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HEAD OF OPERATIONS & DIGITAL
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LAT

ART EDITOR
Paul Bullock

ACCOUNTS
Fiona Keeble

COMMERCIAL DIRECTOR
Maryam Lamond

MANAGING DIRECTOR
Adrian Goodsell

PUBLISHING DIRECTOR
Soheila Kimberley

RACE TECH
Motorsport Engineering

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

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AI: FRIEND OR FOE?

THE imminent extinction of mankind isn't a regular feature on this page. Not even when William was at his most mischievous, would he stoop to that.

But when leading experts – including the heads of OpenAI and Google Deepmind – warn that Artificial Intelligence could lead to the extinction of humanity, it does rather catch your eye.

"Mitigating the risk of extinction from AI should be a global priority alongside other societal-scale risks such as pandemics and nuclear war", their joint statement advised.

It was that stark warning that led me in the direction of our cover feature this month: a fascinating insight into the increasing use of Artificial Intelligence and Machine Learning in motorsport.

With each passing day, AI becomes more deeply ingrained in the world of motorsport. So should we feel threatened by what could be a double-edged sword?

Those who embrace AI will surely fare better, for they will harness its potential to augment human capabilities. AI can act as a powerful tool, providing drivers and teams with invaluable insights and assistance. By utilizing AI for data analysis and simulation, teams can fine-tune their setups, predict race outcomes, and optimize strategies.

This symbiotic relationship between AI and humans can unlock new levels of performance, while maintaining the integrity and excitement that fans crave.

Moreover, AI's impact extends beyond the track. From autonomous vehicles to intelligent safety systems, AI-driven innovations have the potential to revolutionize road car technology. After all, motorsport has always been a crucible for automotive advancements.

Ultimately, the use of AI in motorsport should be seen as an opportunity rather than a threat. By embracing AI as a tool that complements human skills, we can harness its immense potential to push the boundaries of performance and safety.

Let us seize this opportunity to evolve and create a future where humans and AI work hand in hand, achieving feats we never thought possible.

Or is that merely what AI suggested I say? RT

Mark Skewis
EDITOR

"WE WOULDN'T INVEST IF WE DIDN'T THINK WE COULD WIN WITH IT!"

ACO's new hydrogen class handed huge boost by Toyota's Le Mans announcement. By **Mark Skewis**

EVEN as the storied history of the Le Mans 24 Hours was celebrated at the centenary race, the shape of the event's future was unfolding: Toyota Motor Corporation Chairman Akio Toyoda revealed the five-time winner's hydrogen-engined GR H2 Racing Concept.

Developed with future competition in its sights, the prototype's unveiling was spurred by a recent announcement by the ACO, the organizer of the Le Mans 24 Hours, that it would allow hydrogen-engine vehicles to compete in addition to fuel cell electric vehicles in the race's hydrogen category.

Pushing boundaries

"Le Mans is a place where we not only compete in one of the world's most celebrated races but a place where we can push the boundaries of technology – a place where we can realize the future," said Toyoda. "We are grateful to the ACO and Le Mans for providing this unique opportunity to share our efforts with the world.

"My goal is to achieve carbon neutrality in motorsports without sacrificing anything in terms of performance or excitement.

"We look forward to our new GR H2 race car in view of the new Le Mans H2 class in the future. The sound, the torque, the dynamics, it's all there. Not only are we re-imagining the race car, we're doing it with zero emissions. Here's to the next 100 years of checkered flags!"

Although no timeline has yet been set for the car actually racing, Toyoda encouraged competitors to consider racing in the hydrogen category. "And by the way, we wouldn't be investing in this technology if I didn't think we could win with it!" he quipped. "I mean, I do have my priorities, after all!"

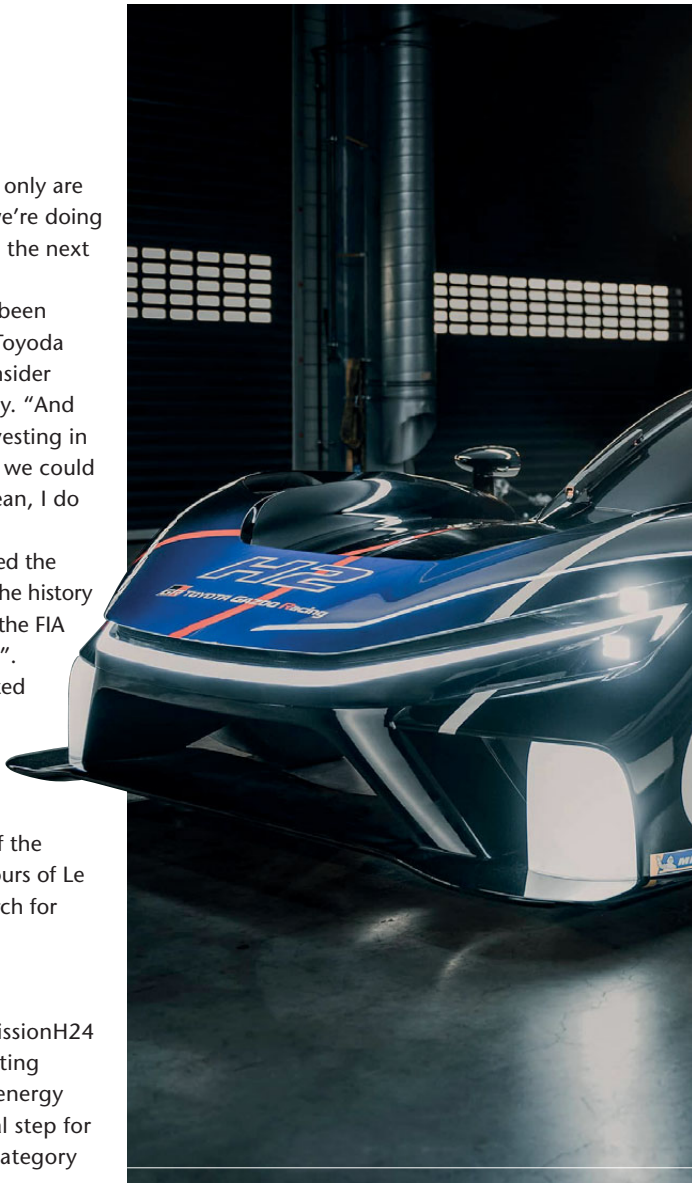
ACO President Pierre Fillon called the announcement "a milestone in the history of the 24 Hours of Le Mans and the FIA World Endurance Championship".

"100 years ago, the ACO created the 24 Hours of Le Mans, a real technological laboratory for a car in full development," he said. "Today, mobility is undergoing a revolution, that of the energy transition and the 24 Hours of Le Mans can participate in the search for sustainable technologies.

