we are delighted that Greybull's investment will provide a strong platform for McLaren Applied to innovate and grow as a world-class technology, data insight and analytics business."

Anthony Murray, McLaren Applied Chief Executive Officer, said: "We are delighted to secure the investment which will underpin our strategic intent to pioneer a better future, leveraging our electrification and telemetry, control and analytics capability. We remain focused and committed to our existing customer and market segments of motorsport, automotive and public transport and this additional investment will ensure we can provide long-term stability and additional finance to develop market-leading innovations for our customers."

"McLaren Applied is at the forefront of British innovation," commented Marc Meyohas, Managing Partner at Greybull Capital. "For over 30 years, McLaren Applied has helped lead the way on the digital and electric evolution of motorsport and the application of these Formula 1 technologies is becoming increasingly widespread.

"Applied is playing a key role across the transport sector providing solutions that allow for greater resource efficiency, connectivity and electrification."

The business will continue to be led by McLaren Applied's current management team and to service its existing customers. RT

**LEFT** McLaren Applied will continue to work with its existing motorsport customers


**BELOW** A McLaren Applied sensor fitted to a Team GB cyclist. The company contributed to a haul of medals at the 2012 Olympics

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Pat Warner, Advanced Digital Manufacturing Manager, Alpine F1 Team

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# Hydrogen class delayed a year – but will fight for Le Mans victory

**THE** Mission H24 hydrogen fuel cell-powered cars are expected to fight for overall victory at the Le Mans 24 Hours when they appear, a year later than originally intended.

Race organiser the Automobile Club de l'Ouest has stated that the new category – based on a one-make chassis jointly developed by Red Bull Advanced Technologies and ORECA – has been devised to put the innovative new cars on the same level as the runners in the top Hypercar class.

"With the regulations it will be possible [to win] on paper," said ACO president Pierre Fillon. "After that you will have to discuss with the manufacturers. Maybe they will need one more year [to challenge]."

Fillon pointed to Audi winning on its Le Mans debut in 2006 with the R10 TDI turbodiesel LMP1 car as evidence that new technologies can be successful straightaway: "Remember the diesel. When Audi announced they would run in Le Mans with a diesel everyone said they were crazy. Two years after, they won."

Fillon revealed that there were eight manufacturers around the table discussing the rules for the hydrogen class. Teams entering the new class will have freedom to develop the fuel cell technology pioneered by the GreenGT group.

The introduction of the new class has been delayed a year, to 2025, as a result of the pandemic. "COVID made a lot of issues for us and we lost one year of development with the H24 programme," Fillon said.

With France crippled by COVID, the H24, the second iteration of GreenGT's test car, has only been able to complete 500 km of testing since it was first shown at Le Mans last year. It is planned that the car will take part in free practice at the final two 2021 rounds of the Michelin-sponsored Le Mans Cup for LMP3 and GT3 cars. If everything runs according to plan, the car will begin racing on an invitational basis next year.


**BELOW** The cars in the hydrogen class are expected to fight for the outright win

# ACO to switch to GT3 category

**A NEW** GT3-based category is to replace GTE at the Le Mans 24 Hours and in associated championships.

The GTE ranks have dwindled with the exit of Ford, Aston Martin and BMW, with the WEC featuring just four full-time entries for the 2021 season.

The current GTE Pro and GTE Am classes will remain in place for the 2022 and 2023 WEC seasons, including Le Mans. From the 2024 season onwards, the ACO will adopt cars based on the GT3 rules package that has achieved so much success around the world, including at showpiece races at Spa, the Nürburgring and Bathurst.

The move will signal further convergence with IMSA's WeatherTech SportsCar Championship. The US series has already announced a switch from GTE-spec cars, dubbed 'GT Le Mans', to a GT3-based GT Daytona Pro class for 2022.

The GT-Am ranks on both sides of the Atlantic have remained popular, playing a role in the extension of the current Le Mans rules for a further two seasons.

**ABOVE** With GTE Pro numbers having fallen, Le Mans will move to GT3-based machinery

It is not yet clear in which way standard GT3 machinery will be modified for WEC, or whether the class will become a single Am-based affair.

Some of the brands racing in GT3, which could potentially swell the Le Mans GT class from 2024 onwards, include Mercedes, Lamborghini, BMW, Audi and Honda/Acura.

It is currently unclear whether the ACO-approved GT3 category will consist of standard GT3 cars or vehicles with technical modifications.

"GT was always an important parameter for the ACO and FIA," said Richard Mille, the President of the FIA Endurance Commission.

The ACO has already adopted GT3 regulations in its Asian Le Mans Series and in the Michelin Le Mans Cup.

# 24 Hours to feature 100% renewable fuel

**A NEW** fuel introduced next season will achieve a reduction of at least 65% of the racing cars' $CO_2$ emissions at Le Mans.

Named Excellium Racing 100, the 100 per cent renewable fuel has been developed by TotalEnergies on a bioethanol basis, made from wine residues from the French agricultural industry.

"Endurance racing, by its nature, has always served as an excellent research and development platform and it is an important milestone to have the FIA World Endurance Championship switching to 100% sustainable fuel," commented Jean Todt, FIA President.

"It's FIA's major goal to implement sustainable energy sources across its portfolio of motorsport disciplines, thus paving the way in the reduction of $CO_2$ emission, perfectly reflecting our race-to-road strategy as well as the FIA's PurposeDriven movement."

Pierre Fillon, President of the Automobile Club de l'Ouest, said: "Increasing awareness of social and environmental matters over the last few years has led the motor racing world to focus deeply on these issues. The 24 Hours of Le Mans has been an experimental playground for innovation ever since the first race in 1923 and this exciting new development is in perfect continuity with our founding principles.

"Our long-standing partner TotalEnergies channels its expertise into developing sustainable solutions. This new, fully renewable fuel is testament to our wholehearted commitment to CSR. When it comes to sustainable development, we continue to step up to the bar, delivering our promise to play our part in sustainable mobility."

Patrick Pouyanné, Chairman and CEO of TotalEnergies, said: "Our ambition is to be a major player in the energy transition and to get to net zero carbon emissions by 2050.

"TotalEnergies is supporting its customers and partners in their evolutions, by thus applying its strategy to motorsport: sustainable liquid fuels, electricity, batteries, hybridization, hydrogen…

"Advanced biofuels have an undeniable part to play in helping the transport sector to reduce its $CO_2$ emissions immediately. This 100% renewable fuel is a perfect illustration. As we are becoming a broad energy company, the racing track is more than ever an open-air laboratory for TotalEnergies." RT

New Le Mans fuel
See page 28


# Sustainable theme dominates Le Mans

**LAST** month's Le Mans 24 Hours was an event dominated by the theme of sustainability.

In addition to the planned introduction of TotalEnergies' 100 per cent renewable fuel, Michelin showcased the sustainable credentials of its new tyre. There was also news of a new Sustainable Endurance Award, plus the ACO unveiled its Corporate Social Responsibility (CSR) strategy.

"Since its foundation in 1906, the Automobile Club de l'Ouest has shown commitment and support for the world around us while providing a testing ground for the technological innovations that will shape our future mobility," said Pierre Fillon, President of the ACO.

"Our commitment encompasses three areas and contributes to 12 of the 17 United Nations Sustainable Development Goals. In recent years, growing awareness of environmental and societal issues has forced us to think hard about how we get around. At the ACO, contrary to widespread belief, we are convinced that the motor vehicle is compatible with the challenges we now face and, indeed, that it could drive the transition.

"As always, we will endeavour to live up to our promise to lead the way in sustainable development and sustainable mobility."

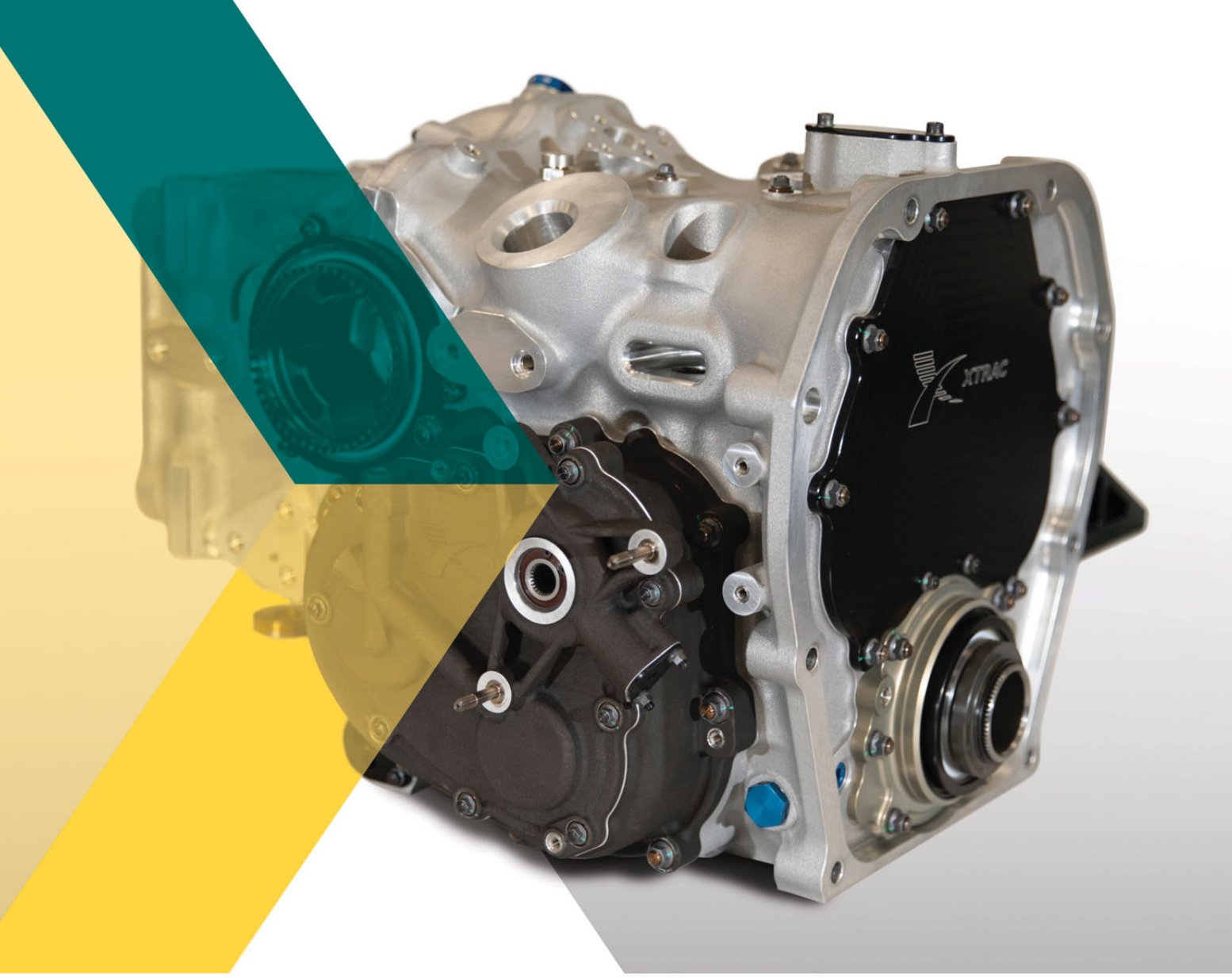
The ACO Sustainable Endurance Award, presented by DHL, will recognise a competitor's CSR approach, with emphasis on the progress made from one year to the next.


**ABOVE** Michelin previewed a new tyre in which 46 per cent of the materials used are sustainable

The prize will be awarded according to two markers: 50% of the score based on a Low Carbon Impact approach to logistics; 50% on an innovative action with a positive social or environmental impact (Positive Innovation).

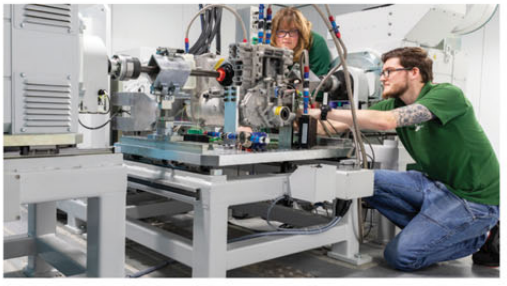
Michelin claimed its 24th consecutive victory at the Le Mans 24 Hours, but also used the event to preview its 'démonstrateur 46' tyre in which 46 per cent of the materials used are sustainable.

Such a high proportion of sustainable materials has been achieved by increasing the quantity of natural rubber and incorporating carbon black recovered from end-of-life tyres. The other bio-sourced or recycled sustainable materials that go into this new tyre include everyday products like orange and lemon peel, sunflower oil, resin oil and pine resin, along with recycled scrap steel. RT




# A NEW DIMENSION

## IN HYPERCAR TECHNOLOGY



With 48 of the 61 entries being taken by Xtrac equipped cars - including the top 21 finishers, 11 of the 12 podiums and all 5 Hypercars - we would like to congratulate all of our customers who raced at the 2021 Le Mans 24 hours, collectively covering 200,000km.

To compete in such an arduous race, entrants need quality, performance and reliability from their transmission, which is why they specify Xtrac.

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# Historic clean sweep for Xtrac

**LEFT** Xtrac celebrated the first Le Mans Hypercar victory with Toyota

**PEOPLE** have talked for years about Le Mans having become a 'sprint' rather than a marathon. But with around 25,000 gear changes, 4,000 km at full throttle and over two million wheel rotations in a typical race, the Le Mans 24 Hours still remains a true test of endurance.

Throw the impact of a global pandemic into the mix, and the task becomes harder still.

This year's endurance classic, the first of the Hypercar era, presented not only a technical challenge for Xtrac, which equipped all five Hypercars in the field, but a logistical one too: the Berkshire, UK-based company supplied an impressive 48 of the 61 entries.

The 88th running of the famous event proved an outstanding success for the transmission specialist. Remarkably, it celebrated not only the historic first win for a Hypercar – with all of the new class entries completing the entire 24 hours – but it equipped the top 21 finishers overall.

Notably, this included all five class winners, who collectively secured 12 of the 13 available podium positions. This year saw the addition of an 'Innovation' class (and the 13th podium position) with Association SRT41's ORECA 07-Gibson LMP2 car adapted to accommodate its two paraplegic drivers, Takuma Aoki and Nigel Bailly. The accelerator is behind the steering wheel and the brakes are actioned by pushing a lever. A trigger on the same lever enables gear changes – a similar system to the one used by Alessandro Zanardi at the 2019 24 Hours of Daytona.

Across the whole grid, Xtrac provided six different types of transmissions including for the new Hypercar class, with 200,000 km completed by Xtrac customers during the race.

"To compete in such an arduous race, customers need quality, performance and reliability from their transmission system, which is why they choose Xtrac," said Cliff Hawkins, Xtrac Development Director.

"With investment in the latest technology, including loaded test rigs and gear manufacturing machinery, and a real focus on providing the very best staff training and development, Xtrac are committed to providing world-beating motorsport transmissions now and in the future." RT

# HPD updates NSX GT3 with Evo22

**ABOVE** The Evo22 targets more consistent performance across a wider range of conditions

**HONDA** Performance Development (HPD) has revealed that an enhanced Acura NSX GT3, designated the NSX GT3 Evo22, will compete on racetracks throughout the world starting in 2022.

The latest evolution of the multiple championship-winning Acura NSX GT3 features a number of important revisions aimed at addressing team and driver needs, and will provide more consistent performance across a wider range of conditions and drivers.

The new Evo22 edition will feature upgraded engine intercoolers, to ensure consistency in engine performance in a wider range of conditions; revised spring rates and suspension geometry adjustments; increased fluid tank sizes for endurance racing; wheel system revisions for faster tyre changes; and a new, FIA-mandated rain light.

Additionally, new variant options will be available for the air conditioning system, and headlights. The NSX GT3 Evo22 is homologated through to 2024.

As with the current NSX GT3 Evo, the chassis originates at the Performance Manufacturing Center in Marysville, Ohio. Final assembly is completed by JAS Motorsport in Milan, Italy, which will continue to provide parts and technical support in Europe. RT

NEWS

# Le Mans gold rush gathers pace as Cadillac commits to LMDh

**CADILLAC** has become the latest manufacturer to confirm that it will compete for overall victory in the 24 Hours of Le Mans.

It joins a list of heavyweights that already includes Audi, Porsche, BMW, Toyota, Peugeot and Ferrari.

Cadillac will compete in the IMSA WeatherTech SportsCar Championship and Automobile Club de l'Ouest (ACO) LMDh category in 2023 with a fourth-generation Cadillac V-Series prototype.

"For nearly 20 years, Cadillac V-Series has brought winning technologies from the racetrack to our performance cars on the road," said Rory Harvey, global vice president, Cadillac. "We look forward to continuing that heritage by competing in this exciting new chapter at the highest level of international motorsport."

The new Cadillac LMDh-V.R prototype is designed to conform to IMSA and ACO Le Mans Daytona hybrid specifications for the new top tier of endurance racing that replaces the current DPi class. As with the other competitors in the series, it will be based on a standardized chassis and incorporate the spec hybrid powertrain system, but will feature a unique combustion engine and distinctive bodywork.

As with the Cadillac DPi-V.R, the Cadillac LMDh-V.R will be a partnership between GM Design and the constructor Dallara. A new Cadillac engine package will work in conjunction with the LMDh common hybrid system.

Cadillac's programme will partner with Chip Ganassi Racing and Action Express Racing. The Cadillac LMDh will debut on the track for the first time at the Rolex 24 Hours at Daytona in January 2023.

"We have had a great relationship across three different racing disciplines with GM and we are looking forward to developing the car with Cadillac and Dallara over the next year-and-a-half," commented Chip Ganassi.

"The IMSA LMDh category is looking to be very competitive with multiple manufacturers," said Gary Nelson, AXR team manager. "We've had a lot of success running the Cadillac DPi-V.R as one of the original teams since 2017, and we are looking forward to being a part of the next chapter of Cadillac Racing."

Recent Cadillac Racing achievements with the Cadillac DPi-V.R include winning the Rolex 24 at Daytona four times in a row (2017-2020) and clinching the IMSA WeatherTech SportsCar Championship in 2017 and 2018.

Prior to contesting IMSA's top-tier DPi category, Cadillac competed in the Pirelli World Challenge Championship, earning five Manufacturers' and five Drivers' titles.

## Lamborghini to LMDh

The likelihood is that the IMSA LMDh ranks will be swelled yet further in 2024, with Lamborghini said to be close to finalising its involvement.

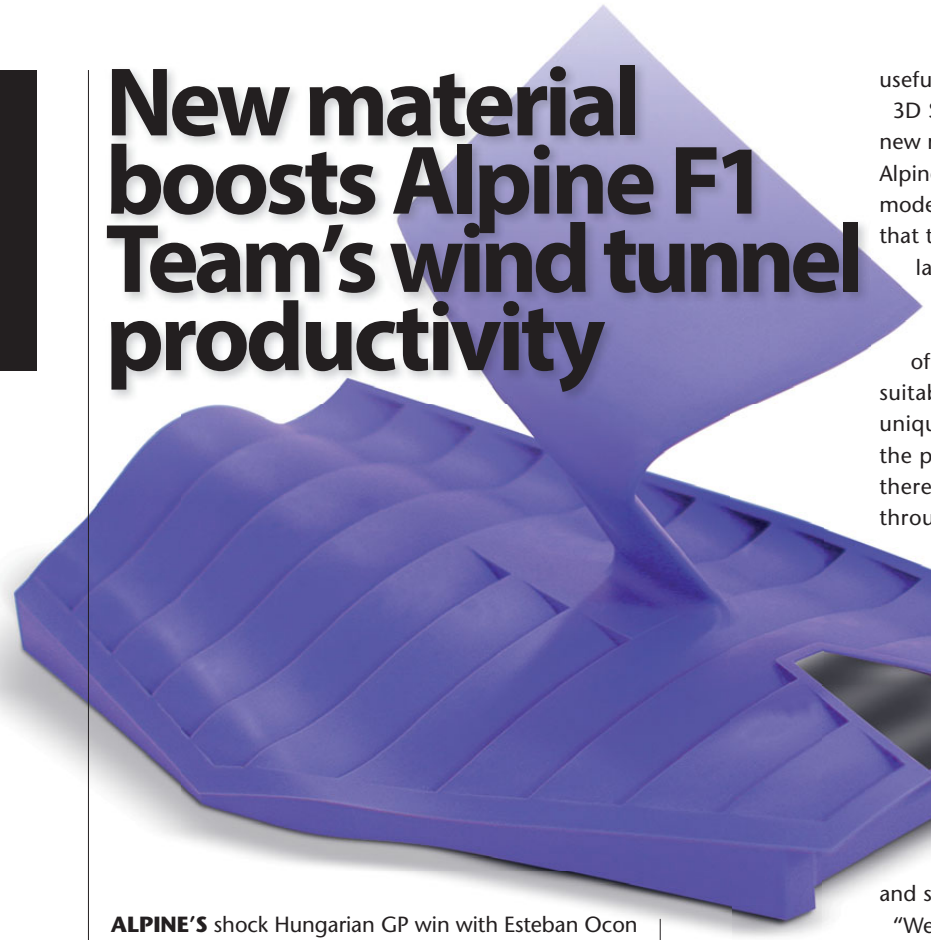
Like sister VW Group brands Audi and Porsche it would utilise the Multimatic chassis. Its focus would be on the involvement of customer teams.