Crucial step

"Since 2018, the ACO, with MissionH24 and GreenGT, has been promoting hydrogen, a safe and efficient energy carrier. This day is a new crucial step for the creation of the Hydrogen category of the 24 Hours of Le Mans. Once again, Endurance demonstrates its commitment to sustainable mobility, in line with automotive players. I would like to salute this challenge from Toyota, the vision of these men and women."

Toyota has been competing using a hydrogen-engine Corolla in the Super Taikyu Series since Round 3 of the 2021 season and raced the same car in the IDEMITSU 1500 SUPER ENDURANCE 2022 at Thailand's Chang International Circuit in December 2022. By doing so, it has been honing its technologies in the harsh environment of motorsports and, with like-minded partners in and outside the automotive industry, accelerating its efforts for producing, transporting, and using hydrogen toward the realization of a carbon-neutral society.



> *"A milestone in the history of the 24 Hours of Le Mans and the FIA World Endurance Championship"*

The Corolla, which was demonstrated ahead of the Le Mans 24 Hours, recently competed in the Fuji 24-hour event, with Toyoda joining the driver line up. Never before had a car running on liquid hydrogen competed in racing.

Even with a scheduled pitstop to replace the hydrogen pump, Toyoda and his four team-mates – Hiroaki Ishiura, Masahiro Sasaki, Yasuhiro Ogura, and Jari-Matti Latvala – completed 358 laps, totalling some 1,634 km. As fate would have it, that number equalled the feat notched up by the Corolla at the same racetrack two years earlier, then running on gaseous hydrogen. RT

BELOW Toyota's GR H2 concept increases the momentum behind the ACO's hydrogen class, due to race in 2026

Toyota GAZOO Racing

ACO opens new class to hydrogen combustion

THE Automobile Club de l'Ouest has opened up its new hydrogen category to H2 combustion engines as well as fuel cells.

Since first deploying its hydrogen strategy in 2018, the ACO's focus, along with that of its partner, GreenGT, has been on fuel cells. In recent years, however, the Dakar Rally's energy transition has prompted a number of companies to experiment with hydrogen powerplants, some of them pursuing the H2 combustion route. It made sense for there to be two categories – Le Mans and Dakar – in which the fruits of their expensive labour could be harnessed.

Pierre Fillon, President of the ACO, explained: "Since 2018, the hydrogen ecosystem has evolved enormously. We are learning by doing. We are exploring possibilities. And that is exactly the objective we set ourselves five years ago when we launched MissionH24. The fuel cell was initially chosen for its potential, which is still relevant. Today, the hydrogen internal combustion engine is also presented as a possibility for manufacturers.

"The 24 Hours of Le Mans regulations have always advocated freedom and variety. As such, we are officially announcing that both technologies, fuel cell and hydrogen internal combustion engine, will be accepted and authorised for manufacturers wishing to enter the 24 Hours of Le Mans in the Hydrogen category." RT

Gromik/Mission H24

ABOVE Until now, it was envisaged that the hydrogen cars would use fuel cells, as trialled in the GreenGT H24 prototype

LEFT The new regulations are applicable to different disciplines, formats and sporting levels

FIA launches technical regulations for Electric Sport Vehicle

THE FIA has launched a new set of technical regulations for Electric Sport Vehicles (FIA ESV), the Federation's first-ever ruleset for electric-powered vehicles, closely derived from road-going production cars and destined for competitions at national and regional levels.

The FIA ESV ruleset, approved by the FIA World Motor Sport Council, is designed to allow affordable, entry-level electric racing in compliance with the FIA's standards for high-voltage safety. The regulations cover both technology and safety, with performance management also an option depending on competition requirements.

The primary target recipients for the FIA ESV regulations are FIA member clubs, in order to grow safe and sustainable motorsport for the future. The unique advantage of this new ruleset is that it enables the same car to be used across a variety of different sporting formats, from circuit racing to various sprint-type events, including those that require vehicles with road-legal homologation, consequently allowing competitors to drive to and from the actual events.

The ability to offer modified electric vehicles ready for competition and built in conformity with recognised FIA regulations will enable the manufacturers to offer cars ready for competition straight 'out of the box'. Alongside the FIA member clubs, competition promoters and organisers, manufacturers' customer racing departments and independent race teams will all be engaged to build this new market segment.

Group N spirit

Much like the Group N of the past, the objective of the FIA ESV ruleset is to have cars with minimal adaptations from the road-going production model. Reflecting the latest trends on the road car market, the class will be open to both Grand Touring cars and four-door, coupe-shaped sports sedans, with the maximum chassis height set at 1460 mm.

As per the technical regulations, the bodywork shape must remain fundamentally unchanged, with the exception of the possibility to extend the wheel arches to accommodate wider racing tyres and additional cooling ducts. In order to save weight, selected bodywork panels, such as the rear hatch and doors, the rear wing and the diffuser, will be replaceable with equivalents made from lightweight materials that maintain original shape.

The class is also destined for cars with a minimum production volume of 300 units over the first 24-month period from the homologation of the road car, resulting in prototype or low-production specials being ineligible. FIA ESV is open to both rear-wheel and four-wheel drive cars, with a minimum power output set at 300 kW, which roughly translates to 410 bhp.

FIA ESV benefits from the expertise which the FIA has gained over the years of managing high-voltage technologies in motorsport competitions. The cars must be fitted with a safety light system, as used in other competitions for electric and hybrid-powered cars.

Given the inclusive nature of the ESV ruleset and potentially wide range of vehicles built to it, the event organisers will have the option to have the cars grouped according to their performance levels, based on the Performance Factor methodology, which is successfully used in FIA competitions, for instance in hill climb racing.

Performance Factor creates a value for each car based on figures representing weight, power unit and aerodynamic performance, along with transmission and chassis parameters, allowing vastly different cars to compete against each other in groups based on their performance levels.

Depending on the format of the competition, ESV will also offer the opportunity for real-time energy consumption monitoring through an FIA datalogging system.

Marek Nawarecki, FIA Director of Circuit Sport, said: "The FIA ESV revives the spirit of Group N, where a car purchased at a dealership, fitted with all the necessary safety equipment, was essentially competition-ready and suitable for various disciplines and formats."

Lutz Leif Linden, FIA GT Commission President, said: "The FIA ESV ruleset very much responds to the demands of the market. Having this set of technical regulations will allow the manufacturers' customer racing departments to offer competition-ready variants of their electric cars, which should be a considerable source of revenue for them, much like GT3 is. It can even open the door for them to create their own one-make series. The fact that the regulations are inclusive and accommodate four-door cars reflects the latest trends on the road car market. We already see several manufacturers having sporty four-door grand coupes in their line-ups."

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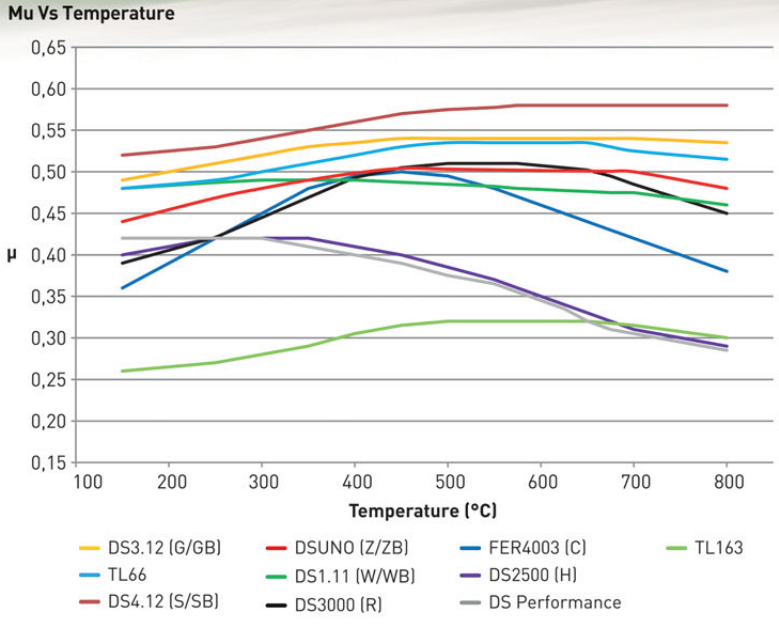

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Alpine reveals new Hypercar

ALPINE has revealed the Hypercar it will be fielding at the 24 Hours of Le Mans, and in the FIA World Endurance Championship. Its code name is A424_β.

Extremely sleek at the front, the car sports two A shapes at the rear. The streamlined style of the cockpit and bodywork is similar to a road-legal Hypercar. From the side, there is a reminiscence of the Alpenglow concept car presented at the Paris Car Show last October.

"It is racy, elegant and distinctive with its symbolic and iconic design. It embodies both our present and our future, thanks to the involvement and investment of our designers in its development," commented Alpine CEO Laurent Rossi. "We do not underestimate the task awaiting us in this exciting challenge. We stay humble but determined to make our mark on both sides of the Atlantic. We hope to offer all motorsport fans some splendid and epic battles."

The Alpine A424_β is based on a chassis from ORECA, with which the French carmaker has worked since 2013. The first wind tunnel tests took place last July, engine testing began in December and engine/gearbox coupling in May. A 3.4-litre V6 single-turbo engine, designed in cooperation with Mecachrome, has been matched to the Xtrac gearbox, Bosch hybrid system and Williams battery that are mandatory in IMSA's LMDh category.

"We'll be the only ones with this configuration," pointed out project engineer Christophe Chapelain. "It must be noted that the synergies with F1 are such that our LMDh software is strongly inspired by F1. The F1 cost cap also works in our favour, as it frees up dyno hours in addition to those available at Mecachrome."

Long-standing partner Signatech will be taking care of operations. A shakedown is planned later this month, before testing at Circuit Paul Ricard throughout August. RT

ABOVE The A424_β is the first prototype of its kind developed by Alpine at Viry-Châtillon since 1978

GCK unveils Foenix H2

THE Green Corp Konnection (GCK) group unveiled the Foenix H2, one of the world's first GT racing cars powered by a hydrogen combustion engine, during the Le Mans centenary celebrations.

The car is manufactured by Solution F, a GCK subsidiary. It is equipped with a 6.2-litre V8 hydrogen internal combustion engine, supercharged by a mechanical compressor and developing 450 kW (612 bhp) at a speed of 6,500 rpm and 700 Nm of torque at 4,500 rpm.

Based on a tried and tested classic 4-stroke architecture, this engine features an innovative direct hydrogen injection system that enables the gas to be used as a fuel. The dihydrogen molecule has a high energy density by mass (1 kg of this gas is equivalent to around 3 kg of petrol), and its combustion generates only water vapour and a small quantity of nitrogen oxides. Fitted with a latest-generation 700-bar storage tank developed by Forvia, the car carries more than 8 kg of H2, giving it a significant range for a hydrogen-powered competition vehicle.

Through this programme, GCK is pursuing two distinct and complementary objectives. The group wants to demonstrate the extent of its expertise in hydrogen combustion powertrains, not only for motorsport, but also for many other mobility applications; it also wants to prove that the Foenix H2 is a high-performance competition vehicle with reasonable running costs that could be of interest to tomorrow's one-make race promoters. RT

LEFT The Foenix H2 took its first promising laps around a circuit in the south of France

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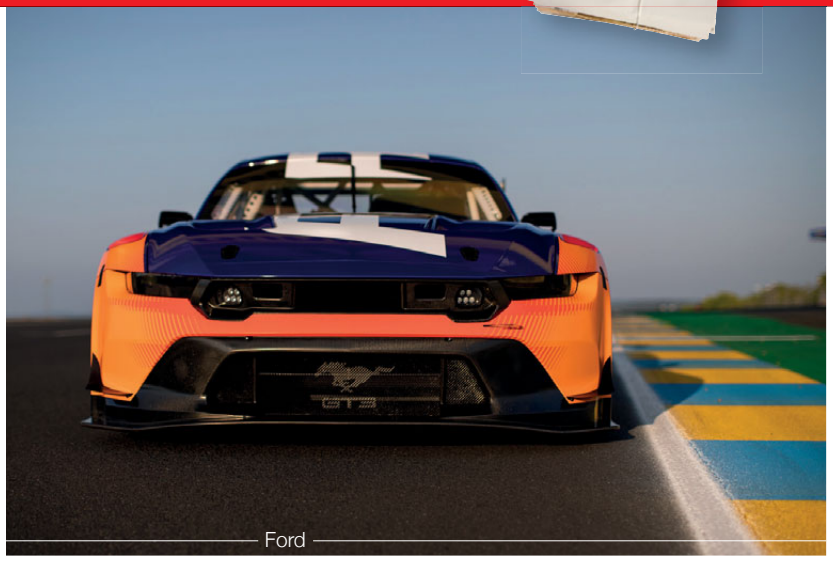
Ford

Forget Ford versus Ferrari. It's "Ford versus everyone"

IT was confirmed at Le Mans that the best-known sports car will compete in the world's most iconic endurance race: the Ford Mustang GT3 will take on the challenge of the 24 Hours of Le Mans in June 2024.

The Mustang GT3 race car, based on the all-new 2024 Mustang Dark Horse, was unveiled with a bold, colourful new look from designer Troy Lee.

With the reveal, Ford officially enters Mustang into the global FIA GT3 category. The Blue Oval's most recent triumph at the 24 Hours of Le Mans was in 2016 with the Ford GT.

"Ford and Le Mans are bound together by history. And now we're coming back to the most dramatic, most rewarding and most important race in the world," said Jim Farley, CEO, Ford Motor Company. "It is not Ford versus Ferrari anymore. It is Ford versus everyone. Going back to Le Mans is the beginning of building a global motorsports business with Mustang, just like we are doing with Bronco and Raptor off-road."