In addition to Audi, Porsche, BMW and Cadillac, Acura has also committed to be in IMSA's top WeatherTech SportsCar Championship class. RT


**ABOVE** A GM Design sketch of a fourth generation Cadillac prototype for LMDh

**LEFT** Cadillac's victory at the Rolex 24 in 2020 was its fourth straight success in the endurance classic

# New material boosts Alpine F1 Team's wind tunnel productivity



**ALPINE'S** shock Hungarian GP win with Esteban Ocon was a timely reminder that success on the racetrack is often a combination of many developments that take place away from the limelight.

One such factor is the recent advances in wind tunnel productivity achieved with a new material co-developed with additive manufacturing pioneer 3D Systems.

Accura Composite PIV is a material specifically designed to address PIV testing applications used primarily in motorsports wind tunnel testing. It is capable of producing rigid parts in a high-contrast colour optimized for PIV testing. Parts produced using this material take significantly less time to prepare – from CAD to wind tunnel – and deliver more accurate, high-resolution data.

When used as part of a complete 3D Systems additive manufacturing solution – comprising Accura Composite PIV, the company's stereolithography (SLA) technology, software, and advanced application services – Alpine F1 Team has been able to maximize its wind tunnel investment.

3D Systems' SLA technology has allowed Formula 1 companies to build rigid aerodynamic parts with high productivity and leverage innovations like integrated pressure tappings. These parts are used in testing that relies on a laser-based technology known as 'particle image velocimetry' or PIV. One challenge with taking reliable PIV measurements is the reflections of laser light from background surfaces other than the airborne particles, which reduces the image quality, resulting in a loss of useful information.

3D Systems developed Accura Composite PIV – a new reflection mitigating SLA material – which Alpine F1 Team is using to print its wind tunnel model parts. The Enstone team has demonstrated that the new SLA material is effective in reducing the laser reflection effect.

The workflow to produce wind tunnel parts in other currently available materials often requires a multi-step process to achieve a suitable finish required for wind tunnel testing. The unique colour of Accura Composite PIV provides the possibility to eliminate some of these steps and therefore compress the workflow for efficiency and throughput gains.

"We've proudly collaborated with 3D Systems for many years," said Pat Warner, advanced digital manufacturing manager, Alpine F1 Team. "The deep expertise of their application engineers and their industry-leading solutions have been an invaluable part of our innovation team. It's been exciting to co-develop Accura Composite PIV and see the benefits it's bringing to our process.

"We produce nearly 500 parts per week for wind tunnel testing. Due to the material's unique optical characteristics, we are now collecting more reliable data from our PIV system in the wind tunnel."

In addition to Accura Composite PIV's unique colour, the material has a high tensile and flex modulus, with a heat deflection temperature of 100° C, which makes it ideal to withstand the rigours of wind tunnel testing. This material is formulated for use with 3D Systems' stereolithography 3D printing technology – including the company's 3D Sprint software – that is designed for rapid production of large (up to 1500 mm in length), high-resolution parts.

"Customer-centric innovation is a guiding force within 3D Systems," said Kevin Baughey, segment leader, transportation & motorsports, 3D Systems. "Working with Alpine F1 Team to develop our newest material is another example of how we're leveraging our F1 application expertise to develop advanced solutions that give our customers a competitive edge.

"We've been impressed by the results the team has experienced in the wind tunnel." RT

**ABOVE** The new material is cutting time from CAD to the wind tunnel

Additive Manufacturing breakthroughs See page 46

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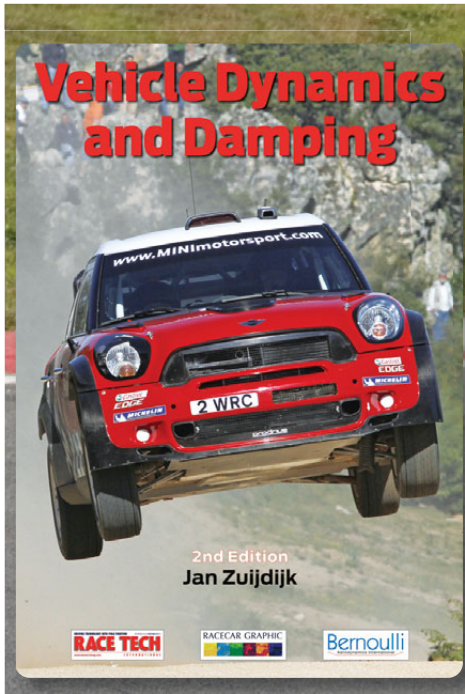


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# Motorsport UK sets out F4 vision


**ABOVE** Tatuus will supply the chassis for the new-look F4 British Championship

**MOTORSPORT UK** has announced that it will become the organiser of the F4 British Championship certified by FIA for the next three years, with a bold vision for elevating the series.

The governing body for UK motorsport will in 2022 introduce the FIA's second generation F4 car, incorporating key safety advancements. Motorsport UK sees this shift in equipment as the right time to take the leadership role for British F4 and further develop the series as the definitive step for emerging talent, building their experience and profile on the international stage.

As part of the FIA single-seater pathway, the championship will provide drivers with the opportunity to earn Super Licence points that are crucial to reach the highest echelon on the professional ladder.

F4 certified by FIA is a globally recognised and affordable step between Karting and the FIA Formula Regional Championships certified by FIA. The category is designed for drivers to build experience in single-seaters and to compare themselves to the best talent, not only in their own country, but across other championships around the world.

## BTCC support bill

Motorsport UK's vision is for a championship that attracts the leading teams and drivers with high-quality grids and the most competitive racing. The governing body will provide a highly visible promotional platform, which includes retaining the championship's place on the British Touring Car Championship roster, with further rounds at key events under consideration to build the drivers' circuit experience and the profile of the series.

Furthermore, Motorsport UK plans to forge strategic alliances with a number of stakeholders within the single-seater pathway to ensure the series offers entrants real prospects for progression to international series.

Commenting on Motorsport UK's new remit as British F4 organiser, CEO Hugh Chambers said: "The F4 British Championship certified by FIA is embarking on an exciting new chapter and Motorsport UK is delighted to be leading its evolution.

"This step represents an important milestone in the governing body's sport development strategy, and we want to further develop the series as the best platform from which rising stars can continue on their pathway to international competition."

Tatuus and Abarth have been nominated as the F4 British Championship chassis and engine suppliers for 2022-24, following the conclusion of a tender process that began in May.

"Tatuus has grown into a world leader in the design and production of single-seater racing cars, in which the vast majority of all professional and Formula 1 drivers have progressed their careers," explained Chambers. "They are well-equipped with the latest technologies required to deliver a first-class chassis and powertrain well aligned with our vision for the series.

"The Tatuus-Abarth package is the most commonly used chassis-engine combination in the 10 other F4 championships around the world, potentially offering a greater pool of drivers the opportunity to test themselves against the cream of talent competing in the UK."

These supply agreements bring to a conclusion the championship's history of being powered by Ford engines. Motorsport UK underlined its appreciation for the immense contribution played by Ford Performance to the growth of the championship in the seven seasons since its inception. RT


**BELOW** The FIA's second-generation F4 cars offer a step forward in safety


# Prodrive overhauls Hunter for Dakar assault

**PRODRIVE** has redesigned its Hunter rally raid car as it steps up its quest for victory in the iconic Dakar Rally.

The Bahrain Raid Xtreme (BRX) squad has overhauled its Prodrive Hunter to meet the new rally raid regulations recently announced by the FIA for T1+, which is now the top class alongside T1-E. The new regulations were introduced to help balance the performance of the four- and two-wheel drive cars in the T1 class.

The Hunter will run on larger tyres, with increased suspension travel and a wider track. 37" tyres on 17" rims replace the current 32" tyres on 16" rims, with suspension travel increased from 280 mm to 350 mm and the body width increased from 2m to 2.3m to accommodate this.

These changes have necessitated some significant revisions to the Hunter's drivetrain, suspension and bodywork. The suspension geometry has been reconfigured with longer wishbones and dampers, and there are larger brakes accommodated in the 17" wheels.

The larger tyre radius increases the load in the drivetrain so driveshafts, the propshaft and differentials have all been modified. The wider track has also meant nearly half the bodywork has been redesigned with Ian Callum restyling the Hunter to suit the new regulations, while keeping the same distinctive look.

Prodrive has taken the opportunity to increase the size of the windscreen and fit a new programmable wiper motor to improve the driver's visibility. The onboard jacks have been improved to not only be lighter and stronger, but to lift the car faster and can now be powered by an electric pump for additional reliability.

Gus Beteli, BRX team principal, said: "We are very pleased the organisers have addressed the disparity in regulations between the buggies and the four-wheel drive T1 cars, where larger tyres had an advantage over rough terrain. We've learnt a huge amount on our debut this year and have put all this learning into improving the car and believe our new Hunter T1+ is a significant step forward. We are looking forward to returning to Saudi in January, where we will be looking to challenge for victory."

BRX competed with the T1 car for the last time at Baja Aragon recently, where the Hunter showed its pace by setting fastest times on eight of the rally's 11 sectors.

The first Hunter T1+ car is currently being built at Prodrive's headquarters in the UK and will run for the first time later this month. The new car is also available to customers to compete in FIA Cross Country events, Bajas and at the Dakar in 2022. RT

**ABOVE** The T1+ (right) seen with its T1 predecessor (left)


**BELOW** Sébastien Loeb impressed with his pace on the T1's final appearance, on the Baja Aragon raid in Spain

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**THOMAS KRAEMER**, Director Motorsport Quality Management, Porsche Motorsport

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**BRYN BALCOMBE**,
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*In a changing world it is important to get unbiased thoughts from leading suppliers, manufacturers, engineers and trend-setters… The World Motorsport Symposium offers insight into different technologies from many different angles – it is a great initiative by RACE TECH to bring key people into the same room to share information and thoughts – this is extremely important for the continuing development of future energy for vehicles."*

**ANDERS HILDEBRAND**,
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# The Davos of Motorsport Engineering & Technology



*"It was a pleasure to attend the WMS this year. As always, the quality of delegates and papers was excellent. This combined with the ever-professional running of the event made it a great success."*

**RICHARD BARDWELL**, Director, SHARC
**MARK GALLAGHER**, Director, SHARC

*"We really enjoyed the event and have thought a lot about it during the last few weeks. It is one of the best events of the year to strengthen our network and to be a part of shaping the future of the motorsport industry – very valuable!"*

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TotalEnergi

# LE MANS REVELS IN LAST OF THE SUMMER WINE

**Chris Pickering** discovers how a 100% renewable biofuel – made with wine residues from the French agricultural industry – will dramatically reduce cars' CO2 emissions at next year's Le Mans 24 Hours

**A BOLD** announcement was made at the traditional pre-race press conference in the lead up to the recent 24 Hours of Le Mans. Next year, the net carbon emissions of all cars competing in the event, along with World Endurance Championship (WEC), the European Le Mans Series (ELMS) and the Michelin Le Mans Cup, will be slashed by at least 65 per cent.

Think about that for a second. Two thirds of the collective tailpipe emissions effectively cancelled out at a stroke. And this step change in environmental sustainability is achieved by a remarkably simple shift – switching to a new fuel.

The new fuel comes from French industrial giant TotalEnergies (recently rebranded from Total to reflect its increasing involvement in alternative and sustainable energies). Known as Excellium Racing 100, it's derived from agricultural waste – appropriately enough for Le Mans, most of it comes from the French wine industry, including yeast residue and grape pomace.

As an active supplier to various championships with its existing fuels, TotalEnergies was keen to investigate motorsport applications for its advanced biofuel technology.

## The right moment

"With the FIA keen to pursue renewable fuels and the ACO announcing their new CSR (Corporate Social Responsibility) strategy, we really felt this was the right moment," comments the company's motorsport multi-energies technical manager, Romain Aubry. "We're looking at various different solutions for different motorsport categories, and 100 per cent renewable biofuel was a good fit for ▶


**LEFT** The Le Mans organisers have leveraged TotalEnergies' expertise in developing sustainable solutions to produce a fully renewable fuel

endurance racing."

Partial blends of biofuel have been around for many years. The American Le Mans Series (ALMS) switched to an E10 blend (10 per cent bioethanol) in 2007. But 100 per cent biofuel, where the feedstock all comes from plant-based sources, is still cutting-edge technology in motorsport. Unlike some earlier biofuels, the so-called advanced biofuels used today don't compete with food crops, and neither do they require any substantial changes to the engine.

Burning this fuel releases roughly the same amount of CO2 as conventional gasoline. However, the CO2 absorbed by the plants as they grow, and the carbon sequestered into the soil, substantially offsets those emissions. In theory, it would be possible to cancel out 100 per cent of the CO2 and render the tailpipe emissions completely carbon neutral.

At present, steps such as transporting and processing the raw ingredients still incur a carbon cost. Using the models set out by the European Union's Renewable Energy Directive (RED), TotalEnergies has been able to carry out a complete lifecycle analysis of the new fuel, which is where the figure of a 65 per cent net reduction comes from.


MissionH24-Thierry Gromik


> *"Two thirds of the collective tailpipe emissions effectively cancelled out at a stroke"*

**ABOVE & LEFT** TotalEnergies knows that a range of different technologies will suit different applications. That is mirrored in its motorsport projects, which range from the hydrogen fuel cell-powered H24 Le Mans prototype (left) to 100 per cent renewable biodiesel for the FIA European Truck Racing Championship (above)

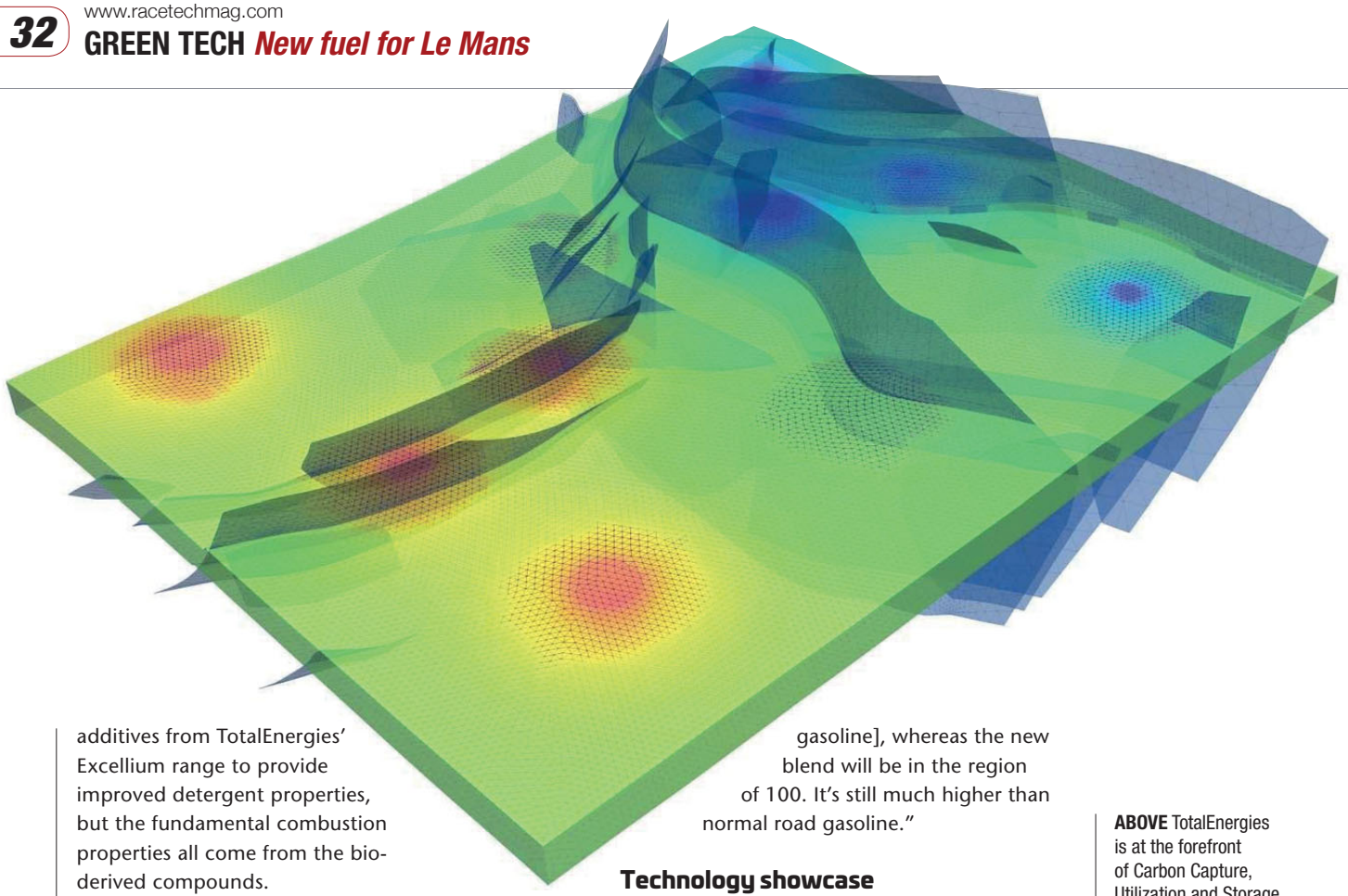
## Fuelled by wine

The creation of biofuel is a well-documented process, but one that needs to be carefully optimised in order to produce race-ready fuels that can serve as a direct substitute for existing gasoline blends. Part of the complexity is extracting compounds with the appropriate octane levels and energy density.

"We need a high energy density for motorsport – especially when it comes to endurance racing – and need a high octane rating to ensure reliability in these extreme conditions," explains Aubry. "We've managed to achieve this within the fuel blend itself without using any additional octane boosters."

It all begins with an industrial fermentation process, which is used to create ethanol from the biomass. This is then dehydrated to remove the oxygenated compounds and put through a series of catalytic processes to extract the different hydrocarbons that can be combined to make gasoline, including paraffins, olefins and aromatics. Collectively, this is known as ethanol to gasoline (ETG).

This base blend provides everything the engine needs to run. It's supplemented by a series of ▶



additives from TotalEnergies' Excellium range to provide improved detergent properties, but the fundamental combustion properties all come from the bio-derived compounds.

Compared to the current fuel, there will be a slight reduction in octane number, but it won't require any fundamental changes to the engine. It's similar to the sort of differences that the engine manufacturers might face if a series moved from one supplier of conventional gasoline to another, Aubry points out.

"The hardware, including the fuel injection system, can stay the same," he says. "The only thing is that the manufacturers will have to re-calibrate the ECUs slightly as the octane rating is changing. This year we are running 103 to 104 [in conventional gasoline], whereas the new blend will be in the region of 100. It's still much higher than normal road gasoline."

## Technology showcase

The Excellium Endurance blend used by the teams at Le Mans this year featured 10 per cent renewable content. As such, the new 100 per cent renewable fuel marks a significant step forward in terms of sustainability, but there are still challenges remaining.

"We're continuing to work on the sustainability," comments Aubry. "We use some road transport for the logistics at the moment, for instance, which is something we could look at."

Alongside the technical development, there is a strong PR message. As Aubry points out, the emissions from cars competing in motorsport are virtually ▶

**ABOVE** TotalEnergies is at the forefront of Carbon Capture, Utilization and Storage (CCUS) research. With partners, it has revealed the first version of a high-performance simulator for large-scale geological CO2 storage


**RIGHT** The ambition of TotalEnergies to be a major player in the energy transition was underlined by its recent acquisition of the largest electric vehicle charging network in Singapore, with more than 1,500 charge points

**ABOVE** The Feyzin refinery, near Lyon, where the new fuel will be produced is no pilot plant: it operates on a full industrial scale

inconsequential in the grand scheme of things – the logistics surrounding the teams and the spectators are far more significant. And yet motorsport can still play a major role in emissions reduction.