ABOVE Ford Mustang officially joins the FIA GT3 category with the new Mustang Dark Horse-based race car

Ford Performance has extended its association with Multimatic and M-Sport for the basis of this project. Multimatic, builder of the iconic Ford GT, was also involved in the Ford GT race program and will help build and support the Mustang GT3s.

Long-time World Rally Championship partner and two-time championship-winning team M-Sport will assemble the Ford Performance-developed 5.4-litre Coyote-based V8 engines that power this powerful new pony.

"For a project like the Mustang GT3, we turned to two of our most trusted partners in the motorsports world to help bring this vehicle and program together," said Mark Rushbrook, Global Director, Ford Performance Motorsports. "I know we'll all be as thrilled as Ford fans when Mustang begins racing at the highest levels of GT racing in 2024."

The Mustang GT3 race car features a bespoke short-long arm suspension, rear-mounted transaxle gearbox, carbon fibre body panels and a unique aero package developed to meet GT3 targets.

Before going to Le Mans in 2024, the Mustang GT3 will compete in various GT3 series across the globe in the hands of customer teams. The first customer squad, announced at Le Mans, is Proton Competition. Based in Ehingen, Germany, Proton intends to campaign a pair of Mustang GT3s in the FIA World Endurance Championship, starting in 2024.

Ford Performance will also field a two-car factory race program with Mustang GT3 in IMSA's GTD Pro class. This will be managed by Multimatic Motorsports and begin at the 2024 Rolex 24 at Daytona. RT

Ford explains Formula E 'snub'

FORD has explained its decision to commit to a Dakar Rally programme, rather than joining Formula E.

The Rally Raid project joins the growing list of Ford Performance campaigns around the world, headlined by the impending entry to Formula 1 with Red Bull in 2026. There are also factory programmes in NASCAR, Supercars and, as of next year, customer GT racing with the Mustang GT3 and GT4 cars.

But while full-electrification is one of the pillars of the Ford Performance philosophy, there are no plans for an electric racing programme.

Speaking to media during the Dakar announcement, Ford Performance boss Mark Rushbrook said the brand would instead focus on its 'demonstrator' vehicles to showcase its prowess in electrification. They include the Ford Mustang Mach-E 1400, the Cobra Jet 1400 drag car, and the SuperVan 4.

"Where we don't have the opportunity to race in what we think is a good or relevant full electric series, we take advantage of those demonstrators," said Rushbrook. "They are rolling innovation labs that allow us to learn about high-performance, full-electric vehicles, and take that learning back to our road car programmes and also to take that electrified learning over to Formula 1.

"When we look at the different reasons why we're in motorsports, we feel that for full-electrification, there's a better return in terms of what we're getting from those full-electric demonstrators than what's available from Formula E.

"That's not a direct knock on Formula E; they put on a lot of great racing. But what we see, for the spend we can put into these demonstrators, with no rules to limit what we can or cannot do, we can learn exactly what we want, in the way that we want, and put on a very compelling story in the way that we want to." RT

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Ford bids for Dakar glory with 'bad-ass' Ranger Raptor T1+

FORD Performance has raced and won from Le Mans to Monaco, Daytona to Bathurst and Finke to Ensenada. But it has yet to take on one of the toughest races on the planet – the iconic Dakar Rally.

It has now announced that the time has come to fill that gap in its sweeping motorsports résumé. Extreme racing versions of the "bad-ass" Ford Ranger and Ranger Raptor will forge the way for the Ford Performance expansion into global off-road racing, including the famed Dakar Rally in 2024 and beyond.

The first step in the multi-year plan to compete in the Dakar Rally is to finish and learn in collaboration with long-time partners M-Sport and Neil Woolridge Motorsport (NWM) for vehicle development, servicing and event management.

"To lead the charge at one of the ultimate global off-road events – the Dakar Rally – has been a goal of ours," said Mark Rushbrook, Global Director, Ford Performance Motorsports. "We cannot underestimate the enormity of the challenge ahead of us. We need to finish and learn first with Ranger T1+ and partners like M-Sport and NWM, who bring their expertise to bear. Together, we can do amazing things in the sand dunes of the Arabian Peninsula."

Leading the charge into the 2024 Dakar Rally, taking place January 5-19 in Saudi Arabia, will be a purpose-built, high-performance Ford Ranger racing in the Rally Raid T1+ category.

ABOVE The Ford Ranger T1+ will compete in the 2024 Dakar Rally on a "finish and learn" basis

The joint Ford Performance, M-Sport and NWM team has implemented a series of development phases through 2023 and continues testing with the Ranger T1+, based on the previous generation global Ranger, with a 3.5-litre EcoBoost engine. Test races are expected to include Spain's Baja España Aragón and Morocco's Rally du Maroc rallies in July and October, respectively, before tackling the Dakar Rally next year.

"Our first time in Dakar will be a learning adventure that will help inform how we compete in the future," said Rushbrook. "But as with all racing, we're not just racing to win, we're also racing to help build better products for our customers."

For the 2025 Dakar Rally, Ford Performance and M-Sport are developing an all-new, custom-built Ranger Raptor – the ultimate performance derivative of Europe's best-selling pickup – designed and built to Dakar's T1+ class regulations.

"The Dakar Rally is truly among the pinnacle of global off-road racing events," said Malcolm Wilson, M-Sport managing director. "We've achieved great success over the years with Ford in FIA WRC rally racing and can't wait to apply this same level of focus, energy and effort to competing with Ranger in Dakar."

M-Sport is well regarded as a leading developer and campaigner of the M-Sport Ford Puma HybridRally1 in the FIA World Rally Championship, as well as engine builders for the Mustang GT3 program. NWM has played a pivotal role since the infancy of the Rally-Raid Ranger, as the team developed and built units at its facility in Pietermaritzburg, KwaZulu-Natal, specified to compete in full Dakar T1+ regulations in the South African Rally-Raid Championship (SARRC) and around the world. RT

Dakar launches Mission 1000

NEXT year's Dakar Rally will feature an experimental offshoot, Mission 1000, designed to promote and evaluate future technologies.

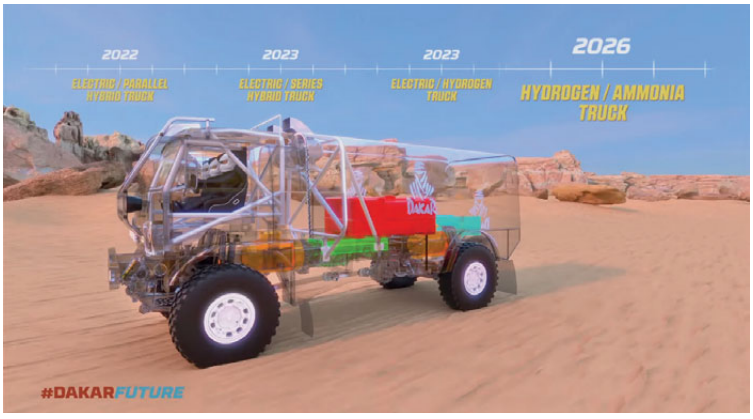
While the TU category continues to progress and biofuels gain ground, the most innovative technologies in the field of decarbonisation are being called upon to show their worth in a parallel challenge. Each day, the vehicles taking part will set off on a route of around 100 kilometres that will not be the same as the official route but will pose similar difficulties.

In an experimental mode, only the energy sources that consume the least fuel are included in Mission 1000: hydrogen, 100% electric or hybrid engines with a minimal amount of biofuel on board.

There will be no winners, no losers, although Mission 1000 participants will eventually be entered into a real competition. Initially, they will be invited to participate in a full-scale test, allowing carmakers to gather as much information as possible. However, their performance in terms of technical reliability, energy consumption and carbon footprint will be assessed by a panel of experts.

Around 10 vehicles – motorbikes, cars and trucks – are expected to participate in this project supported by the FIA and FIM. They will meet every evening in a designated area of the bivouac that will be energy self-sufficient but open to all to encourage as much discussion as possible on the subject.

The main event, the fifth edition to be held in Saudi Arabia, will be held from 5 to 19 January 2024. Starting in the thousand-year-old city of AlUla, it will cross the country in the direction of the Empty Quarter, finishing in Yanbu on the shores of the Red Sea. RT



BELOW Mission 1000 is intended to act as a laboratory for future technologies

Audi recreates Dakar failures

TEAM Audi Sport has been working hard to explain the tyre and suspension problems that dogged its Dakar Rally assault earlier this year.

The Audi RS Q e-tron's record in January included a total of 14 podium results on 15 event days but also various setbacks. While the innovative electric drive concept worked flawlessly, tyre failures hampered all three crews in the most important competition of the year.

In addition to the analysis carried out since then, the team completed its investigation of the causes with a test in Saudi Arabia. There it encountered temperatures of up to 42 degrees Celsius and repeatedly strong winds, but still completed 2,568 kilometres with the innovative car.

Head of Audi Motorsport Rolf Michl had set his squad a clear target: "Our technology, the entire team and our drivers and co-drivers have the potential to drive at the very front. Our stage results proved that. So it was all the more annoying that tyre failures and other problems set us back in January. Now we have to find solutions. Our systematically planned test was the next important step on this path after the theoretical analysis."

Team Audi Sport and the three drivers, Mattias Ekström, Carlos Sainz and Stéphane Peterhansel, spent several days in Saudi Arabia working for this purpose.

Using two different types of tyres from BF Goodrich, the official tyre supplier of the Dakar Rally, the team compared the performance and attempted to recreate the conditions of January's damage in order to develop countermeasures. Various terrains were available for this purpose. Also on the agenda was work with the shock absorbers. Measurement sensors in the chassis for loads and accelerations supported this analysis.

Sven Quandt, Team Director of Q Motorsport, summed up: "The test organization was definitely demanding. We were able to reproduce tyre failures during the runs, which is pleasing in that it allows us to analyse very well the conditions and circumstances that caused us headaches in January. Closely related to this are the suspension settings, which we have varied. We haven't worked out a one hundred percent solution yet, but the test was valuable and we're on the right track." RT

LEFT Audi tested in extreme conditions in Saudi Arabia as it sought to get to the bottom of its Dakar woe

Penske Entertainment/Joe Skibinski

Bridgestone to rival Pirelli for F1 deal

BRIDGESTONE has lodged a bid to become Formula 1's tyre supplier from 2025.

Pirelli, which has supplied F1 since 2011, is reported to be facing serious competition. Drivers have complained of the effect of overheating tyres on overtaking recently, and insiders say Bridgestone has pledged as part of its bid that it can produce a tyre on which drivers can push harder for longer.

Lewis Hamilton, Fernando Alonso and Nico Hulkenberg are the only active drivers to have experience of driving on Bridgestone tyres in F1. They used them from 2007 to 2010, after which the company pulled out of F1.

BBC Sport has been told that the two multiple champions have been vocal within the driver group in expressing their approval of the way Bridgestone tyres behaved when the company was last in F1, especially for the way they could drive flat-out throughout grands prix without fear of the tyres overheating.

However, cars are now significantly heavier than in that era, with more downforce. The short timeframe involved also works against Bridgestone, while some figures believe Pirelli's loyalty must also be taken into account.

Bridgestone already supplies the tyres to the US-based IndyCar series under its Firestone brand. F1's inroads into the US market are said to be one of the factors attracting the Japanese manufacturer's interest.

ABOVE Bridgestone's Firestone brand supplies IndyCar's single-seater ladder

First sustainable fuel launched for classic vehicles

THE recent trend for a switch to sustainable fuels in historic motorsport has now been mirrored on the forecourt, with the UK's first publicly available sustainable petrol, designed specifically for classic vehicles, going on sale last month.

The SUSTAIN Classic range will allow motorists to fuel their vintage vehicles with plant-based petrol, without any modifications to their engines, with three types of fuel initially available. Developed by fuel specialist Coryton, the fuel with the highest sustainable content promises a reduction of at least 65% in greenhouse gas emissions when compared to fossil fuels.

The pioneering products use advanced second-generation biofuel manufactured from agricultural waste, such as straw, by-products or waste from crops which wouldn't be used for consumption. The fuel utilises the carbon that already exists in our atmosphere, which the plants absorb as they grow, recycling it, rather than releasing additional CO2 that is currently locked underground in fossil fuel.

With an octane number >98 and bio-ethanol content of <1%, SUSTAIN Classic has been technically tailored for classic vehicles, although it can be used on any vehicle which runs on standard forecourt petrol. It's also formulated with a premium additive package included, which stabilises and extends the life of the fuel and helps clean and protect the engines.

Priced from £3.80 per litre, SUSTAIN Classic will initially be available from distributor Motor Spirit at Bicester Heritage. The fuels range from at least 33% sustainable content to at least 80%: Super 80; Super 33; and Racing 50 (at least 50% renewable content and, at 102RON, ideal for performance and racing use in vehicles that require a higher-octane fuel).

At the recent Rally for The Ages event held at Bicester Heritage, over 70 cars used the Super 80 fuel to complete the course.

Andrew Willson, CEO at Coryton, said: "It's estimated that there are almost half a million classic cars in the UK, each one with its own unique purpose, build and history. By creating a collection of second-generation biofuels that are compatible with their needs, as well as those of other vintage vehicles, we hope to provide these much-loved motors with a more sustainable future and preserve them for years to come."