"According to the ACO's CSR study, the gasoline and tyres [for the cars competing on the track] are only responsible for 1.7 per cent of the total CO2 emissions from the Le Mans race," he says. "It's almost nothing. Even if you took it away completely it wouldn't make an especially big difference to the event's total emissions. But it gives us an opportunity to showcase renewable fuels – in the mainstream they could have a huge impact."

For this technology to make a real difference it needs

> *"A significant step forward in terms of sustainability"*

to be scaled up, but it's already a comparatively big enterprise by motorsport standards. "The facility where we produce this fuel isn't a pilot plant, it's operating on a full industrial scale," Aubry points out.

He's remaining tight-lipped on the cost at present, but it's fair to assume that substantial investment would be needed to upscale the production. On top of that, there's also a question of which applications to prioritise if 100 per cent renewable biofuel was to make it to the mass market in limited quantities.

It's now generally accepted that the majority of the passenger car fleet will eventually transition to battery electric vehicles, but industries such as long-distance haulage and aviation will be dependent on liquid fuels for far longer – perhaps forever.

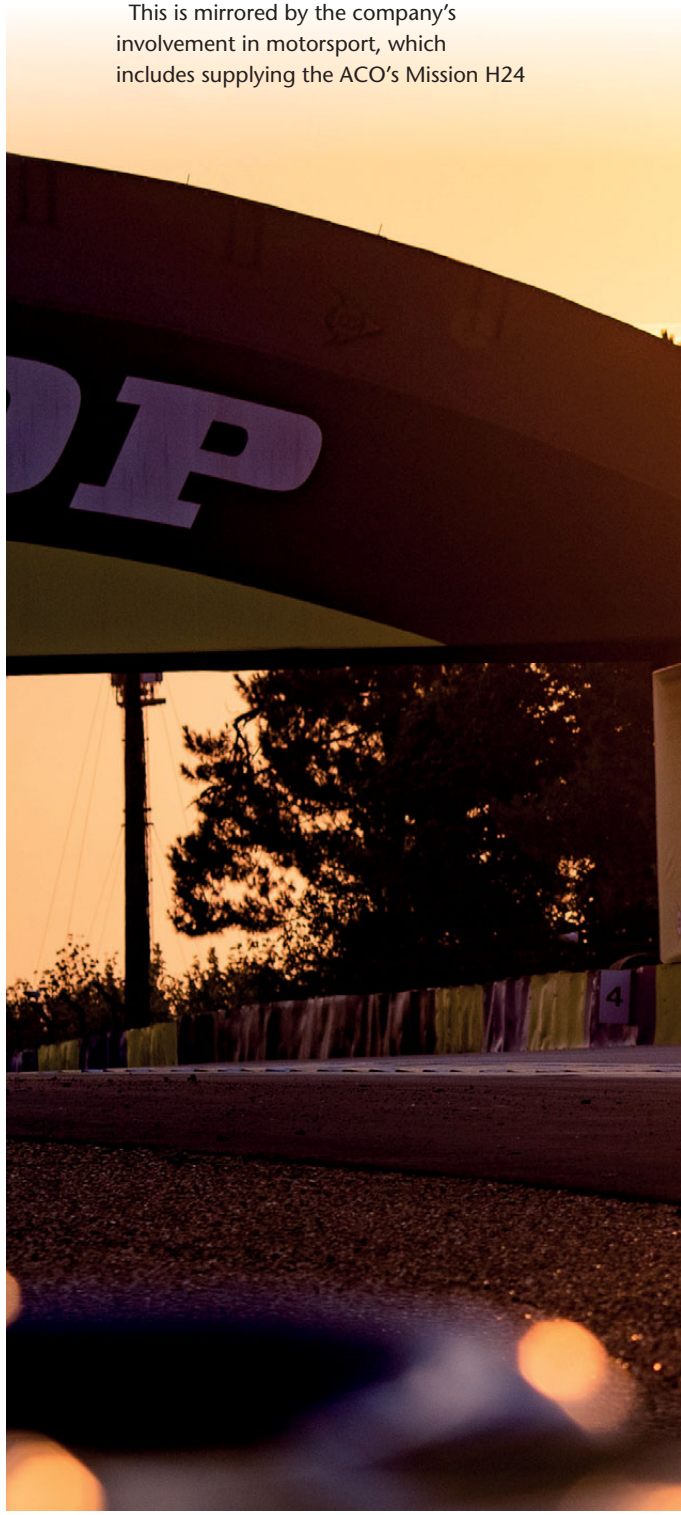
## Used cooking oil

TotalEnergies has already begun producing Sustainable Aviation Fuel (SAF) at its La Mède biorefinery in southern France and its Oudalle facility near Le Havre. This is made from different feedstocks – primarily used cooking oil – but it follows a similar principle to the new endurance racing fuel.

"There will be a range of different technologies to suit different applications, and we're working with all of those," comments Aubry.

TotalEnergies recently acquired and will manage and operate the largest electric vehicle charging network in Singapore, with more than 1,500 charge points installed in the city-state. This after Paris, Brussels, Amsterdam and London, where the company will operate important networks of charging points. Alongside that it continues to work on solutions such as hydrogen, biofuel and biogas.

This is mirrored by the company's involvement in motorsport, which includes supplying the ACO's Mission H24



**RIGHT** The Excellium Endurance blend used by the teams at Le Mans this year featured 10 per cent renewable content, so the switch to 100 per cent renewable fuel represents a giant leap forward

programme for fuel cell vehicles, along with 100 per cent renewable biodiesel for the FIA European Truck Racing Championship. The biodiesel comes from the same refinery as the SAF aviation fuel and uses the same Used Cooking Oil (UCO) process.

Another option on the horizon is synthetic fuel, also known as e-fuel. Rather than using biomass, e-fuels combine hydrogen, captured by electrolysis using renewable electricity, with CO2 that's taken from the atmosphere or stored as a byproduct from other chemical processes. In many ways, it's the Holy Grail of renewable fuels, but the concept is still very much in its infancy at present.

"We need quite a large volume of fuel to supply the complete WEC and the ELMS," notes Aubry. "We're talking thousands of cubic metres per season. At the moment, we couldn't meet those volumes with e-fuel."

Supply is a challenge for the industry as a whole. Even Porsche's dedicated factory in South America isn't currently producing enough for a complete WEC season.

TotalEnergies has its own R&D programme looking at carbon capture and e-fuels, but it's still in the very early phases. Advanced biofuels, on the other hand, are here already. And with a 65 per cent reduction in on-track CO2 emissions due next year, the World Endurance Championship and its associated series can justifiably lay claim to a step change in environmental sustainability.

# DON'T LOOK BACK IN ANGER...

When BMW announced its exit from Formula E, it suggested it had exhausted the opportunities the series offered for technology transfer. So now, after its farewell in Berlin, what did the manufacturer *really* learn? **Chris Pickering** investigates

**THE** official arrival of BMW in Formula E, at the beginning of the Gen2 era, marked a turning point for the all-electric championship. Although by no means the first major OEM to join the series, BMW was one of a number of high-performance heavyweights that officially committed to Formula E around that time (Audi having done so the season before, while Mercedes and Porsche followed the season afterwards). It cemented Formula E's status as one of the top series in the world for manufacturer involvement.

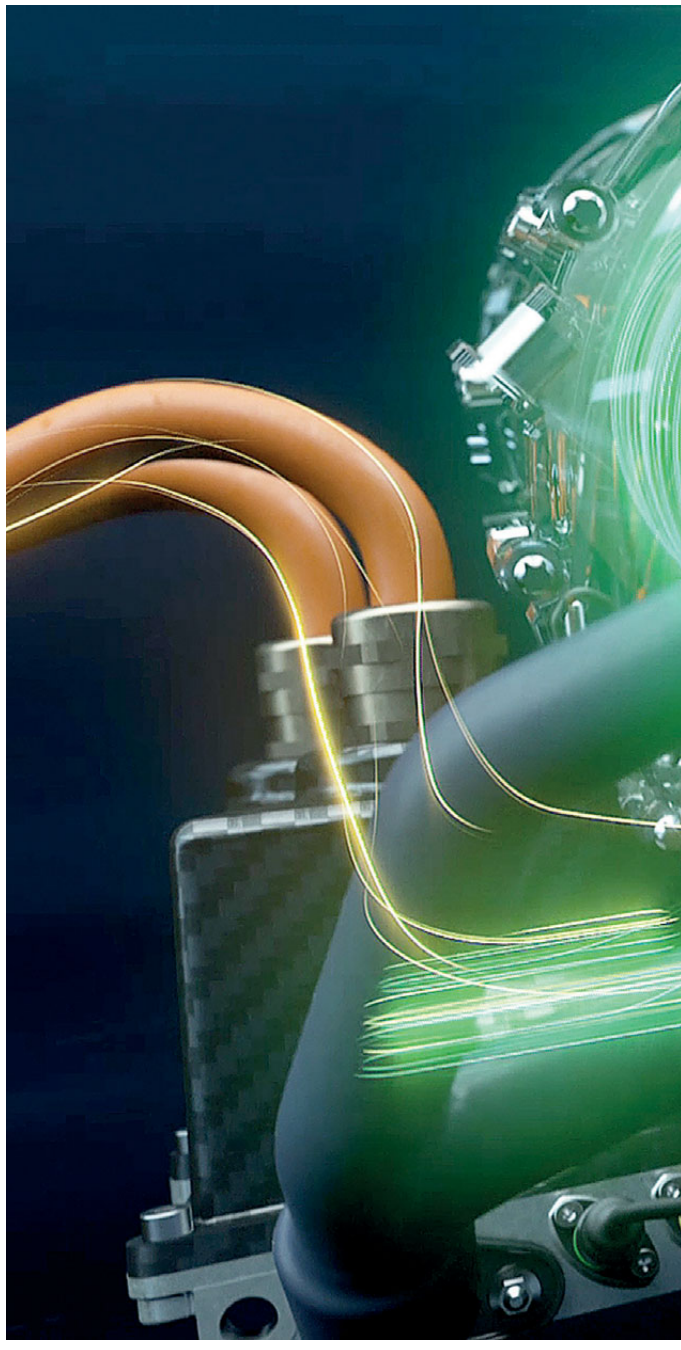
Strictly speaking, BMW's involvement in the series goes right back to the beginning. The group has been supplying safety cars to Formula E since its inaugural season, while its competitive involvement began when it started providing technical assistance to the Andretti team at the tail end of the Gen1 era.

## Bittersweet ending

Now, though, the adventure is over. The Berlin ePrix that concluded the 2020-2021 season was a bittersweet ending to BMW's involvement in the category. Jake Dennis was within striking distance of the drivers' championship when he suffered a technical issue that put him into the wall. It meant that the German manufacturer would exit the series with some notable victories, but no title wins to its name.

"I think we had a good car throughout our time in Gen2. It's a shame that we never won a championship – I don't think that completely represents the capabilities of the car or the team," comments Valentino Conti, chief engineer of BMW i Andretti Motorsport. "But it's been a great experience and we've learnt a lot."

The final iteration of the team's Formula E car, the BMW iFE.21, was built to a set of regulations that had remained essentially unchanged from the previous year, but it featured a number of detail revisions. For instance, new parts produced with 3D printing processes helped to optimise the centre of gravity height and the weight distribution. Meanwhile, an innovative composite material made from sustainable flax fibres was also adopted for parts in the cooling system.



**RIGHT** BMW was among the manufacturers quick to exploit the marketing potential of Formula E's 'green' drivetrain

Many of the developments over the final two seasons focused on efficiency. In its final form, the motor achieved 98 per cent efficiency with a power density of more than 14 kW/kg, spinning to more than 30,000 rpm.

## Sharing information

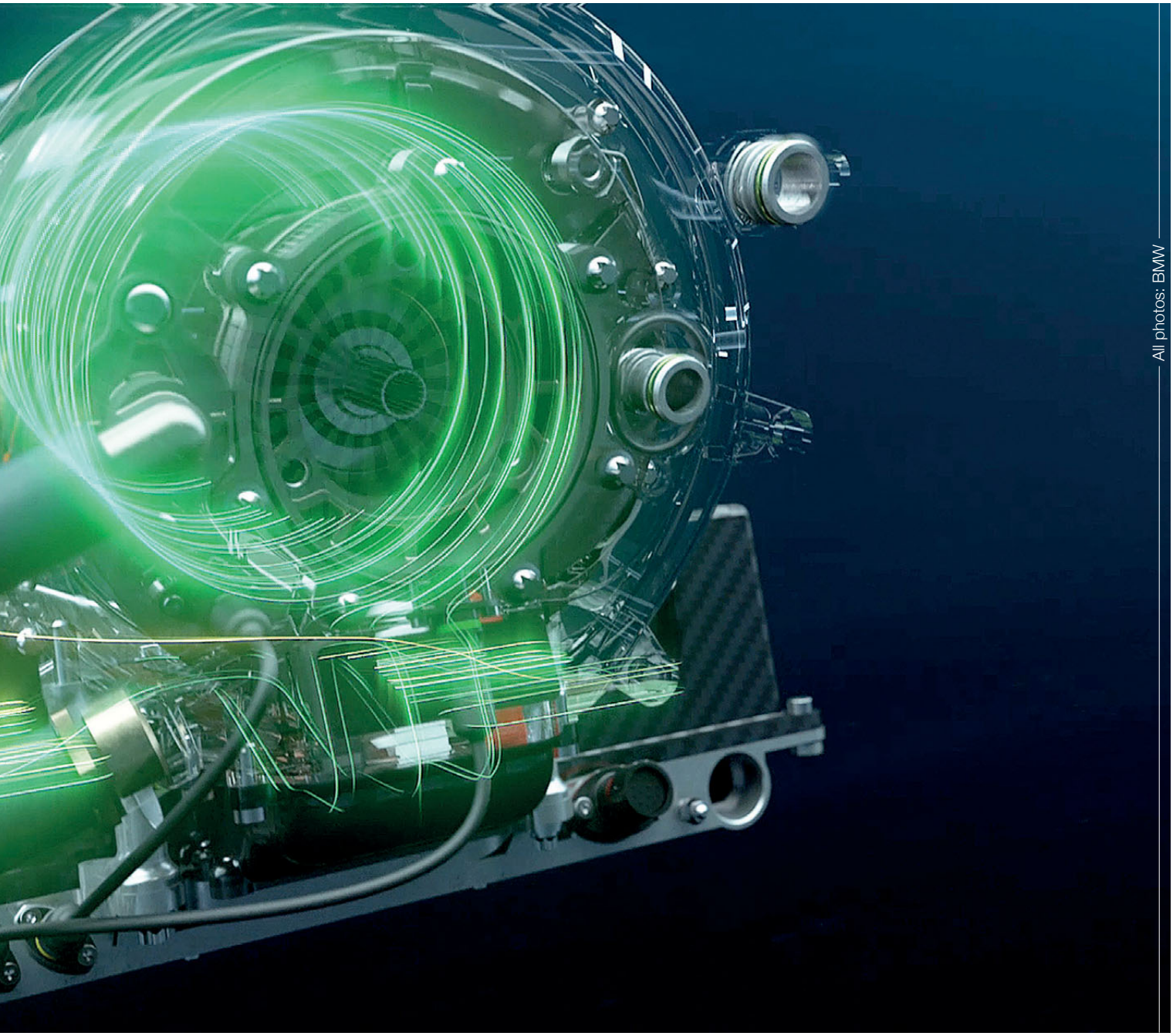
The motor and inverter design for the Formula E car was handled by the same department that works on the powertrains for BMW's electric road cars, Conti explains: "We definitely benefited from [the production car engineers'] experience. There's not much physical carryover, but in terms of expertise it was about the closest connection you can have. I think it's been a long time since we've had that level of connection [between motorsport and road cars] on the combustion car side."

There has also been a degree of technology transfer in the other direction, with a new bandage design for the rotor of the Formula E motor expected to increase the rev range of production car motors.

> *"If software was 30 per cent in Gen1, I'd say it's 70 per cent in Gen2"*

The Formula E programme is also said to have contributed to the development of silicon carbide inverter materials. Highly efficient MOSFETS with minimal switching and conducting losses housed in a lightweight Kevlar case have enabled the 900-volt inverter to achieve a power density of 45 kW/kg.

"As a chassis engineer, I didn't really appreciate to start with how much ▶



All photos: BMW

performance gain you can get from optimising the design of an inverter," comments Conti. "A lot of materials development went into the MOSFETs for the inverter, as well as the stator and magnets of the motor."

Elsewhere, the hardware development has slowed somewhat in Formula E as the teams have all tended to converge on a common powertrain concept. In the early days, there was a wide range of drivetrain concepts, from single-speed to five-speed gearboxes, while some also experimented with twin-motor configurations (legal at the time, but since banned). Now, however, all teams use the same single-speed, single motor configuration.

"There's only so much that you can physically do with an electric motor and a single-speed

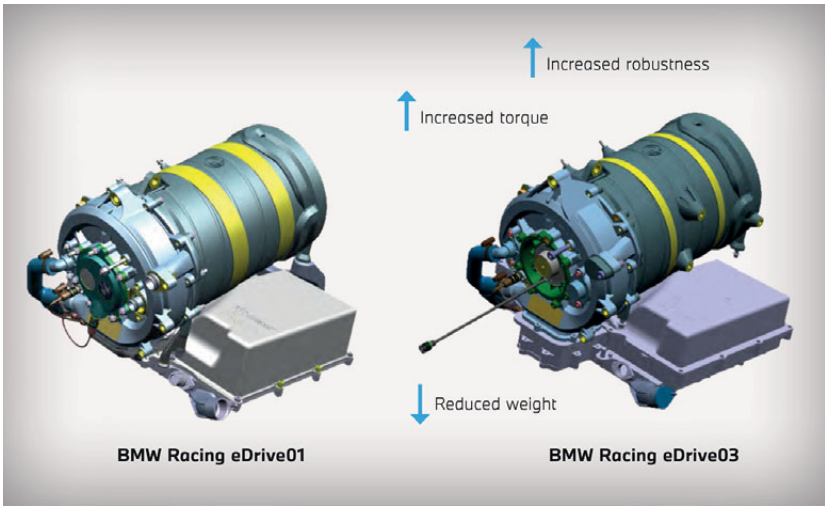
gearbox," comments Conti. "We've made big steps in terms of efficiency. But to take the next step from here would be hard. Clearly, there are incremental improvements to be made on the materials and the software, but I think it would be really difficult for the teams to make the sort of progress that we saw in Gen1 and Gen2."

The biggest remaining philosophical divide in terms of hardware is that between high rpm motors and low rpm motors. For the manufacturers, this is a case of front-loading the development process with simulation to determine where within the speed range they want to achieve peak efficiency. This, in turn, tends to determine the transmission layout. Lower rpm designs are typically able to get away with a single-stage reduction gearbox, which can be packaged in a longitudinal configuration; high rpm designs generally require a two-stage reduction, which is easier to accommodate with the motor placed transversely across the chassis.

"Once you've set the speed range, you can find the optimal package. And sometimes that's not the best package in the first year, but the one that gives you the most scope to develop," notes Conti.


**LEFT** BMW bowed out in Berlin, having transferred the knowledge gained from the highly complex energy management in Formula E to its production vehicles

> *"Some pundits were critical of an electronic brake-by-wire system but it provided an intriguing extra dimension for the engineers"*



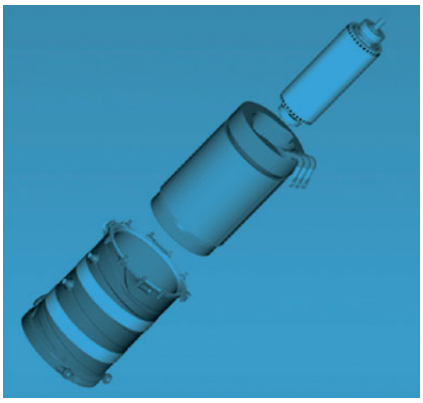

**ABOVE** By the end of BMW's Formula E journey, improvements in weight, torque and robustness had achieved 98 per cent efficiency in the drivetrain

## Control systems

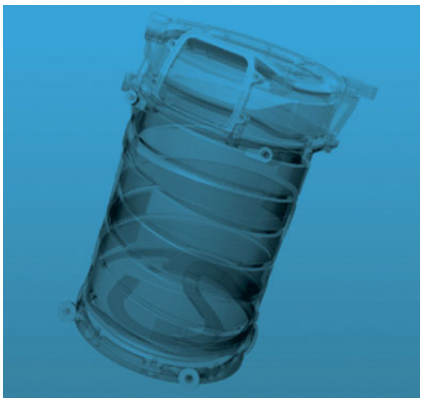
Overall, Conti says, the biggest technical challenges and the greatest opportunities to engineer a competitive advantage in the series have all related to software: "Obviously, software plays a key role in other areas of motorsport too. But coming from a traditional motorsport background, I think we underestimated the software challenge at the beginning."

Part of the complexity comes from understanding the full ramifications of making a change to the software, he explains: "Sometimes, you think you have a solution to a particular issue, but the bigger challenge is actually anticipating how that will affect other things."

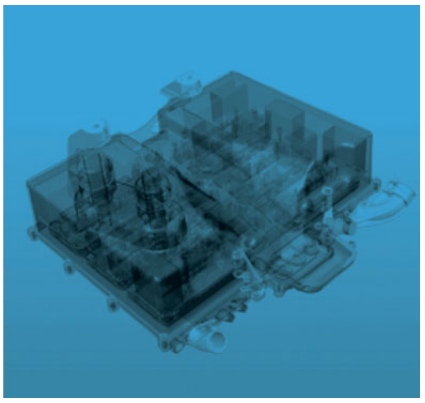
The arrival of the Gen2 cars in Season 5 introduced an electronic brake by wire system, in place of the manual system previously used to control the level of regenerative braking. Some ▶



**ABOVE** The compact electric motor features cutting edge materials, high gravimetric energy density and high engine speeds



**ABOVE** CFD optimisation ensured minimal pressure loss in the cooling system. The materials used, such as ceramic, made for high thermal conductivity



**ABOVE** State of the art SiC technology was developed for use in the inverter

pundits were critical of this approach, claiming it required less skill from the drivers, but it provided an intriguing extra dimension for the engineers.

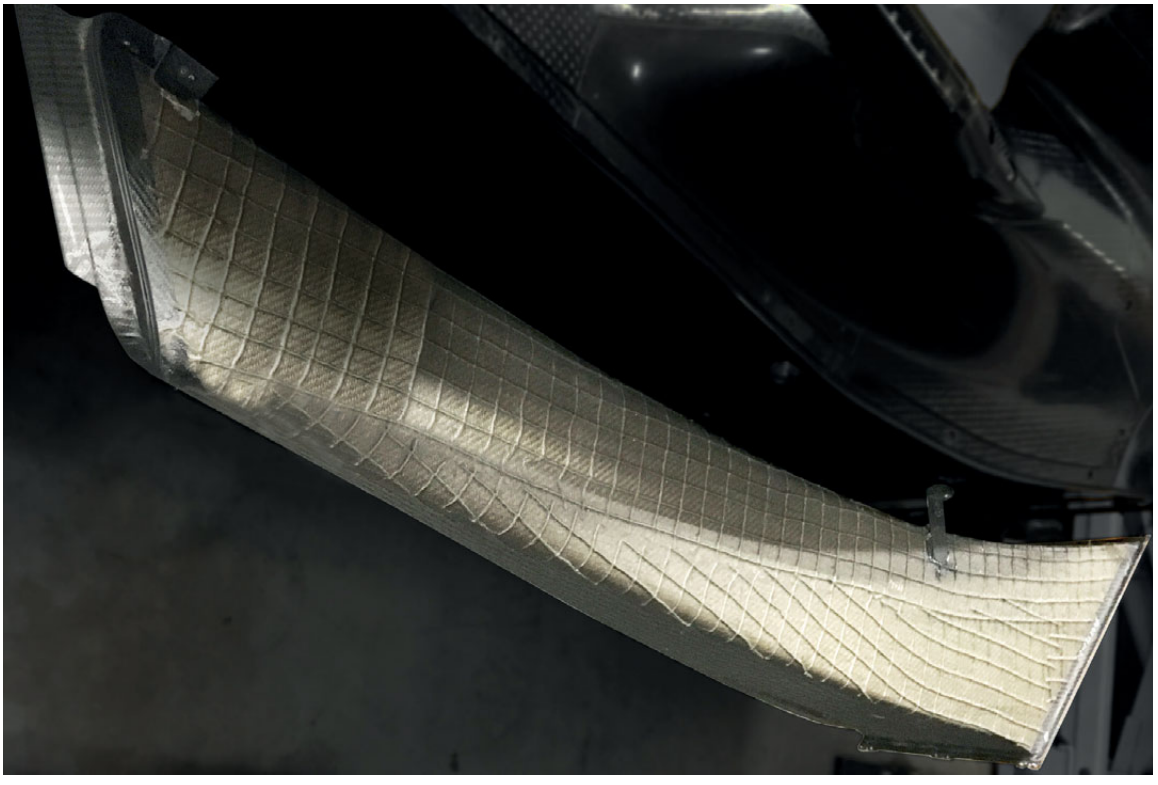
## Software breakthroughs

"There's quite a lot more control complexity in the Gen2 car than there was in Gen1," comments Christian Baetz, controls, software and systems engineer for BMW i Andretti Motorsport. "Year by year, during Gen1, people started to see the potential for software development, but then there was a big step up; if software was 30 per cent in Gen1, I'd say it's 70 per cent in Gen2."

The battery management system (BMS) remains off-limits to the teams, but the current rules allow them to design their own vehicle control unit (VCU) and inverter. Broadly speaking, the VCU handles the high-level control and the energy management, while the software in the inverter is responsible for the control of the motor. However, different teams have varying approaches as to how much of the workload is decentralised to the inverter.

> *"We've made big steps in terms of efficiency. But to take the next step from here would be hard"*

"Theoretically, the energy management is quite easy – you can simulate it and find the figures that you need. But the key thing is that it needs to be done in a way that's driveable. A human being needs time to react and needs some feeling. The more sophisticated it is, and the more you automate it, the harder it is to get that connection," says Conti. "In theory, you can regenerate ▶



**LEFT** The Formula E car was the first BMW racecar fielded by a works team with parts made out of renewable textile fibres. The flax cooling shaft first used in the BMW iFE.20 underlined the role the series played as a tech lab for the BMW Group

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very late into a corner [rather than relying on the mechanical brakes] but the drivers don't always feel comfortable with that and they can end up being too slow mid-corner, which means that they have to accelerate more [and use more energy] coming out of the corner."

## Dealing with oscillation

There were challenges in the fine details too. Electric motors are inherently prone to oscillation through the drivetrain, so production engineers tend to avoid operating conditions that will excite these oscillations. In motorsport, however, that would mean giving away performance.

A similar issue presents itself when it comes to calibrating the motor to work within Formula E's power limits. It's down to the teams to develop a system that gets as close to the power limits – 250 kW in qualifying and 200 kW in Race Mode – without exceeding them. Not only is this a technical challenge, but also a legislative issue, Conti points out: "There were times when it can be difficult to understand exactly what the governing body wants: they give you a limit or boundary and you try to achieve it but later you realise that you don't speak quite the same words. That caused some issues."

It's a hint perhaps that not everything was rosy in Formula E. And there also seemed to be a degree of frustration in the statement issued by BMW when it announced it was leaving the championship. It's summed up by a paragraph in the manufacturer's official ▶

**ABOVE & BELOW** The control software in the high-voltage range, which controlled the Formula E motor after the inverter, is to be used in the manufacturer's forthcoming road models like the iX and i4

# Giorgio Piola

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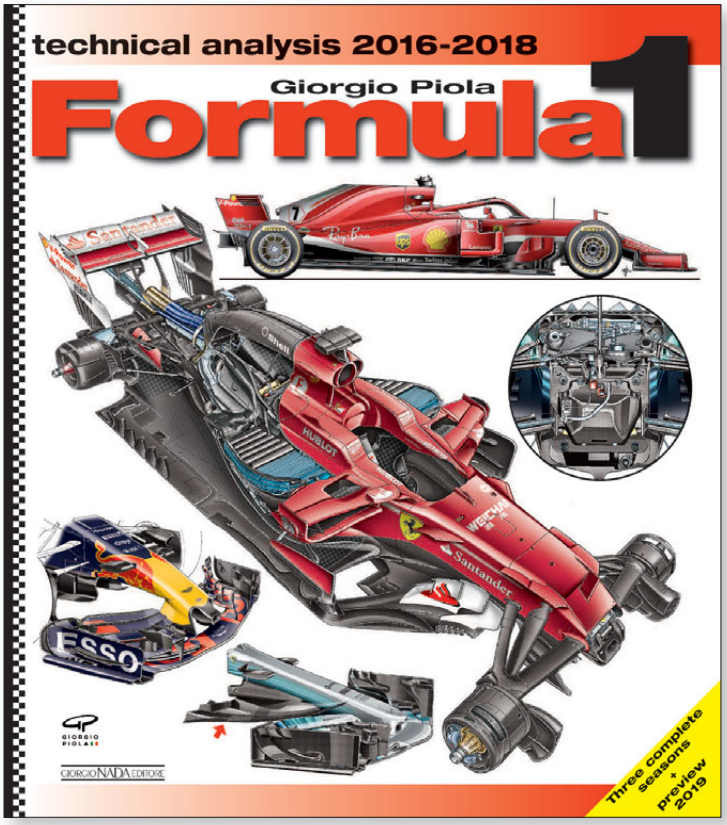


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media guide to Season 7, which reads: 'The BMW Group has always used Formula E as a tech lab for production [but] when it comes to the development of e-drivetrains, the opportunities for this form of technology transfer in the competitive environment of Formula E have essentially been exhausted.'

## Battery debate

Could opening battery development up to the teams be the next step to stimulate innovation? "Possibly, but it would be a very expensive exercise," replies Conti. "So I can understand if people don't want to go down that route. It would open up an endless cycle of development and it would be very heavily related to the amount of money you had to spend."

> *"The programme contributed to the development of silicon carbide inverter materials"*

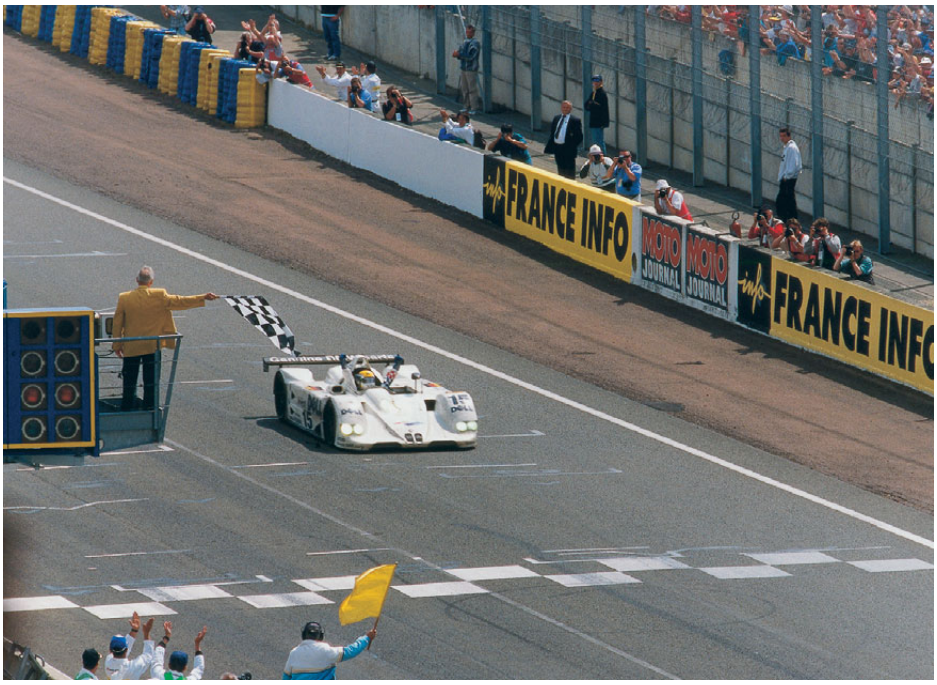
Baetz agrees, but he points towards the forthcoming FIA Electric GT Championship as an example of how battery design could be opened up. This category will allow the manufacturers to build their own bespoke battery layouts based on standard Saft-supplied cells.

In general, though, BMW's reflections on Formula E seem to be an observation more than a criticism. The potential for innovation (and, if we're being cynical, the marketing value of promoting that innovation) inevitably tends to decline after a manufacturer has spent a few years in any new category. That's why companies move on, and BMW's experience in Formula E should certainly stand the engineers in good stead for future projects. A key one for Conti and his colleagues will be BMW's forthcoming LMDh entry – with its spec hybrid system it's unlikely to see any physical carryover, but he says he can see expertise gained on the software side coming into play.

It's not quite the end for BMW's involvement in Formula E, either.

**LEFT** Making a splash: in three seasons together, BMW i and Andretti Autosport celebrated a total of seven wins, five pole positions and twelve podiums

**RIGHT** What next? A return to Le Mans, which it won in 1999, is on the cards with an LMDh project




Although the works team has now withdrawn, its technical partner Andretti Autosport will remain in the series and will continue to use the existing BMW powertrain next season. That's been made possible by the FIA's decision to delay the introduction of the new Gen3 cars until Season 9.

For now, Formula E remains in technological limbo, and it faces tough times with the recent Berlin ePrix also marking Audi's exit from the championship, while Mercedes has announced that it will withdraw at the end of Season 8. However, just as the introduction of the Gen2 cars prompted an influx of new teams for Season 5 – BMW among them – it's likely that the next-generation car will give the championship another boost. RT


**RIGHT** The home race in Berlin provided BMW Group with a stage to demonstrate the current range of fully-electric production vehicles whose drivetrains benefited significantly from the knowledge gained in the competitive environment of Formula E

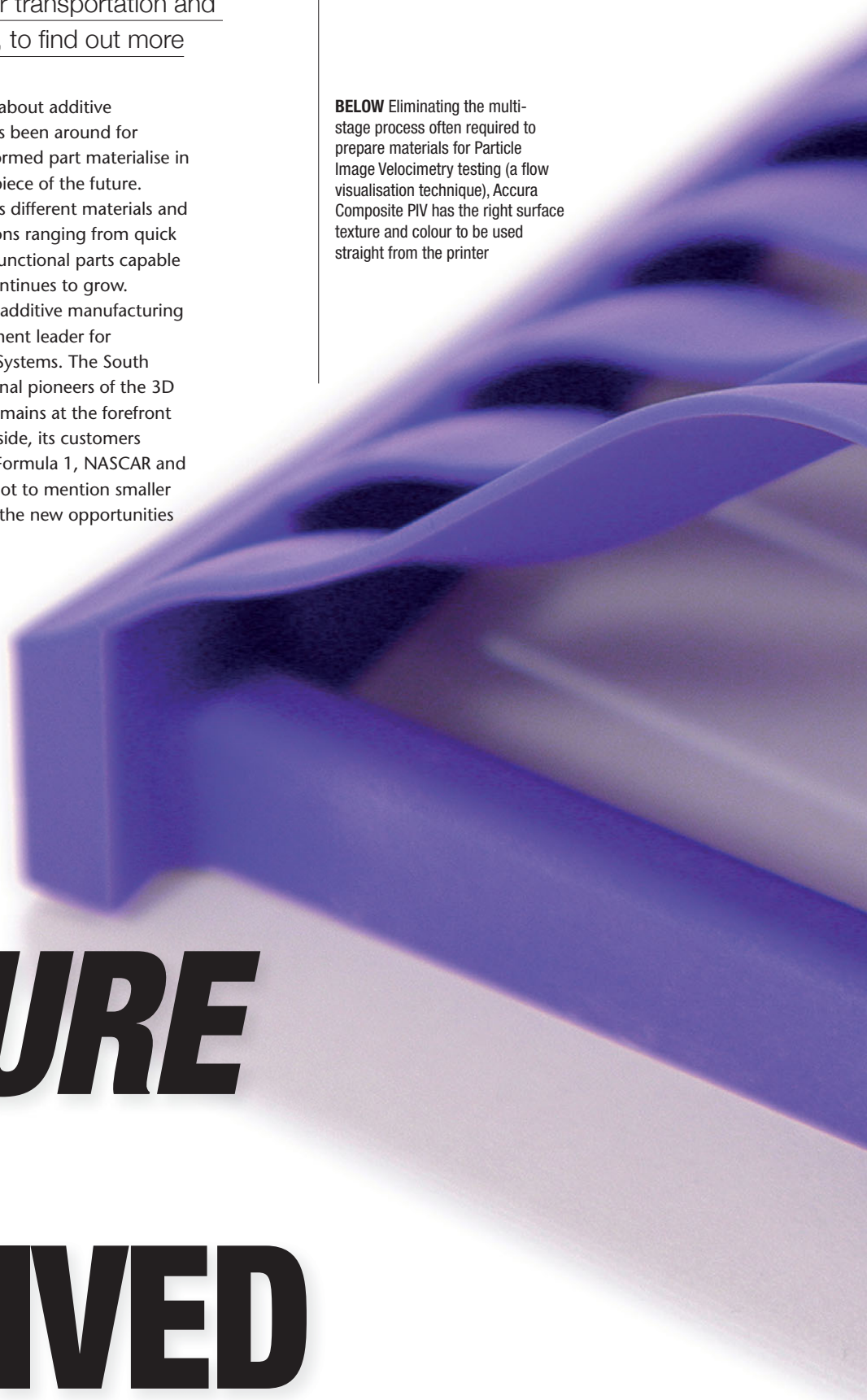
# THE *FUTURE* HAS ARRIVED

The range of applications for additive manufacturing is expanding fast. **Chris Pickering** talks to Kevin Baughey, segment leader for transportation and motorsports at 3D Systems, to find out more

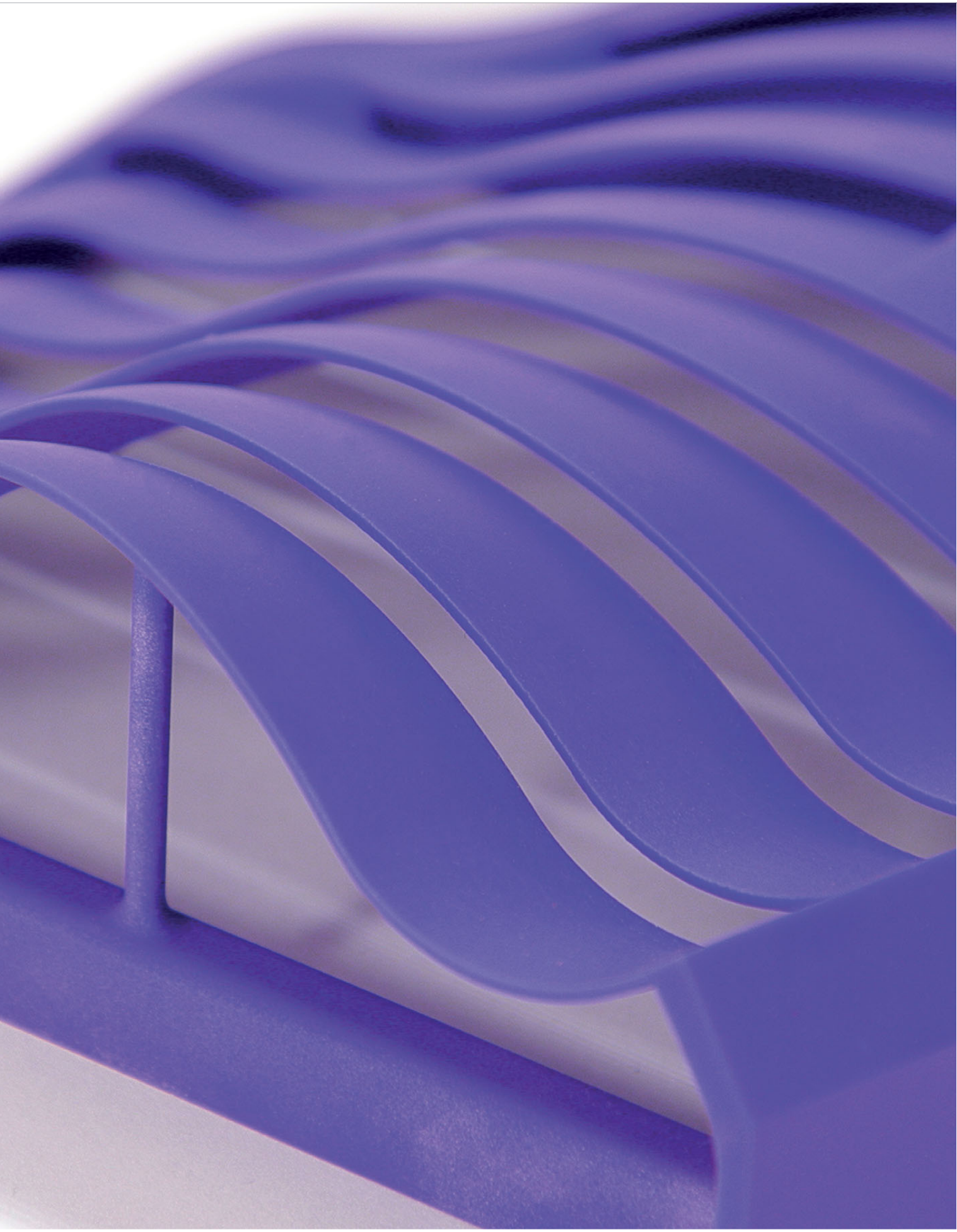
**THERE'S** something faintly sci-fi about additive manufacturing. The concept has been around for decades, but watching a fully-formed part materialise in front of your eyes still feels like a little piece of the future.