Marelli to help IAC push autonomous limits

MARELLI will be the exclusive race control technology sponsor of the Indy Autonomous Challenge (IAC).

A technical partnership for connectivity solutions has been signed, based on which Marelli will supply, to all IAC fully autonomous racecars, technologies to ensure vehicle connection, race control, and data analysis. It will also provide technical support.

The IAC is a series of competitions among full-scale autonomous racecars, driven by software programmed by top engineering and technology university teams from around the world, that compete on iconic tracks. A primary goal of the IAC is to advance technology for fully autonomous vehicles and advanced driver-assistance systems (ADAS).

As a global supplier of automotive technologies and a telemetry leader in motorsport, Marelli will provide essential technologies to all competing racecars through one of its advanced connectivity systems, the Smart Antenna LTE. This compact device, installed on the vehicles, ensures reliable and high-quality communication between autonomous cars and control systems, leveraging the public mobile network provided by a global telecommunications operator.

Marelli has also developed for the IAC an innovative race control software for monitoring and managing the races. The system enables precise supervision of autonomous racecars during competitions, ensuring maximum safety and performance optimization.

Furthermore, Marelli will provide the comprehensive WinTAX data analysis system package, offering essential support for interpreting and processing data collected during the races. This will enable participating universities to gain valuable insights into the performance of autonomous cars and continuously improve their driving algorithms.

The company will offer specialized training sessions to university teams for a full understanding of the features and potential of Marelli systems for the IAC. A highly qualified technical support team will also be available to address any needs and assist the IAC throughout the development and racing process.

As part of the agreement, Marelli's logo will be featured on the livery of all vehicles participating in the IAC competitions.

"We are thrilled to apply our expertise in telemetry to the innovative front of autonomous racing vehicles," said Riccardo De Filippi, Head of Marelli Motorsport. "We have a long tradition in supplying connectivity technologies for the main motorsport championships worldwide and are always willing to push innovation ahead with solutions that combine performance and safety. Therefore, we immediately recognized the potential of this partnership as a fertile environment for technological development."

"With a track record of innovation and excellence, Marelli is exactly the kind of partner we need and want as our exclusive race control technology provider," said Paul Mitchell, president, Indy Autonomous Challenge. "Marelli technology will allow IAC to develop a highly automated race control system that can marshal our university teams' AI drivers. This level of real-time communication and automated instructions between race control and racecars will be a first of its kind and will demonstrate an extra level of safety for AV and ADAS systems.

"We are excited to have Marelli onboard to help us push the limits of autonomous driving." RT

ABOVE Marelli and the IAC have announced a technical partnership to progress the autonomous racecars

Autonomous speed records set at Monza

MORE than 10,000 spectators filled the stands at Monza to witness a first-of-its-kind spectacle of fully autonomous racecars competing on an F1 circuit during the Milan Monza Motor Show (MIMO).

Hometown team PoliMOVE won the competition, the first to be organised by the Indy Autonomous Challenge (IAC) outside the United States. Its final lap was recorded at 2:05.87 on the 5.79-kilometre/3.6-mile-long track, with 11 turns, with its autonomous Dallara AV-21 reaching a top speed of 273.4 kph/169.8 mph.

PoliMOVE's AI driver was piloting a backup racecar due to a wreck of its original car during practice earlier in the week.

The IAC brought six autonomous racecars and five university teams to MIMO to compete in six sessions over three days, totalling more than 1,300 miles of testing where the cars ran progressively faster lap times. RT

Spéirling successor unleashed at Goodwood

THE commercially-available successor to the record-breaking McMurtry Spéirling is to be unveiled at this month's Goodwood Festival of Speed: the McMurtry Spéirling PURE.

The Spéirling's fan car technology stunned fans at Goodwood last year, smashing the outright record for the hill. So impressive were its feats, that a panel of experts voted to award the team the Race Tech Dino Toso Aerodynamicist of the Year award.

Thomas Yates, founding director of McMurtry Automotive, said: "The Spéirling PURE will herald a new era on the track. The sound, grip, acceleration, aesthetics and technology of this car are distinct. Witnessing the car as a spectator or from the cockpit offers a rare and exhilarating experience. With pre-orders from around the globe, I can't wait for fan cars at the racetrack to become a new normality."

ABOVE The new car boasts a 15% increase in fan efficiency over its predecessor

The Spéirling PURE track car is the first sealed skirt fan car to be made commercially available. The Validation Prototype (VP1) to be unveiled is said to have the capability of exceeding the performance of its predecessor.

The rear-wheel drive car features a 60 kWh battery system developed with Molicel. With <1,000 kg weight, it produces 1,000 bhp (745 kW) peak output with a 190 mph top speed.

Features include: an all-new fan system; updated skirt design; new battery and E-axle; revised chassis; improved underbody aerodynamics; wider tyres; and new electrical architecture.

Pre-production prototypes will follow in 2024, with final production limited to 100 units. Deliveries will start in 2025. RT

MBE awarded to engineer George Imafidon

GEORGE Imafidon, Performance Engineer for Extreme E Season 2 Champions, X44 Vida Carbon Racing – owned by Sir Lewis Hamilton – has received an MBE in the King's Birthday Honours List for services to young people and STEM sectors.

Imafidon was featured in Race Tech recently (issue 271). Alongside his engineering role at X44 Vida Carbon Racing, he also holds the title of the Young Engineer of the Year 2022/23, awarded by the Royal Academy of Engineering.

On receiving an MBE, Imafidon said: "I am honoured and grateful to be awarded the MBE for services to young people and STEM sectors. It has been a privilege to be able to use my voice over the last decade for so many of us that feel unseen and humanise STEM for communities traditionally far removed from the industry.

"I hope this recognition can open more doors for those that are underserved and have lost hope on the journey."

George's fascination with how things work stemmed from his early years spent fixing bikes for his friends and community in Peckham in London, a pastime that would eventually lead him to graduate from University College London (UCL) with a First Class Master's degree in Mechanical Engineering with Programming.

Imafidon is also CEO and co-founder of Motivez, an award-winning youth-led organisation founded in 2015, which empowers young people aged 14-25 to access entry-level STEM jobs and become changemakers. RT

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> "Racing is the fast track to the adoption of advanced technologies on the road but the path from race to road is only open if knowledge is shared"
>
> **PAT SYMONDS**, Chief Technical Officer, F1

> "This was my first time attending the World Motorsport Symposium and it was an overwhelmingly positive experience. The quality of people, content and discussions were at the highest levels but the camaraderie amongst those in attendance really stood out. I plan to mark it on my calendar now for 2023 and bring several people from NASCAR to attend. Can't wait"
>
> **ERIC JACUZZI**, Managing Director, Aerodynamics/ Vehicle Performance, R&D Center, NASCAR

> "After the sad years of COVID, it was a pleasure to meet the motorsport community again. We share the same passion and are all aware that motorsport has to evolve to green technologies, as we are doing in the ACO with the hydrogen project. These technologies were at the core of all the discussions I had"
>
> **BERNARD NICLOT**, ACO Mission H24 Innovation Director

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The end of mankind? For motorsport, this is just the start...