It's a broad field that covers numerous different materials and 3D printing techniques, with applications ranging from quick and convenient space models to fully functional parts capable of years of rigorous use. And the list continues to grow.

To catch up on some of the trends in additive manufacturing we're speaking to Kevin Baughey, segment leader for transportation and motorsports at 3D Systems. The South Carolina company was one of the original pioneers of the 3D printing industry in the 1980s and it remains at the forefront of the technology. On the motorsport side, its customers include some of the biggest names in Formula 1, NASCAR and the World Endurance Championship, not to mention smaller teams that are increasingly embracing the new opportunities offered by additive manufacturing. ▶



**BELOW** Eliminating the multi-stage process often required to prepare materials for Particle Image Velocimetry testing (a flow visualisation technique), Accura Composite PIV has the right surface texture and colour to be used straight from the printer



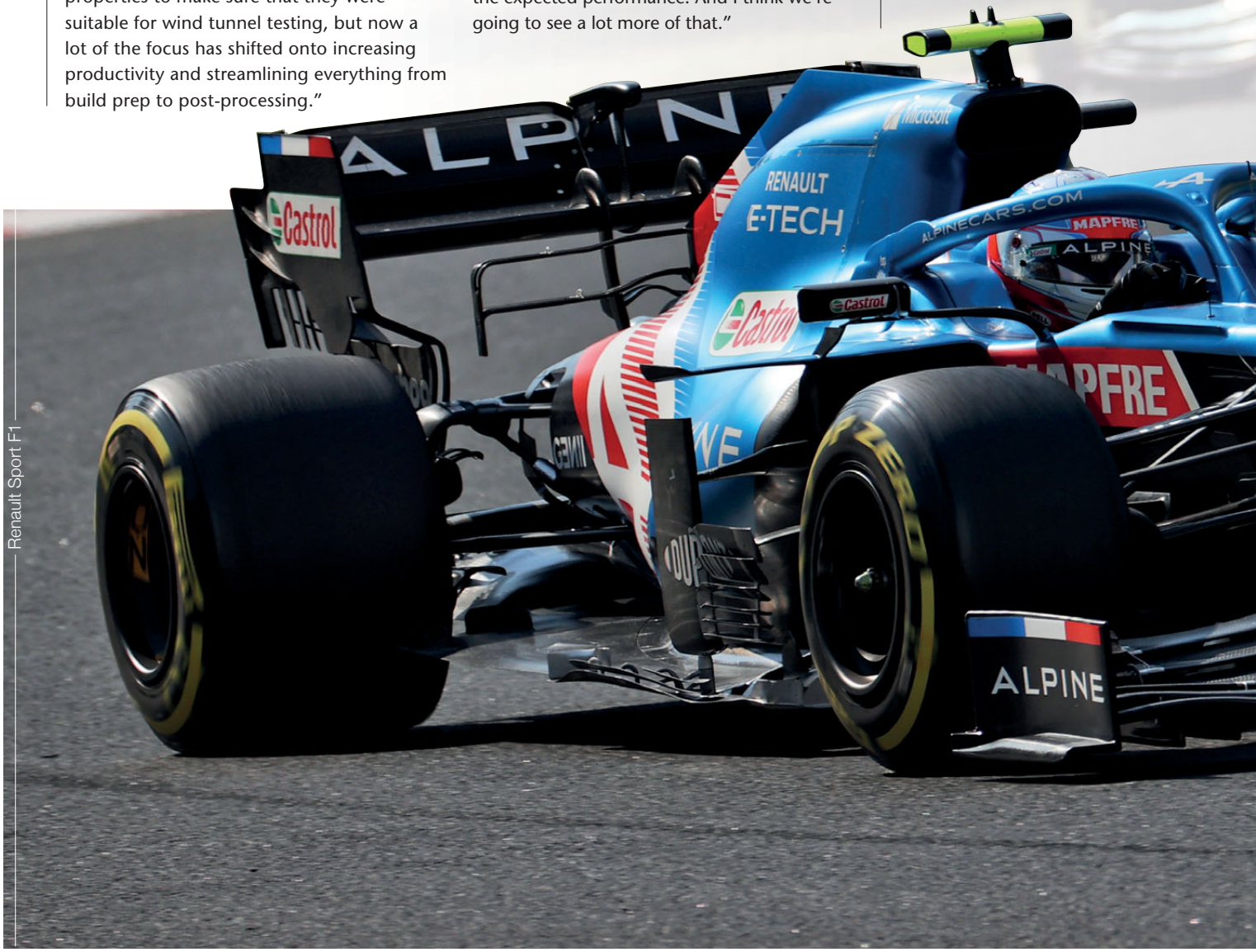
Historically, one of the biggest application areas for 3D printing in high-end motorsport has been wind tunnel testing. This continues to be the case, with new developments aimed at both full-scale and scale model testing.

Here, one of the recurring themes in this development has been the drive for increased productivity, explains Baughey: "Early on, it was really about dialling in the material properties to make sure that they were suitable for wind tunnel testing, but now a lot of the focus has shifted onto increasing productivity and streamlining everything from build prep to post-processing."

It might sound strange to talk about productivity in the niche, low-volume world of motorsport, but here it's a question of maximising the number of design iterations that can be tested and making the most of the available wind tunnel time. "That's the key thing for these teams," comments Baughey. "It's not about reducing cost so much; it's about maximising the throughput of parts that they can put into the wind tunnel, get more data, and then tweak and modify the design."

In some respects, this helps to strengthen the case for physical testing at a time when simulation is becoming increasingly prevalent, but Baughey points out that the two techniques can complement each other: "CFD and wind tunnel testing is a great illustration of the digital twin methodology. If you can rapidly iterate on the physical, then you've got a really good conduit for going back and forth between the CFD and the wind tunnel and really validating the expected performance. And I think we're going to see a lot more of that."

**LEFT & BELOW** The Alpine F1 Team, seen here winning the Hungarian GP with Esteban Ocon, has embraced the benefits of AM. It uses both stereolithography and selective laser sintering to produce complex jigs and fixtures, fluid flow rigs, and on-car components in hours rather than weeks




Renault Sport F1

The freedom to modify the internal geometry of the part is another big advantage. Features such as integrated pressure tappings and sensor pads allow the models to be tested without introducing external probes that could affect the results of the test.

But there's more to creating a wind tunnel model than just capturing the right geometry. The material needs to provide the right stiffness and surface finish to mimic the behaviour of the final part. Again, this tends to be a question of iterating back and forth to ensure that the model matches the performance of real-world parts.

Modern 3D printed materials are heavily optimised for stiffness. Aeroelasticity – or rather the absence of it – has always been an important part of wind tunnel testing, and the recent controversy surrounding flexible wings in Formula 1 has only served to highlight this.

"We've seen additional tests for wing surface stiffness coming into F1, so, it's a critical characteristic," comments Baughey. "From our perspective, it's about making sure the parts are as stiff as possible to give accurate results in the wind tunnel, but we also have to do that without making them brittle. Getting that stiff yet durable combination is very important for wind tunnel testing." ▶

**ABOVE** Digital-direct thermoplastic manufacturing opens the door to novel design parameters not possible with injection moulding, while also bypassing the long lead time and up-front investment in tooling

> *"A new material that's enabling additive parts to be used in applications where they wouldn't have been found before"*

## PIV material

The company's new Accura Composite PIV is one example of materials development helping to streamline the physical testing process and improve throughput.

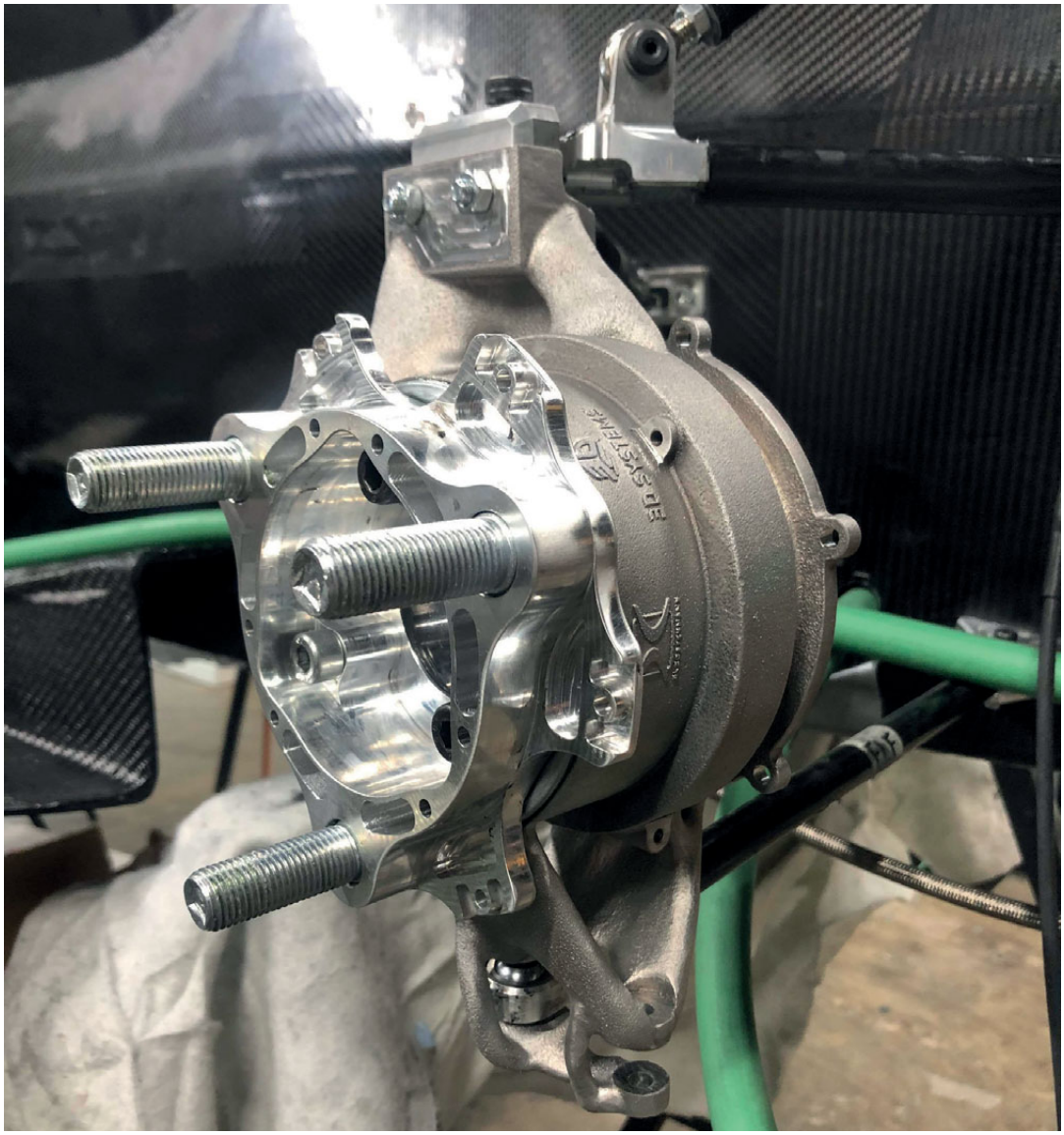
Particle image velocimetry (PIV) is a flow visualisation technique, which involves introducing tracer particles into the airstream and illuminating them with a laser in order to capture the speed and direction of the flow. This means that the parts being tested not only need to provide the right physical attributes, but also the right optical properties.

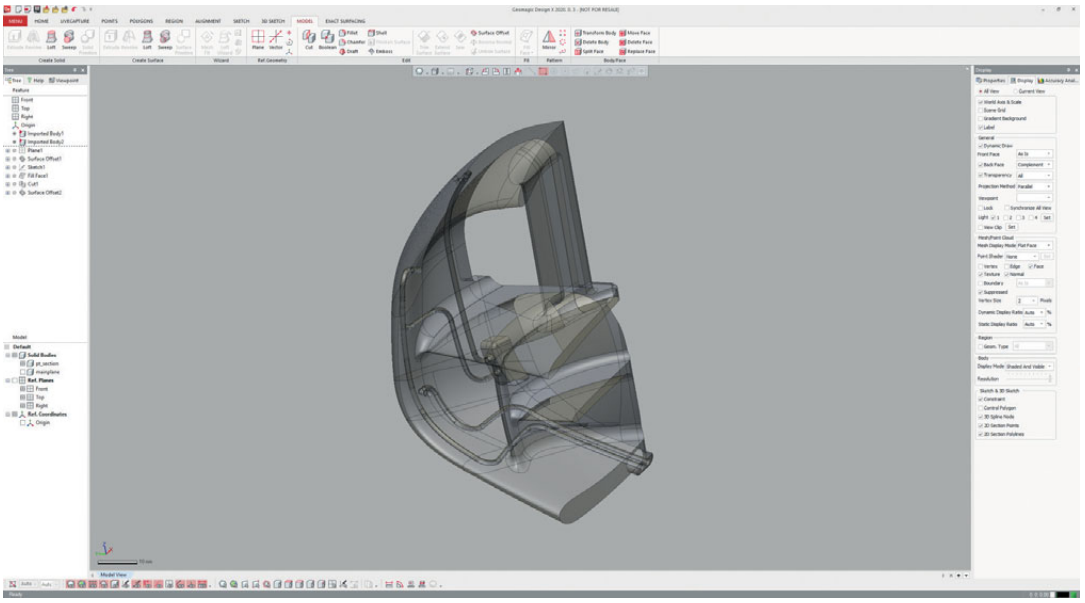
While previous materials have generally required a multi-stage process to prepare them for PIV testing, Accura Composite PIV has the right surface texture and colour to be used straight from the printer. It's designed to minimise reflections and maximise contrast to improve the resolution of the technique.

"It's fundamentally a pretty straightforward concept," says Baughey. "We saw all the painting and surface finishing that the teams were having to do, in order to get the right contrast between the component and the particles. It just made sense to find a natural colour that would reduce that without the need to paint the part."

The purple colour of Accura Composite PIV was chosen because it's dark enough ▶

**ABOVE & RIGHT** The strength and weight of structural metal components can be optimised with 3D printing





**LEFT** AM offers the flexibility to create part geometries that would be difficult or even impossible with conventional manufacturing techniques

to show up the contrast to the particles, without being so dark that it becomes hard to pick out the contours of the surface or distinguish those from the background.

"Being able to control both the surface quality and surface finish of the parts is a big deal for us. So we'll continue to work on those material properties and parameters," he adds.

## Functional parts

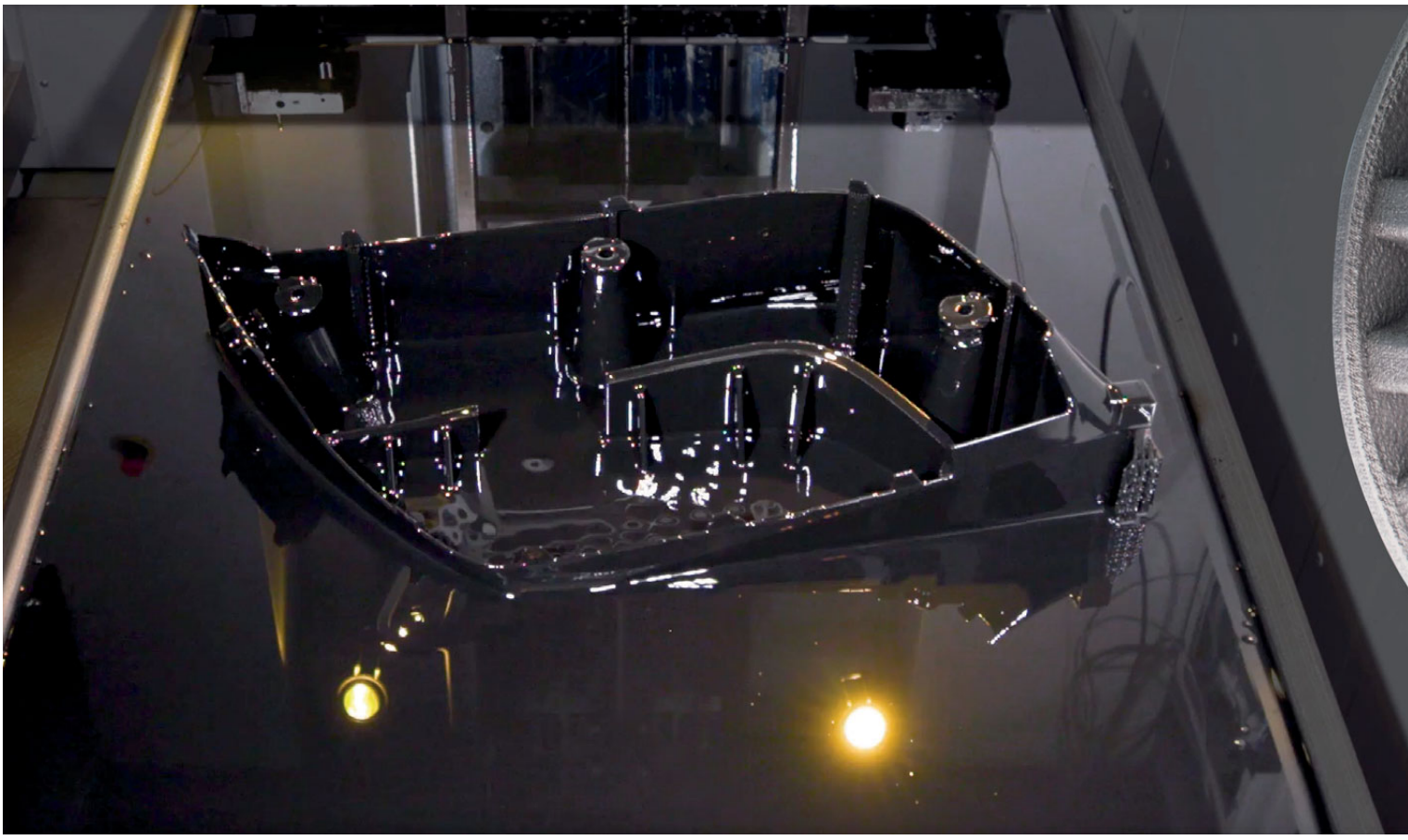
Recent years have also seen additive manufacturing evolving – from something that was once predominantly used for form and fit prototypes, to a concept that's now used for an increasing number of functional parts.

"For us, functional doesn't just mean two weeks of testing – it's potentially about a whole season or more," comments Baughey. "We've just released a very tough, rigid material – Accura AMX Rigid Black – that's designed to offer that performance for 18 months outdoors, with UV exposure, or up to eight years indoors. That's enabling additive parts to be used in applications where they wouldn't typically have been found before."

One particular growth area for these functional parts is interior components, he explains. Likewise, custom retention components that are used to route and to hold things like wiring harnesses and cooling hoses: "When you're dealing with these components ▶

**BELOW** Sauber Engineering produces an average of 100-150 3D printed part sets daily, of which 80-90% are for wind tunnel testing

> *"There's huge potential for additive parts in energy and fluid management"*

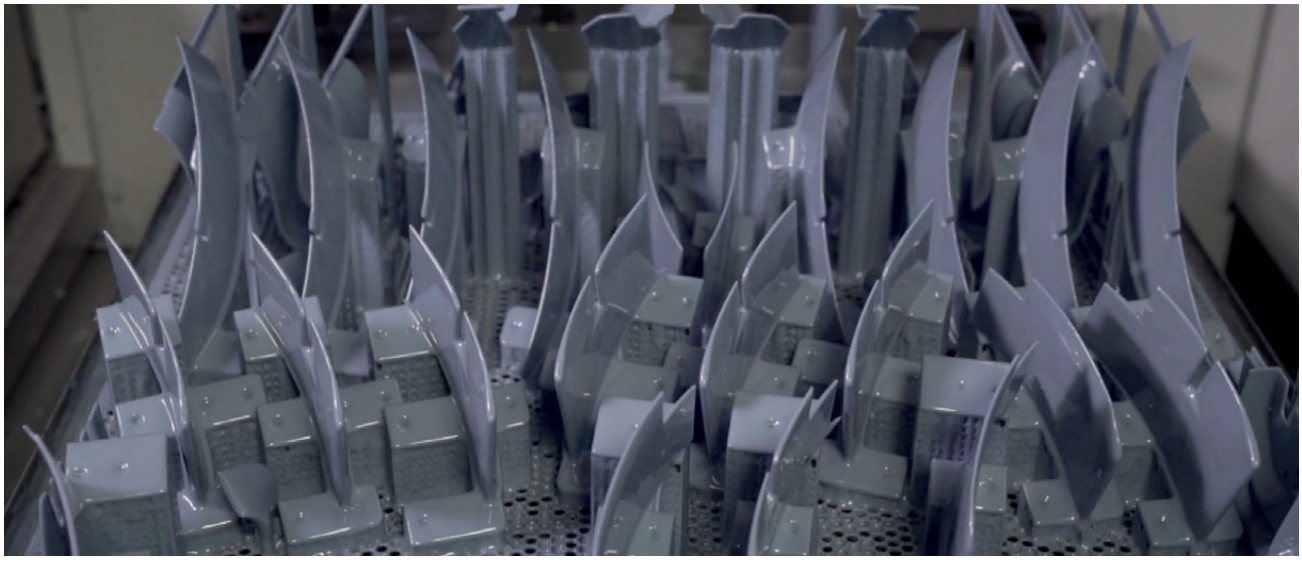


you need to be very confident that you can hold them securely in place, even in a very harsh environment in the engine bay. A big piece of my background, when I was working in automotive, was electrical harness design and ECUs. At the time, we weren't really able to leverage additive, because the material properties weren't there, but now I can see a lot of potential for the new, more robust materials. It means that teams and manufacturers working on a lower budget can now produce their own custom parts tailored to the engine bay of that particular car."

## Metal components

Additive manufacturing is also a major trend for metal components. It offers the flexibility to create part geometries that would be difficult, or potentially even impossible with conventional manufacturing techniques.

**ABOVE** Accura AMX Rigid Black is a game-changing resin that combines long-term environmental stability and high performing mechanical properties with the proven advantages of stereolithography, including superior surface finish, accuracy, and repeatability



**ABOVE** When the Oregon-based English Racing team experienced repeated engine failures on its Mitsubishi Evo, it struggled for over two years to produce a new under-pulley gear as the original pulley was a cast part. When it eventually discovered metal 3D printing, it was able to produce a working prototype in just five hours

**LEFT** Proven materials, large format and innovative software solutions enable teams to produce many concepts all at once for physical test and tune

Typically, this is seen as a way to manage structural forces and produce a part that's light for a given level of strength, but it can also bring advantages in terms of fluid dynamics and thermal management.

"I think there's a huge potential for additive parts in energy and fluid management," comments Baughey. "You can design parts with very thin walls, and you can get some very intricate internal geometries. It opens up that design freedom, but you do have to understand how to use the post processing techniques to maximise that."

## Lower budget categories

Tapping into the benefits of additive manufacturing requires an in-depth knowledge of the techniques and their capabilities. Although high-end motorsport has been one of the most innovative adopters of additive techniques, Baughey believes that there's still scope to take the concept further – especially in lower budget categories where there hasn't been so much uptake so far. "There's still a lot of movement that we need to make in terms of instructing the engineers on how well these new materials are performing from a functional perspective," he notes.

Much of that comes down to communicating the benefits of the strengths of additive manufacturing techniques and helping people to understand the design parameters that they introduce. But 3D Systems has also been making a concerted effort to lower the barriers towards adoption of this technology with software tools that simplify the design for manufacturing process.

Baughey predicts that the range of applications for additive parts will continue to broaden. On the aerodynamics side, for instance, what started as a tool for creating parts of wind tunnel models has now expanded to produce things like pitot tubes and sensors used on the vehicle. Meanwhile, when it comes to metal materials, he predicts a lot more high-energy, rotational inertia components being created from additive manufacturing processes, along with a continuing trend towards greater use in high temperature applications such as exhaust components.

> *"For us, functional doesn't just mean two weeks of testing – it's potentially about a whole season or more"*

In some respects, there's never been a better time to embrace these new materials and techniques. Beyond the normal desire to innovate, the future also looks set to bring an increasing amount of disruption in the form of new powertrain technologies, such as battery electric and fuel cell vehicles. This will inevitably bring new challenges, even in things as simple as clips and pipe fittings.

"The nice thing is that additive has become an integral part of a lot of the teams now. So as they innovate into these spaces, they're going to be leveraging that right from the start," comments Baughey. "It's not going to be 'how can we take this application and migrate it to additive?', it will be designed from the start with additive in mind."

So, it seems the future is bright for this technology. Although, when it comes to 3D printing, it still feels like the future is here already. RT

# HYDROGEN WILL POWER MOST OF MOTORSPORT BY 2030

**Chris Ellis** explains why the growing momentum across different industries is making hydrogen impossible to ignore in motorsport


MissionH24-Thierry Gromik

**RIGHT** The H24 takes the dream of racing hydrogen sports cars at Le Mans a step closer to reality. Where its predecessor was a laboratory car to trial technical solutions, the latest design chases performance with new aerodynamics and an improved powertrain

**ARE WE** looking at the car that will spawn a hydrogen fuel cell-powered winner of the 2026 Le Mans 24 Hours?

Not so long ago, the suggestion would have been laughed out of town. Yet, as Automobile Club de l'Ouest president Pierre Fillon pointed out, people dismissed Audi's notion of competing in the endurance classic with a diesel powerplant as "crazy". Two years later, it had won the race.

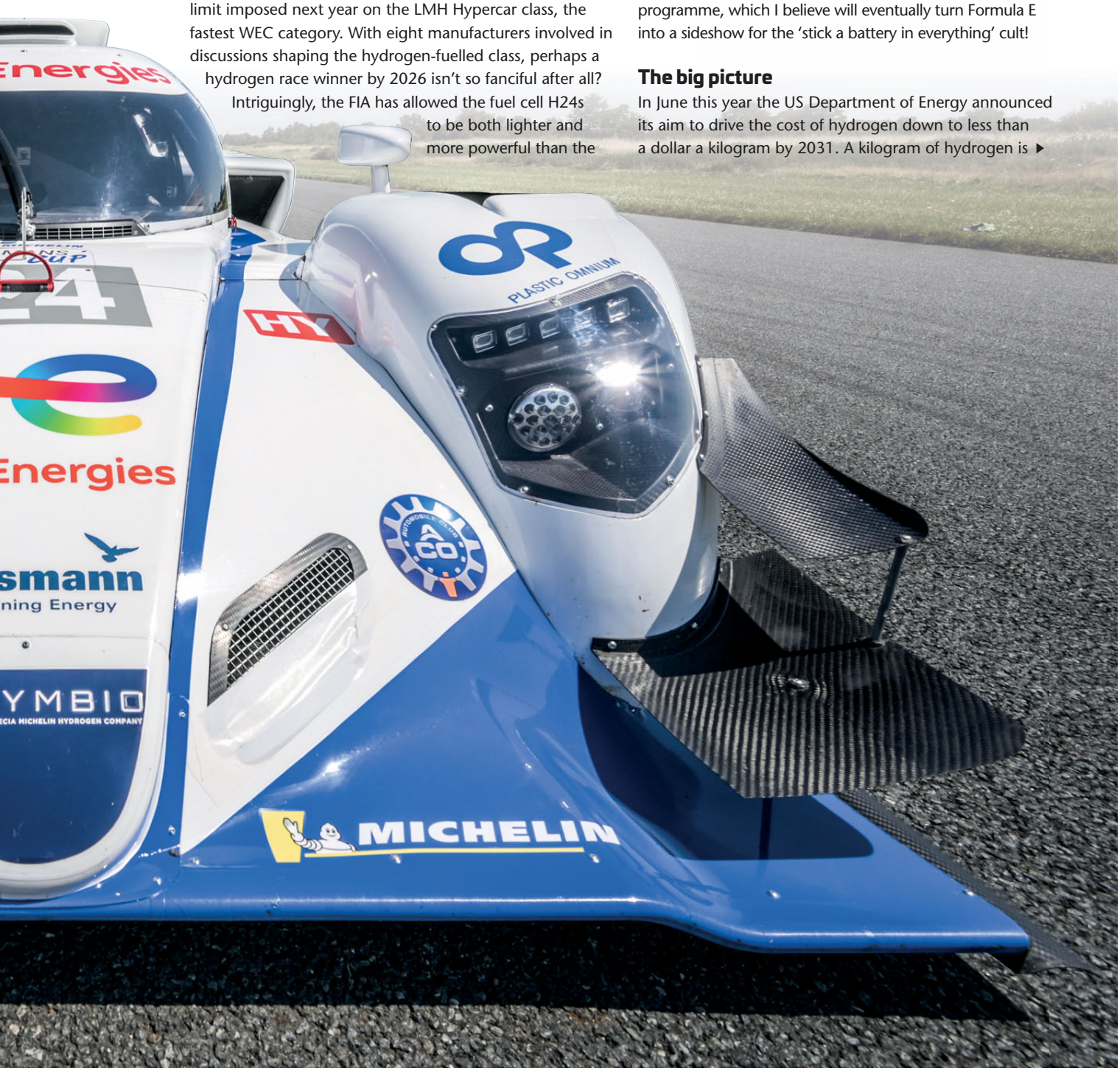
The H24 car you see below is the embodiment of Mission H24, the ACO's project to have fuel cell cars racing at the Le Mans 24 Hours in 2025. It's worthwhile noting that the peak power allowed will be 50 kW more than the 500 kW limit imposed next year on the LMH Hypercar class, the fastest WEC category. With eight manufacturers involved in discussions shaping the hydrogen-fuelled class, perhaps a hydrogen race winner by 2026 isn't so fanciful after all?

Intriguingly, the FIA has allowed the fuel cell H24s to be both lighter and more powerful than the 'battery-only' cars in the new FIA Electric GT Championship, announced in April. Could this be because the FIA has believed for years that fuel cells will eventually beat batteries in the air, at sea, on the road, and soon, on the track?

There is evidence for this dating back to 2015, in the 13th edition of 'Auto', the official journal of the FIA, with this quote: "If I could dream I would say that for me the ultimate achievement of this championship would be to introduce hydrogen into motorsport." This was FIA technical director Bernard Niclot speaking, and he was referring not to WEC but to Formula E! Now Niclot is helping make that dream come true as Director of Innovation on the Mission H24 programme, which I believe will eventually turn Formula E into a sideshow for the 'stick a battery in everything' cult!

## The big picture

In June this year the US Department of Energy announced its aim to drive the cost of hydrogen down to less than a dollar a kilogram by 2031. A kilogram of hydrogen is ▶



enough to drive a large fuel cell SUV more than 60 miles at 70 mph. A similar conventional SUV needs two gallons of gasoline to cover the same distance at $2.50 a gallon. So the most compelling reason to use hydrogen rather than diesel or petrol will eventually become lower running costs, not just zero emissions.

Hydrogen will eventually fuel most heavy-duty road vehicles, from big trucks to SUVs, but also most other forms of transport, including planes and trains. A year ago, Airbus announced its plan to develop a novel airliner fuelled by hydrogen. Although the initial motivation is to achieve zero-emissions, the key reason airlines will want to buy these new aircraft will be because the cost of using liquid hydrogen will be much lower per passenger mile than using 'pseudo-kerosene' SAFs (Sustainable Aviation Fuels).

At a more mundane level, the British government has funded the HydroFLEX project which is already testing a fuel cell train in Warwickshire. The basic intention is to avoid most of the cost of electrifying branch lines. And it will, when hydrogen costs less than a pound a kilogram.

Hydrogen will also have a major role in storing and distributing renewable energy. It is much cheaper to store energy long-term as hydrogen in salt caverns rather than in batteries, and this is already happening in Germany, the UK and the US. Also, it costs much less to carry energy as hydrogen in pipelines than over electricity transmission lines, see the Italian government's strategy to profit from Germany's future consumption of renewable energy from Southern Italy and North Africa.

Other massive investments in hydrogen infrastructure are already being made. For example, China's central and regional governments have committed more than 10 billion dollars to hydrogen infrastructure in just the first five months of this year.

Note that direct use of hydrogen as a fuel is not just about transport: it is expected to have a major role in making cement and steel production fully sustainable, which currently consume huge volumes of natural gas. One result is that oil producers such as Saudi Arabia and the UAE are already investing heavily in solar power with the objective of becoming major exporters of hydrogen.

Battery proponents often choose to quote out-of-date numbers for the efficiency of hydrogen storage and distribution. But the game moves on: for example, Jeff Bezos and Bill Gates have invested in H2Pro which has developed a novel electrolyzer with a claimed efficiency of over 95%. And again, with a target of $1/kg.

Efficiency is just a component of cost-effectiveness. If renewable energy is normally going to be stored and distributed as hydrogen, then recharging a vehicle will add the extra cost of the fuel cell stacks needed to produce the electricity and the cost of the energy lost in conversion. What will count is the total cost from panel or turbine to electric motor in the vehicle. Put simply, if hydrogen must be used to store, ship and distribute energy, why not wait to convert it to electricity until it's in the car?

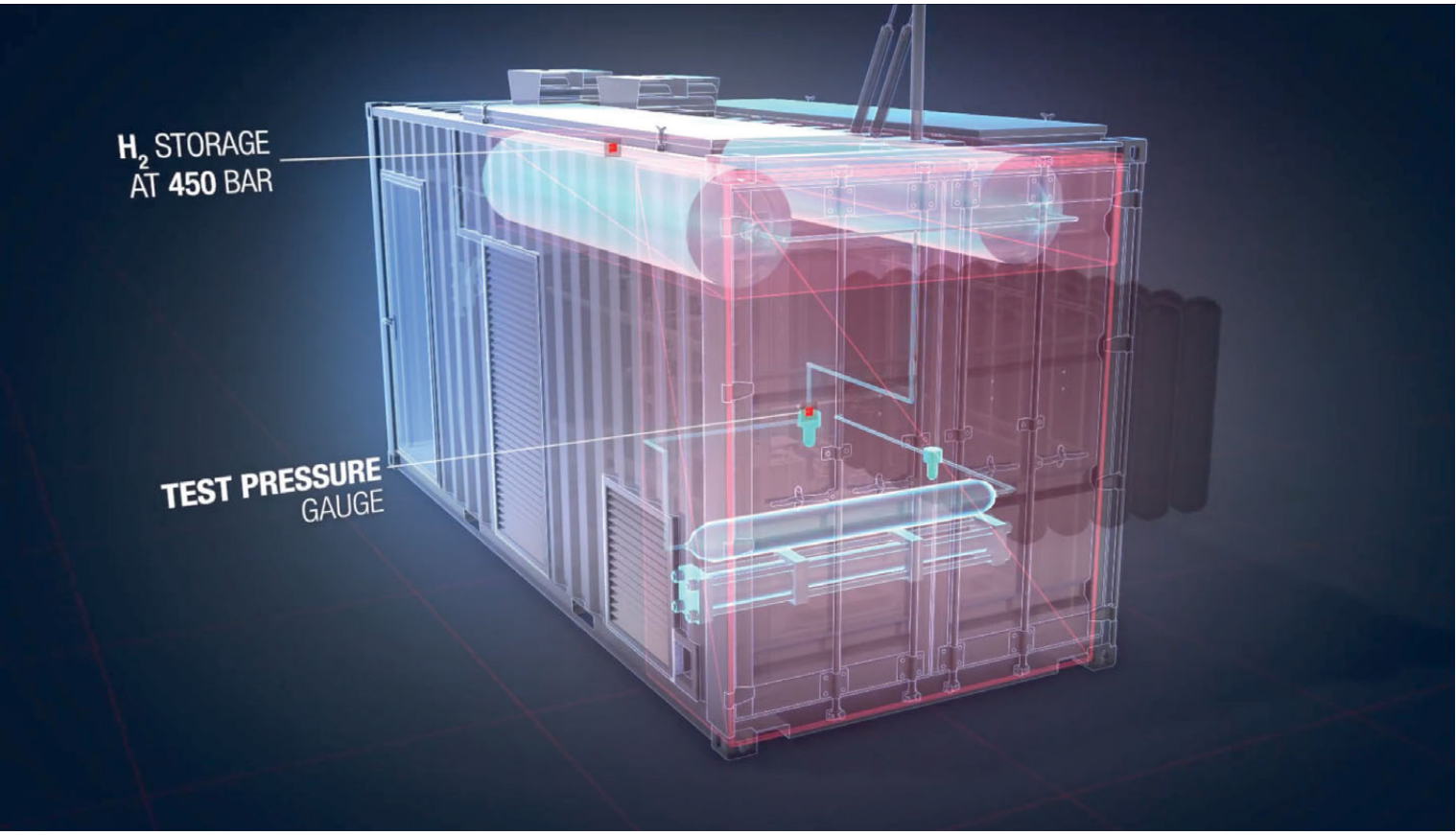
Today, owning a fuel cell car makes little sense in most countries when hydrogen is so expensive and there are so few filling stations. But by 2030 the picture will be very different. The cost of fuel cell cars will also have fallen dramatically.

The Toyota Prius went into production more than 10 years before the initial attempt to allow hybrids in Formula 1. So it makes sense to look at the latest developments in road-going hypercars for techniques that may be the basis of the powertrains in F1 cars by 2031. Let's start with battery-only hypercars.

## Lotus: EV hypercar benchmark

A Lotus Evija can get from 120 to 180 mph in roughly half the time it takes a Bugatti Chiron, which should deliver enough hype for anyone. However, an Evija


**LEFT** Hydrogen is seen as the future in the sky, as well as on the racetrack. Airbus has revealed three concepts for the world's first zero-emission commercial aircraft, which could enter service by 2035




**ABOVE** The mobile hydrogen refuelling station developed by TotalEnergies for racing represents a major technological step forward

**BELOW** The Apricale hypercar perhaps offers motorsport a few pointers to the direction in which hydrogen is heading

has a WLTP range of only 215 miles because its battery has a usable capacity of less than 70 kWh, despite weighing 708 kg. Consequently, a recharge may be needed after less than 20 minutes when driven flat out on a track day.

The battery's relatively poor specific energy probably results from the choice of battery cell needed to deliver a peak of 1,472 kW without wearing out the battery too quickly. However, the rest of the Evija seems light enough because the total weight of the car is 'only' 1,680 kg.

Meanwhile, in California…

At the beginning of this year a camouflaged (to attract attention?) Hyperion XP-1 'hydrogen hypercar' was seen on some of the streets of Las Vegas and Hollywood.

The Hyperion XP-1 is expected to begin production next year. A headline-grabbing range of up to a thousand miles is promised, and it should weigh as little as 1,248 kg. Which sounds more like a Lotus than an Evija does! As a road car, the XP-1 needs less than 100 kW from the fuel cells, which means the stack could weigh less than 100 kg. So a potential weight saving of over 300 kg, allowing for the hydrogen tanks. Hyperion claims its tech is NASA-derived, and NASA announced three years ago it had developed a novel solid oxide fuel cell capable of reaching 2.5 kW/kg. Supercapacitors with over 100 Wh/kg are also imminent, from Superdielectrics and others.

'Space technology for the road' – not a bad second headline! Obviously ideal for the track too. But while the more enlightened of our motorsport engineers have ▶

— Viritech

hydrogen on their radar, they need to be certain that the tech underpinning the likes of the Hyperion works properly under maximum stress, and this probably won't be obvious until at least 2025.