Chris Pickering consults experts who firmly believe that, rather than posing a threat to humanity, Artificial Intelligence has the remarkable potential to revolutionize motorsport for the better

FOR those of a certain age, 4th August 1997 is a date that lives in infamy. According to James Cameron's Terminator 2, it was the point that Skynet, a neural network-based artificial general intelligence (AGI) system, went live.

Shortly afterwards, human decisions are removed from strategic defence. Skynet begins to learn at a geometric rate. The system becomes self-aware at 2:14 am Eastern time on 29th August. In a panic, the engineers try to pull the plug.

The rest, as they say, is history. Or rather it isn't, as nearly 26 years later, artificial intelligence has yet to take over the world and enslave humanity.

It has, however, begun to permeate every aspect of our lives. If you order your groceries through Alexa or browse the personalised recommendations put together for you by Netflix, you're already embracing this technology. Even the quotes in this article were automatically transcribed from the interview using an AI-based speech recognition program.

> *"The humans in the process will still be there; they'll just be operating faster and able to explore more ideas"*

AI is already being employed in motorsport. Last year, Race Tech spoke to an independent team running in the World Endurance Championship that credited its giant-slaying performances partly to the use of AI-based data analysis techniques. But there could be far more to come.

"AI, or more specifically machine learning in our case, is really about learning from data," comments Alan Patterson, co-founder of BeyondMath. "Some tasks are governed by quite straightforward rules that a software engineer can write into an algorithm – something like solving a maze, for instance.

"But when you get complex problems like analysing all the data coming off a car, it becomes very difficult to write the rules manually. Machine learning really changes that. It learns the algorithms from data at its fundamental level, so it works very well in any complex system that's hard to analyse with traditional methods."

Although BeyondMath is a relatively new name in AI, it's got some heavyweight engineering talent behind it. Patterson first met co-founder Darren Garvey when the pair were working at Cambridge-based tech startup Evi Technologies, which was bought out by Amazon and formed the basis of its Alexa function.

Earlier this year, Rob Kirk joined the team at BeyondMath. Formerly director of motorsport at Cosworth, he's a racing industry stalwart, whose CV also includes senior positions at ATL and Performance Friction.

"Motorsport was always one of the first markets that BeyondMath approached. The applications of this technology are wide-ranging, but motorsport is particularly relevant to us as a start up, because it's an industry that iterates very quickly," he notes.

Hidden trends

There are numerous potential applications for AI in motorsport – all of which can loosely be sub-divided into data analysis and design.

The first category is perhaps the most obvious. If you want to analyse the comparative strengths of different setups or different drivers, AI can be used to spot the hidden patterns that determine this performance.

A simple example might be a race engineer trying to determine why two drivers who achieve the same lap time with the same setup experience different levels of tyre degradation. Detailed analysis can shed light on how their driving styles differ – for instance, it may be that one driver is loading the tyres more ▶

ABOVE Undecided on a lead image: ask AI to generate it!

Paul Bullock / Midjourney AI

LEFT Pit stop strategy was an early application for the technology

BELOW Virtual windtunnel: AI can solve problems in Fluid Dynamics, Electromagnetics and Physics and use it to transform engineering design

heavily during corner entry, while the other leans on them harder during exit.

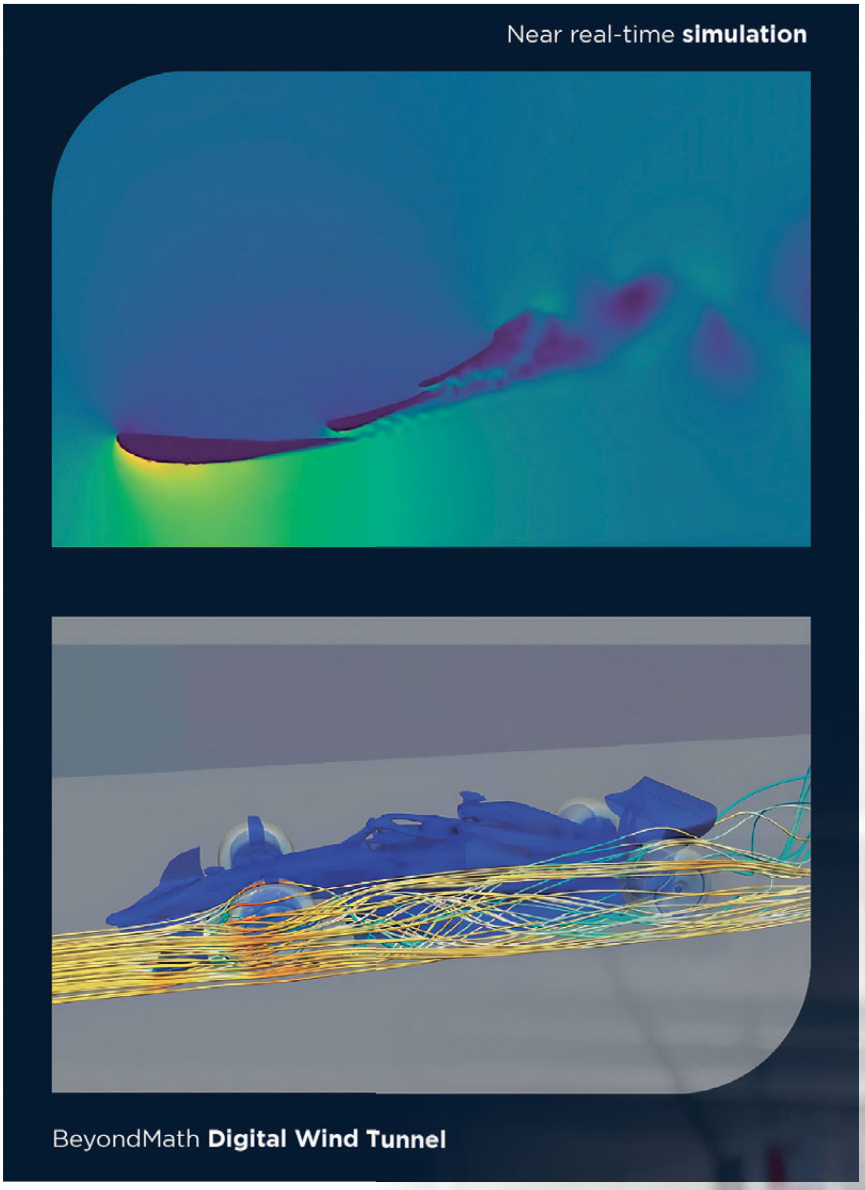
That much perhaps could be determined by manually interrogating the telemetry data. But AI comes into its own once the relationships become more obscure. Patterson points to an example from a previous project he worked on with an aerospace client.