The Hyperion XP-1 won't be unique for long. By 2023 the Apricale should be in limited production, offering similar performance in a car which is promised to be even lighter, weighing just over a tonne, about the same as an LMH but with almost twice the peak power. Viritech has developed a new type of hydrogen storage tank using graphene to increase strength and lightness. The tanks act as stressed members in the Apricale's chassis, helping to reduce the vehicle's weight and improve not just acceleration but cornering and braking. It will be fascinating to see the first track test of a WEC Hypercar versus an Apricale fitted with similar tyres…

## Balance of power

All fuel cell vehicles need some form of RESS (Rechargeable Energy Storage System – current FIA terminology) between the cell stack and motor(s), essentially to support regenerative braking and supply the above-average levels of power required during acceleration. This is reflected in the initial regulations for H24, where the peak power of the fuel cells is limited to 250 kW, while the RESS will be allowed to add up to 300 kW, giving a combined peak of 550 kW.

The initial generations of road FCEVs from Honda, Hyundai and Toyota all adopted 'minimal battery' designs, almost a 'fuel-cell-only' approach. For example, the latest Mirai has a 125 kW fuel cell stack but the combined peak power delivered to the motor is only 136 kW, which reflects a small battery with a capacity of only 1.2 kWh. This contrasts with the Hyperion XP-1 which probably has a fuel cell stack of similar power but delivers a total of over a thousand kilowatts courtesy of its supercapacitor stack, which may have a capacity not much larger than the battery in the Mirai. It seems the fuel cell SUVs being developed by BMW and JLR will offer a sensible compromise, including a plug-in battery pack of around 15 kWh and 150 kW. So can we expect a Range Rover Rex fuel cell range-extender soon from JLR? 'King of all it surveys'?

## Setting new standards

In motorsport, the new kid on the block will be the FIA Electric GT Championship.

To quote the FIA: "The cars will compete at full-length permanent circuits and will set new standards for electric vehicles in motorsport in terms of performance and range... Each round will be staged within a spectacular two-day format. Saturday will consist of a qualifying sprint race followed by Sunday's 45-minute main race featuring super-fast recharging pit stops."

The table below shows the threat EGT poses to Formula E.

### How they compare...

| Category | Min weight | Peak power | Power-to-weight | RESS capacity |
|---|---|---|---|---|
| **2022 Formula E** | 780 kg | 300 kW | 364 kW/tonne | 52 kWh |
| **2023 EGT** | 1,490 kg | 430 kW | 289 kW/tonne | 87 kWh |
| **2025 WEC H24** | 1,400 kg | 550 kW | 393 kW/tonne | 3.1 kWh |

**ABOVE & BELOW** The Lotus Evija (below) currently sets the benchmark for EV hypercars, but only until the Hyperion XP-1 supercar (above) appears

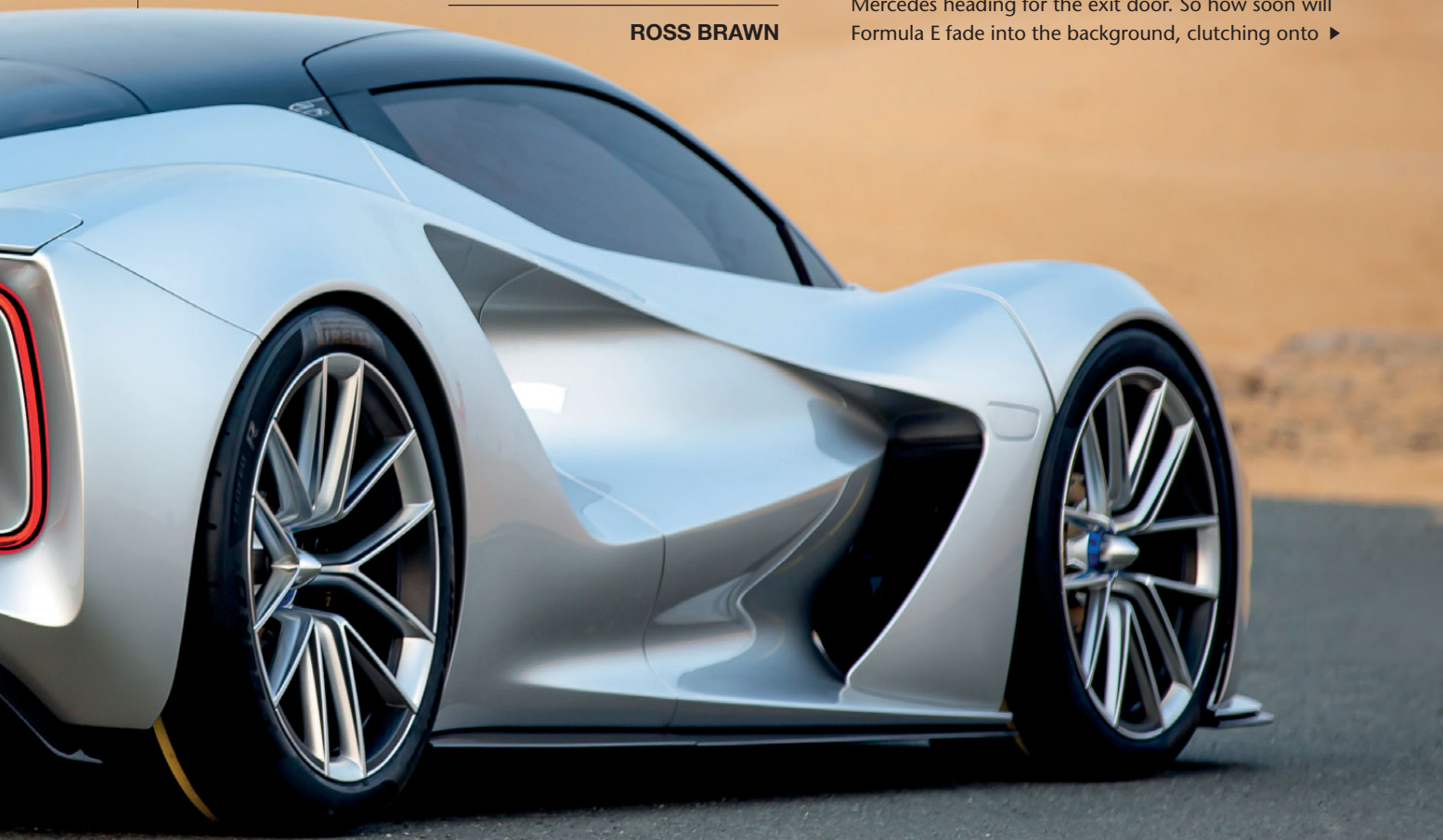
Now imagine how much more impressive EGT cars will seem racing flat-out on 'proper' circuits when compared with Formula E. In two years' time the global TV audience should have been convinced. Several commentators described the recent FE races at London's Excel Centre as "surreal". This was perhaps a polite way of saying 'unreal', given the apparently endless single line of cars travelling at bicycle speeds queuing up for the narrow, very slow corners.

Then along will come H24, with a higher power-to-weight ratio and practically unlimited range, racing with the 'big boys' at Le Mans. Right from the start, they will be allowed 50 kW more power than the Hypercars, although they will initially be obliged to weigh 370 kg more than the 1030 kg Hypercar minimum. However, with the evidence coming from Hyperion and Viritech, how long will it take before the H24s are simply allowed to be classed as another form of WEC Hypercar? And who will dare oppose that?

> *"Maybe hydrogen is the route that Formula 1 can have where we keep the noise, we keep the emotion"*
>
> **ROSS BRAWN**

The FIA recently announced a long-term partnership with Discovery to promote the Electric GT Championship. But one point the governing body didn't labour is that Discovery is also largely responsible for the broadcast coverage of Formula E. So I am agog to see how this conflict unfolds, particularly when a powerful player (such as BMW, Hyundai, JLR or Toyota?) asks for hydrogen range extension to be introduced in EGT.

Formula E currently enjoys exclusivity as the standard bearer for EVs in mainstream motorsport, but this will soon vanish. Already, manufacturer support has flagged, with Audi, BMW and now Mercedes heading for the exit door. So how soon will Formula E fade into the background, clutching onto ▸



> *"Mission H24 will eventually turn Formula E into a sideshow for the 'stick-a-battery-in-everything' cult!"*

its exclusive right to 'open-wheel battery-only' racing?

And what of its off-road cousin, Extreme E? Energy for the series is already brought to the side of the course as compressed hydrogen, and then a 48 kW fuel cell stack is used to recharge the battery-only cars. So how long before the fuel cells move onto the cars?

Here is what series founder Alejandro Agag said back in 2019, even before the first XE championship had started: "We're going to open the door on Generation 2 of Extreme E to hydrogen. I think hydrogen could be really interesting technology to test in Extreme E."

## Is F1 brave enough for hydrogen?

Former Audi Sport engine head Ulrich Baretzky is one of a number of leading figures to suggest it is far from outlandish to consider hydrogen combustion engines as a future route for Formula 1, as well as endurance races like Le Mans.

"In 2025 we will still see combustion engines (at Le Mans), because the energy density is unbeatable at the moment with any technology we know today," he told the recent MIA conference. "Five years later I hope we will see a mix between hydrogen, combustion, and fuel cell."

There may be no agreement, as yet, on the future direction of Formula 1, but there is consensus on one point: it won't be following Formula E down the battery-only, open-wheeled racecar route. This would make no sense technically.

Here's a simple reality check: to maintain F1 lap times, the average power from the battery pack would need to be over 300 kW, even allowing for substantial improvements in regenerative braking. 300 kW for two hours is 600 kWh. If the battery pack is not allowed to weigh more than 300 kg, the specific energy of the battery cells would need to exceed 2,000 Wh/kg – 10 times the 200 Wh/kg of the 2022 FE cars.

Solid state batteries delivering 500 Wh/kg are not expected to become available until at least 2025. Even then, the battery pack would weigh at least 1,300 kg, implying the cars will weigh almost two tonnes!

So how much extra power will be needed to stay

**ABOVE** Formula 1 to run on hydrogen? Ross Brawn acknowledges it's one of the options on the table

**BELOW** Extreme E is making waves with its all-electric SUVs now but the ambition is for the next generation of its cars to be opened up to hydrogen


competitive? And how much extra downforce? And consequently more energy per lap? Or will races last less than 30 minutes? Or will a pit stop take 20 minutes to add 300 kWh, even recharging at 1,000 kW? Any more will fry the battery!

Instead, Ross Brawn, Formula 1's managing director for motorsports, has admitted that hydrogen could be an option as a future fuel for the pinnacle of motorsport. "We can't have a sport which is seen as a dinosaur and out of step," he acknowledged to the BBC. "Maybe hydrogen is the route that Formula 1 can have where we keep the noise, we keep the emotion but we move into a different solution," he suggested.

A consensus now seems to be emerging within F1 that the next step, from 2025 to 2030, should be to retain the current V6 but drop the complex and expensive MGU-H exhaust energy recovery system and increase MGU-K power, perhaps driving the front wheels as well as the rear. The key to improving F1's 'climate image' in the near-term will be to replace petrol with a sustainable fuel that is genuinely net-zero.

Fortunately, F1 cars use so little fuel per season that it will cost each team less than £100,000 per year to adopt a fuel costing as much as £10 a gallon, so they should easily be able to afford a fully sustainable e-fuel that is functionally identical to petrol, thus minimizing development costs. This fuel could be made using electricity from wind and solar to electrolyse water and combine the hydrogen produced with CO2 extracted from the air.

**BELOW** Former Audi engine supremo Ulrich Baretzky is among the high-fliers who expect hydrogen to become increasingly prominent in top-level motorsport

## ICE to become obsolete?

However, the internal combustion engine will be seen as obsolete well before 2030, so running V6s (and V8+s?) on hydrogen is not going to be acceptable, however attractive that may seem to some of us. For example, Daimler recently announced that it will cut its development budget for ICEs by 80% over the next five years, so it won't want to put more funds than absolutely necessary into ICEs for F1.

In April last year Daimler announced it was halting the limited production of the Mercedes GLC F-CELL SUV because it cost twice as much to manufacture as the equivalent battery-only SUV. But recently it stated that it aims to reduce the cost of fuel cells by a factor of five or six by 2027, so it will be interesting to see when production re-starts.

But the cost of fuel cells is almost irrelevant in F1. The current limitation is specific power: this will need to rise to the level promised by NASA before it makes sense in F1. Around 2026? In time to commit to fuel cells in 2031 and beyond?

The other key reason for fuel cells rather than ICEs in F1 (and everywhere else) is they will need much smaller fuel tanks than hydrogen V6s. And emit no NOx.

While today's typical 1 kW/kg is acceptable in a large SUV needing only a continuous 100 kW from its stack, an F1 car is going to need at least 300 kW. Back in 2018, NASA patented an SOFC potentially capable of delivering up to 2.5 kW/kg. Hyperion is claiming access to NASA technology; we should soon see how far this extends. But currently it is too early for Formula 1 to commit to a timescale for the end game of fuel cells running on hydrogen, so the decision to persist with the nasty little V6s until 2030 is correct, sadly. It has the key benefit of being the least-cost medium-term solution to the challenge of sustainability on the track.

By as early as 2026, it will surely have become obvious that fuel cells will power most of motorsport – eventually.

Mainly because hydrogen "adds lightness" as Colin Chapman would say. It adds range too.

By then perhaps artificial sound effects will prove capable of providing a choice of satisfactory substitutes for 'V12 music'? RT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# BENTLEY BRINGS ON THE THUNDER!

**Hal Ridge** talks to the project leader of the team behind the most extreme road-going Bentley ever built

**THE** tagline 'Bring The Thunder' was a key part of Bentley's marketing strategy for its circuit racing programme with the Continental GT.

Having contested iconic events such as the Spa 24 Hours and Bathurst with the GT3 4.0-litre twin-turbo V8 machine since 2014, the British marque entered 2021 seeking a platform from which to promote greener credentials.

While other automotive brands continued to wrestle with the tricky decision of which series to step into, amid the plethora of avenues offering electric, hybrid and other propulsion methods, Bentley headed to America and took its thunder into the mountains. It identified the world-famous Pikes Peak International Hillclimb as the perfect playground for a breathed-on version of its GT3 monster. ▶

**LEFT** One of the challenges was to overcome low speed corner exits yet maintain engine performance at high speed

This was to be no ordinary assault on the 'Race to the Clouds'. Instead of the fossil fuel petroleum the car had run on in race trim, Bentley converted the car to use biofuel.

And, despite the Colorado mountain presenting a rather different challenge to that of lapping Oulton Park in the fastest possible time, the luxury brand impressed. "We'd done the event previously and it is quite addictive, as any form of motorsport is. It's a very unique atmosphere to be in, where without any limitations the event allows you to fully express your engineering abilities, as a group," explains project leader David Argent.

"In the road car category [which it had won at its previous two attempts] we were promoting how good these road cars are, but always at the back of our mind was 'what could we do with our race car?'"

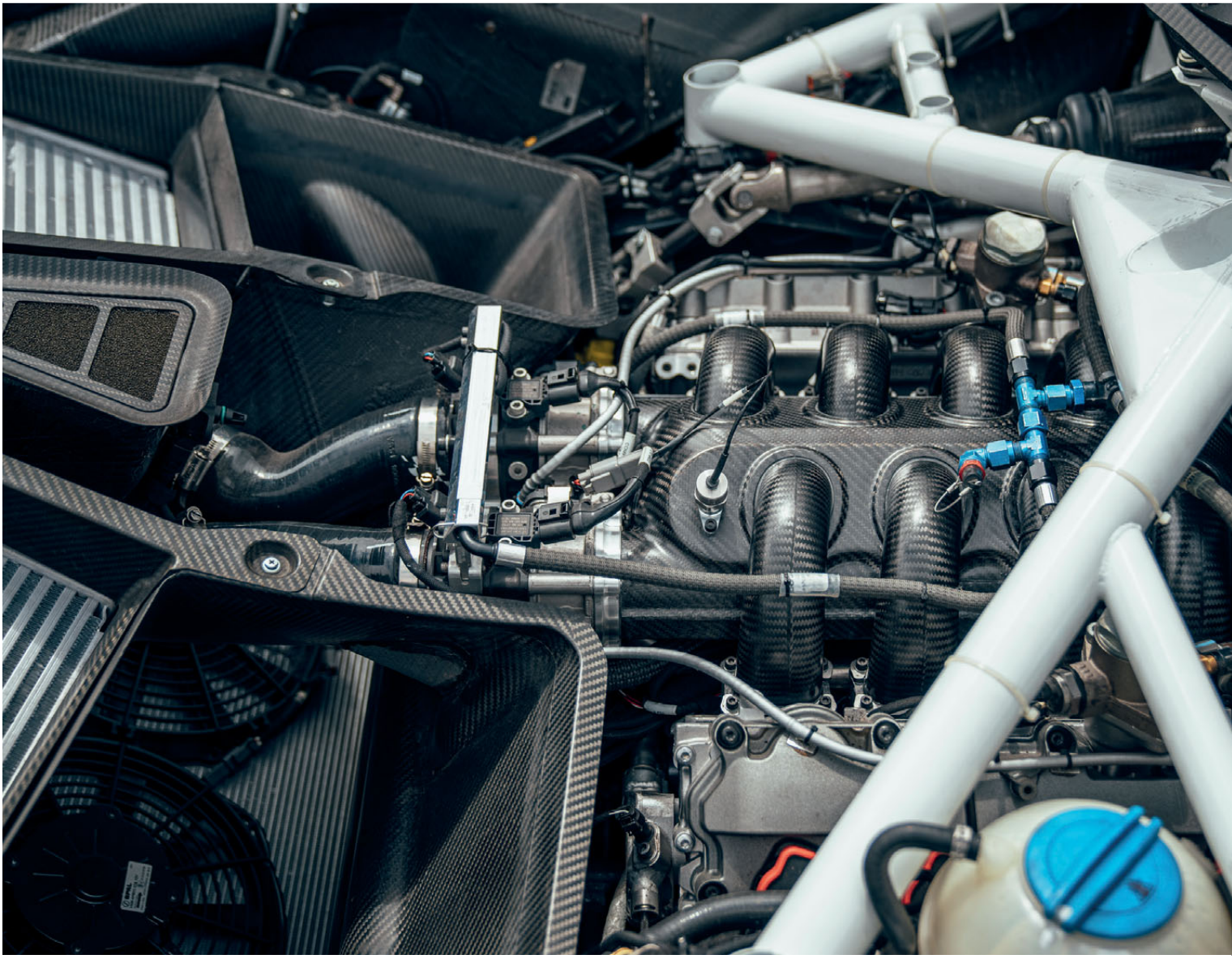
The GT3 used for the PPIH project wasn't plucked straight from a race bay. The car is actually owned by a customer, FastR's Luke Clayton, who has campaigned the machine with an increased aero package in UK Time Attack events for the last two years, run by Roger Clark Motorsport. The car was chosen to give Bentley the best chance of challenging for the Time Attack 1 class record.

## Attack at altitude

"I knew straight away that the base car wouldn't give us the advantage we needed, so we had to take it that level up in the regulations," notes Argent. However, the Time Attack version of the car was still fundamentally a GT3 racer, but in 'unrestricted calibration' trim, basically without any of the BoP [balance of performance] restrictions forced on constructors as part of the GT3 rules.

"There had been no hardware changes [aside from the aero]; it was just purely a calibration," he says. "So to take it to Pikes Peak, we thought about all the environmental factors: the cooling and how do we regain that lost power at altitude with 30% less dense air. Aerodynamics was a factor, and the engine performance. In an event that's biased towards low-speed corners, how do you overcome that low speed corner exit and maintain engine performance at high speed? Those were the core areas we looked at and made hardware changes to suit."

Argent describes the learnings from having been at Pikes Peak in recent years with the road car programme as "absolutely vital" to understanding the




**ABOVE** There is a lot to juggle within the cockpit during the assault on the summit

**LEFT** The engine was the main focus, featuring new pistons, conrods and high-performance valves

environment and challenge of the event, and the limitations it puts on vehicle performance. With that knowledge in his pocket, he sat down with engineers at Continental GT3 creators M-Sport in Cumbria, including engine guru Nigel Armfield, to discuss plans for this extreme event that has, compared to GT3 racing at least, fundamentally open regulations.

The only main change to the chassis from the GT3 racer is the visually different aerodynamics, carried across the Time Attack version of the machine with further additions. Pikes Peak rules allow for an increase for 932 square surface inches to the aero package. The large front splitter and bumper-mounted diveplanes, together with the large rear wing and diffuser, were run through a CFD programme to confirm the car had maintained its inherent neutral balance, while enjoying 30% more downforce.

"Our car is designed to be quite neutral for gentleman drivers, and with its tendency at high end to turn into understeer, rather than snap oversteer, it's a lot safer, especially on a mountain," says Argent. "We wanted to keep that same sort of balance and approach with the vehicle, but with an overall gain.

"The engine was where the main focus was. We wanted to make sure we had a power capable of getting us in a position we needed to be. We had a figure in mind within the design, so I worked closely with Nigel [Armfield]. He is a fantastic engine engineer, so I had a sit down with him, and said we needed to target a specific figure, taking into account the thermal challenges we were going to face once we get up the mountain.

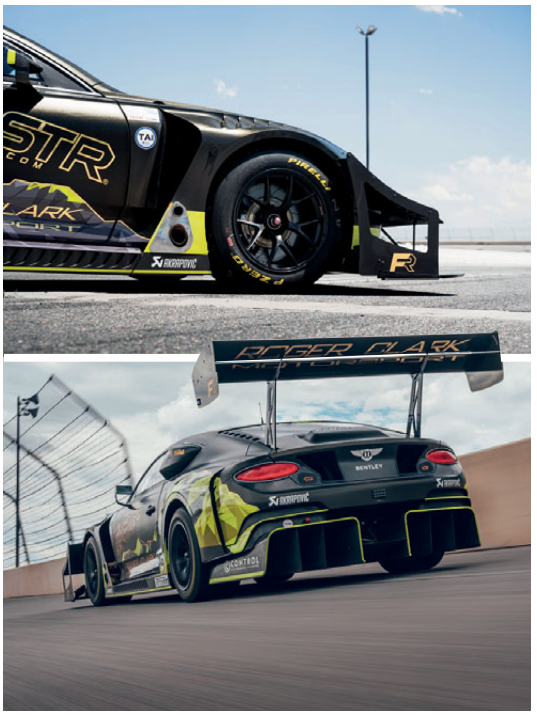
"We carried over the block, cylinder heads, crank [from the GT3 engine] but with new pistons, conrods and high-performance valves inside the engine, then externally we had enlarged turbos [with 2.2 bar of peak pressure] to improve our compression ratio, and additional fuel injection with pre-throttle injection as well as direct injection."

> *"The event allows you to fully express your engineering abilities"*

Water injection was also introduced to the engine to aid combustion temperatures, while an additional water radiator was added in the rear of the car to accompany the primary unit in the front, fed cold air by ducts in the rear windows. Exhausts exit the sides of the car at the front, effectively between the door aperture and front wheels.

The GT3-spec machine produces 550 ▶


YOKOHAMA
GRAN TURISMO
Mobil 1



**LEFT** The aggressive aero package was refined with Computational Fluid Dynamics before the record attempt

**BELOW** The Alcon brakes are water-cooled, to handle the increased loads that an all-out attack on the course brings

> *"The traction control system was used in more of a last resort role than it was originally designed for"*

horsepower in unrestricted trim, but the engine work on the Continental for Pikes Peak made for a peak delivery of 750 bhp and 738 lb/ft of torque at sea level.

The combined experience of Bentley having already been at Pikes Peak in the years preceding the GT3 effort, and M-Sport's rally knowledge, put the programme in good stead for the challenge, but there are always unknowns.

"That's always the enticing part of this event: the challenge," grins Argent. "We did a test very early on, on a public road called Independence pass, which was at 12,000 feet. That first test we did as a priority that actually highlighted we'd gone slightly too large on the turbo exhaust housing, which gave us a little bit too much turbo lag. We were in the right ballpark but we reduced the housing size for testing after that point. You can prepare really well, but there's nothing like doing the real thing."

The addition of the biofuel element, courtesy of ExxonMobil's renewable racing fuel, made for surprisingly little additional work, other than the mapping of the Cosworth engine management system required for the altitude of the event.

"It's great in a sense that it's a drop-in fuel," says Argent. "We didn't have to change any hardware because of the fuel; we literally put it in, did a comparison run on a dyno as it's a standard fuel, and were pleasantly surprised with the results. So it made our life easy in that sense."

## GT3 racecar base

Engine aside, a study was conducted on the other major components of the car. The end result was that many of the GT3 parts were carried over directly. They included the Ricardo six-speed sequential transmission, coupled with an AP Racing clutch and operated by a steering wheel-mounted pneumatic paddle gearshift system.

"The timeframe we had from approval of this project to the race was about three months," reports Argent. "We did some calculations to work out if we had ▶


**LEFT** The engine effectively ran in naturally aspirated form for the last two miles

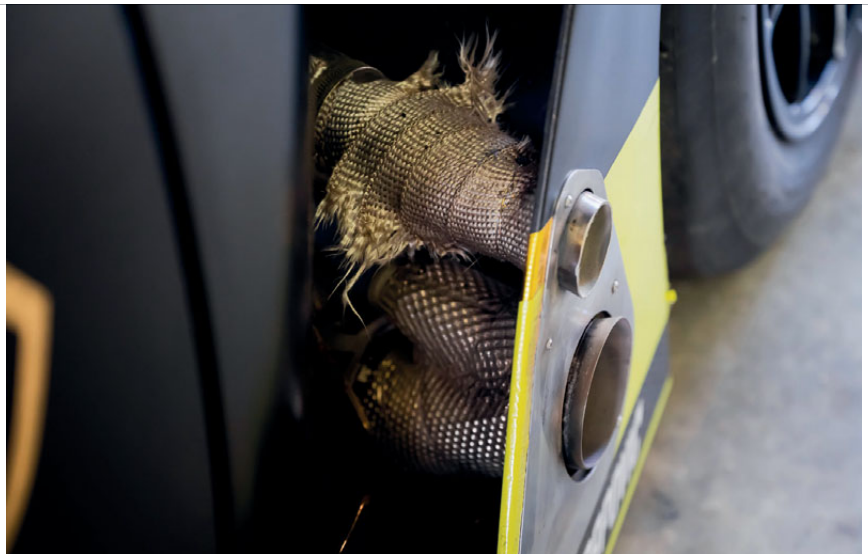
time to do proper development on the 'box, and what the effect of running the standard longer gears from the GT3 would be. Actually, we found with the power and torque figures we had, there wasn't really a detrimental effect with the gear splits we had for the certain scenarios we were planning. The gearbox was proven – we'd run it for four years in endurance races – so we stuck with what we knew on that and we didn't have a single issue with the gearbox."

## Rally approach

The same philosophy was taken with the six-pot front, four-pot rear Alcon brakes, the four-way adjustable dampers coupled to the double-wishbone suspension, and BBS Motorsport wheels at each corner.

"We just changed our logic of how you set up the vehicle," Argent explains: Taking it from a track, where you'd traditionally run stiffer, higher camber angles and lower ride heights, we had to come with a more Tarmac rally approach of high ride height and lots of damper travel. We really took a lot of camber out of the thing to try and optimise the contact patch at low speed. We softened if off in roll as much as we could too. We carried it across because this was all proven: we'd won Bathurst at the beginning of last year and if you can come with a proven package, it makes your life a lot easier."

Driver Rhys Millen, the man who had captured Bentley's two existing Pikes Peak records – the ▶



**ABOVE** With this project, as with previous attacks on the hill, Bentley worked with Akrapovič exhaust systems

**BELOW** An extra water radiator was added at the rear, fed cold air by ducts in the rear windows

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Production SUV record attained in 2018 with a Bentayga W12, and the outright Production Car record scored in 2019 with a Continental GT. – also benefited from the driver aids allowed under GT3 rules, which were kept in the car's system. The traction control system was used in more of a last resort minimum usage role than the aid to help with amateur gentleman drivers keeping the car on the straight and narrow that it was originally designed for. Meanwhile, the Bosch ABS system was used in testing to help Millen find the limits of the car's stopping capabilities.

> *"When you're pushing everything to the absolute limit, you're going to find a weak point at some point"*

With the preparation done, the British effort headed to America, initially for the official tests in the weeks before the race weekend. The car remained totally reliable in these and pleased its creators with its performance. Weather would play its part in qualifying, however.

"Throughout that week different classes qualify on different days," says Argent. "We were the last of the lot, which is sometimes good because you can see what your benchmark is, but in our case it caught us out a little because we turned up on qualifying day and it was raining. Everyone else had qualified in the dry; our class had to qualify in the wet.

"It was the traditional scenario that it stopped raining, you were on a drying track and it's whoever's out last [that] gets the most benefit. We went out for what we thought was our second to last run with an hour to go, but there were a couple of issues with other cars which meant we never got to run again and we didn't qualify where we knew we could.

"We knew we had the potential to be P1 or P2 in qualifying, but we were still really pleased and proud of the car and how it performed in that scenario."

This wasn't the first time that the weather had played a major part in proceedings, for snow and ice had already limited the event organisers to running the course to just 12,780 ft instead of to the usual 14,115 ft summit. With the finish line located almost a third of the way from the end of the normal course, at the Devil's Playground, it prematurely ended any hopes of claiming an outright class record. But there was still an event to win in its own right.


**ABOVE** The car being put through its paces at Pikes Peak International Raceway. It ran faultlessly – until the event itself

**LEFT** Running on Esso's renewable fuel, the Continental GT3 Pikes Peak made for a spectacular start to Bentley's sustainability initiative

**BELOW** With the 99th running of the famous event truncated, could Bentley return to sort its unfinished business at the centenary event?


Across the first two sectors of the shortened route on race day, Millen twice went six seconds faster than Romain Dumas [the outright PPIH record holder this year driving a Porsche 911 in Time Attack 2]. He was 12 seconds up heading into the third and final sector.

That was where, despite literally hundreds of thousands of kilometres of running and testing in the GT3 programme, a scenario occurred that M-Sport and Bentley had never come across before – with just two and a half miles to run.

Argent takes up the story: "Essentially Rhys requested a gearshift. He went from the full throttle, requested a gearshift and backed out of the throttle. At that point the car was trying to instate the gear but it went dog-to-dog, so we cut spark on gearshift, but because it had gone dog to dog it re-engaged spark when he had the throttle shut.

## Perfect storm

"We must have had a perfect storm of things to overlap where we actually ended up igniting the fuel in the intake manifold, and it cracked the intake manifold. So we were essentially naturally aspirated all the way to the end."

Millen still finished fourth overall, second in class and fastest of the machines propelled by alternative fuels, but that isn't the result the squad was looking for.

That could be a blessing, though. Nobody at Bentley was willing to talk on the record about the potential for a return to Pikes Peak, ideally running at its full length, to put the disappointment of 2021 to bed, but the wry smiles tell their own story.

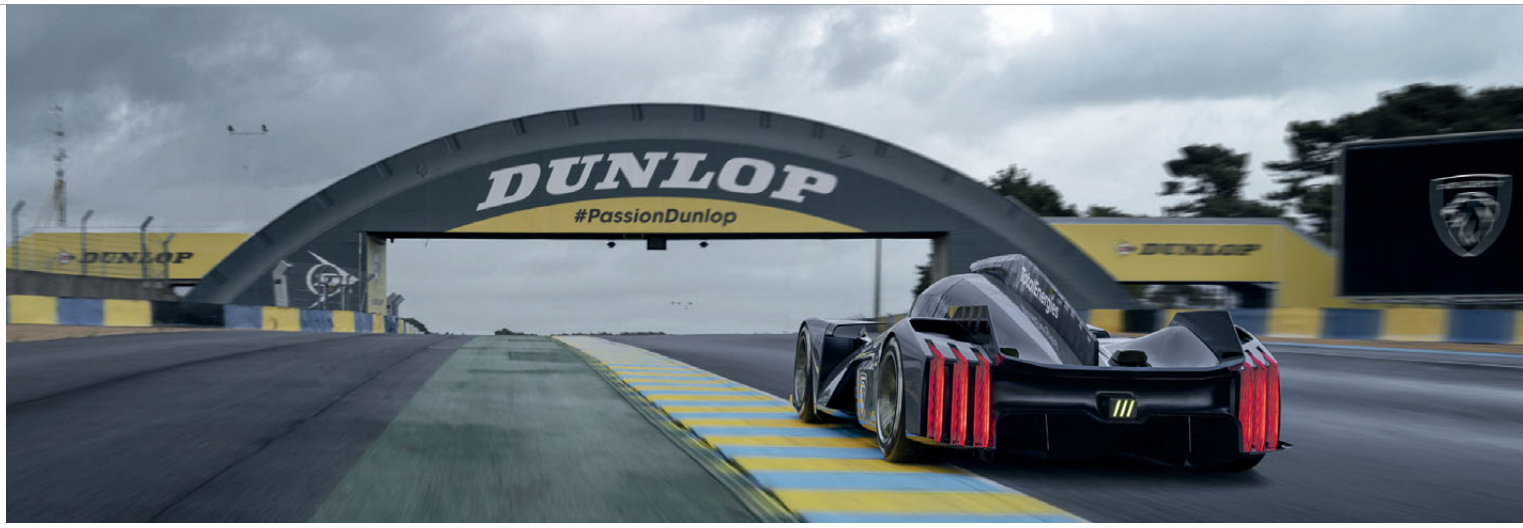
Discussions may not have even started about whether Bentley might return to the US in the future, but having come so close, there must be appetite to complete the mountain run as they know they can.

"It's heart-wrenching to watch that last sector time fall away from you," admits Argent. "It's the same in any sport, but to still have a car that finished, even with a naturally aspirated engine for the last two miles, is something I'm still incredibly proud of.

"It would have been quite easy for that explosion to have completely ruptured the manifold and ended the race right there and then. It's the nature of motorsport: when you're pushing everything to the absolute limit, you're going to find a weak point at some point.

"In an ideal world you plan for it to be picked up beforehand, but it's not something I look back on and I'm negative about. We did really well to get there and I think it leaves a hunger there, hopefully within the business to go and prove it."

The 2022 event will mark the Pikes Peak International Hillclimb's centenary and Bentley just turned 102. Surely that's the ideal scenario for the marque to continue its biofuel work next year with what must be the wildest, fastest Bentley ever built? RT




# A COMING OF AGE FOR LE MANS HYPERCARS

Peugeot's 9X8 Hypercar is just what motorsport has needed for years, says **Sergio Rinland**

**A FEW** years ago, RACE TECH proposed a novel way of regulating motorsport. Our suggestion was to specify the outcome (downforce, drag and power) instead of regulating 'how to achieve it'.

At the time, this was quite a big ask. After all, it entailed abandoning the way regulations have been written since the beginning of time! But now, years later, the car that we had in mind when we formulated that rules proposition has just been unveiled: Peugeot's 9X8 Hypercar.

The idea behind such rules is to encourage diversity, allowing designers to find different solutions to the same problem. (A chimera for Formula 1 designers who, from next year, will have to just tweak the concept conceived by Liberty Media's technical team.)

Our embryonic idea was then taken by the FIA and Automobile Club de l'Ouest (ACO) and developed into the Hypercar category, which came into effect from the start of this season.

Initially those Le Mans Hypercar rules spawned the Toyota GR010 and Glickenhaus 007, both very traditional LMP designs, not dissimilar to those we witnessed up until last year in LMP1. But when we saw the Peugeot, it was a 'wow' moment! At last, someone had the idea and the courage to make it into a Le Mans prototype, using all the tools and knowledge available today to create something different, distinct.

**ABOVE** Peugeot's use of ground effect to generate the downforce on its 9X8 should pay off in traffic

Nothing wrong with that. When the regulations try to dictate the design with the preposterous idea that by using that method the performance will be limited, we know the outcome: innovation at the beginning, converging into one or two solutions and the cars always end up looking very similar to each other.

With the LMH rules, the limitation is the measured KPI (key performance indicators) but enough leeway is left in those targets – particularly the aero values – to allow the fact that with different forms those figures can be achieved, which is what Peugeot just did.

Are those targets so easy to achieve? As peak performance, perhaps, but the key to exploiting the new regulations is not the ultimate aero performance (as in Formula 1, for example), but in the consistency of achieving those allowed 'peak' values. The winner will be the car that can have an L/D (efficiency) of 4.0 across a big spectrum of the aeromap and in traffic, the common denominator in sportscar racing.

Is the Peugeot solution designed to achieve that? Looking at what we can see today, I would say they are heading in the right direction, putting emphasis on ground effect instead of external draggy wings. The good thing about ground effect is that its characteristics are less affected by traffic.

By working cleverly within the specifications of the aeromaps, they can achieve the desired consistency at different ride heights, hence speeds. The more you rely on the front splitter of a sports prototype, the more sensitive to ride height it becomes, losing that consistency so appreciated by drivers and tyres.

The limits set by the regulations are low enough to be able to work in that direction. Which, funny enough, has a lot of relevance to passenger cars. Did the ACO and FIA have that consequence in mind? If they did, they forgot to mention it!

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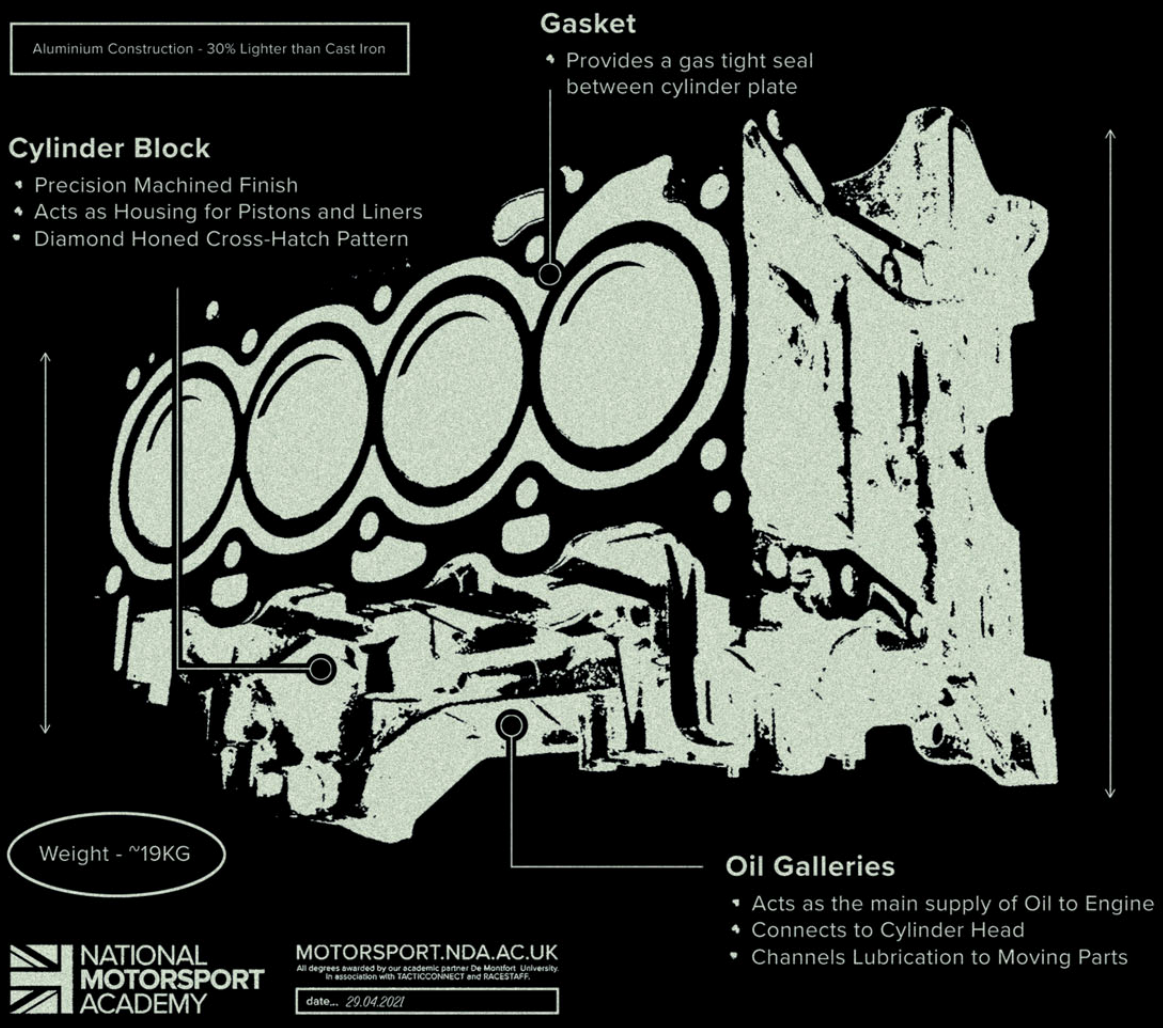


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