"By analysing the data with machine learning we found that we could detect the early warning signs of a potential failure in a jet engine weeks before the ground engineers could," he comments. "These tell-tale signs were things you'd never expect, like weird correlations between pressure and vibration. For instance, it turned out that a pressure change at the rear of the engine was causing the fan blades to vibrate, resulting in wear in the ball bearings. Spotting that pressure rise allowed the engineers to replace the bearings early and prevent damage to the blades."

Data fusion

These complex rules can be applied to predict future performance, whether that's the best car setup or the best pit stop strategy. One of the reasons that AI excels at this sort of task is that it's very good at what's known as data fusion – combining numerous different data sets that aren't directly linked.

"If you're trying to predict, say, the optimum pit stop strategy, you've got a lot of different factors," notes Garvey.



> *Suddenly, the simulation could take minutes or seconds rather than days or weeks”*

“There’s weather, tyre degradation, traffic … possibly fuel consumption in some categories. These aren’t necessarily that difficult to model in isolation, but balancing them and fusing them all together would become a very complex thing to hand code.”

Design tool

AI has already started being applied to analyse the results of traditional modelling techniques such as computational fluid dynamics. One potential application is to compare data from CFD, wind tunnel and real-world aerodynamic testing to better understand the correlation between the three methods. With finite resources, another option is to focus on a set of key points during physical testing and then use AI to fill in the gaps.

The next big frontier could be using AI to generate the models themselves. Again, it’s the ability of machine learning to capture complex relationships that’s key here. Traditional numerical methods rely on breaking down these complex systems into hundreds of millions of cells, iterated across very small timesteps to make the individual calculations manageable. This inherently requires a vast amount of computing power to process, with simulations potentially taking days to run.

AI techniques aren’t faced with the same problem, Patterson points out: “Machine learning models are nonlinear. That means it can learn a much more complex function – one that we wouldn’t be able to write an equation for using traditional techniques – and apply that with a much bigger ▶

ABOVE Last month’s headlines suggesting that AI would destroy humanity conjured Terminator-type images. Not that Ross Brawn was concerned…

BELOW Mercedes was among the first to harness the potential of machine learning, employing it with success on the racetrack and in the factory

cell size. That means the number of cells in the mesh could be an order of magnitude lower than traditional CFD. Suddenly, the simulation could take minutes or seconds rather than days or weeks."

Traditional machine learning uses vast amounts of training data to create empirical models, which can itself be computationally demanding. But what Patterson is proposing is using a much smaller volume of data, together with the physics equations, to learn to produce the local physical interactions far more efficiently than the traditional CFD approach.

Another point he makes is that the very small cell sizes used in traditional CFD mean that neighbouring cells are generally performing much the same calculations. This leads to a significant degree of redundancy across the model, which Patterson says can be greatly reduced with the use of a machine learning approach.

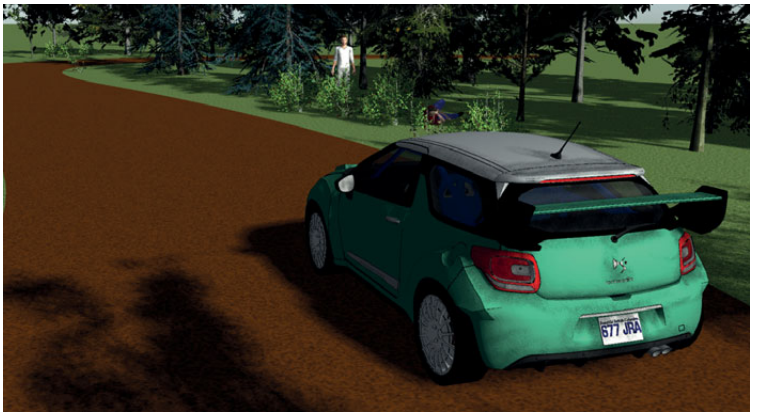
Could AI have stopped porpoising?

AI's affinity with complex multi-dimensional problems also makes it inherently suitable for situations where you need to model several different branches of physics. Patterson points to the example of aeroelasticity in wings and underfloor devices that can lead to porpoising. Here, the downforce rises, until the loads on the aerodynamic device are such that it deforms in shape and suddenly stops working, setting up a resonance. A similar effect can occur if the increasing downforce causes a reduction in ride height that cuts off air flow to the underfloor.

"As things stand today, we don't have one numerical tool that can simulate both the mechanical stress on the component and its aerodynamic performance," comments Patterson. "Instead, we use FEA for one and CFD for the other, and we have to iterate between the two. You can imagine the potential for a machine learning model that's capable of merging the material properties and the aerodynamic performance into one."

> *"We found that we could detect the early warning signs of a potential failure in a jet engine weeks before the ground engineers could"*

In theory, you wouldn't have to stop there. There's no reason why these models couldn't merge mechanics, aerodynamics, thermal effects, electrical behaviour and any other properties. ▶



BELOW The World Rally Championship is working with AI towards being able to predict and head off dangerous spectator movement

LEFT The Indy Autonomous Challenge promotes the development of novel AI driving algorithms that can then be transferred to real cars. The teams are given chassis based on the Dallara chassis used in the Indy NXT series, with alterations to allow for autonomous driving

Faster and smarter

Faster simulations bring their own benefits, but Patterson points out that they can also change the way models are used: "When the simulations are that fast, you can very quickly assess different design choices and get a feel for how those choices impact your objectives. But there are also fundamental differences. For instance, machine learning models are differentiable, which means you can get the change on the inputs for the effect on the outputs. So if I state that my target is to maximise downforce over a range of wing heights and angle, it can use what's called gradient descent to automatically optimise the parameters for that objective."

Man vs Machine

In some respects this is a logical progression from the topology optimisation already seen in CFD and FEA. Over the years, the use of CFD has helped to drive increasingly complex geometries in aerodynamic devices – the 2018 front wings in Formula 1 being a good example – and Garvey believes we could see more weird and wonderful computer-generated concepts if the rules allow.

"I think over the next few years, we could see some curious designs, which look strange, but work really well, where an aerodynamicist has been using AI tools," he notes. "Someone who's manually iterating through ideas for a design might be able to look at 10 different concepts, while a fast machine-based optimisation might be able to do a million iterations. I don't think you'll ever get a case where a machine optimisation isn't better than a human being using the same tools."

In some respects that might sound rather ominous. Are human engineers set to be rendered superfluous?

"My general view is that it's a reasonable concern for people to have, but it never plays out like that," comments Garvey. "In the end, it's just like any other tool that humans have come up with over the centuries – it just makes humans more efficient at the core task. Aerodynamicists, for example, spend so much time fighting with the tools that are available today – meshing, ensuring that the geometries are all sealed together and things like that. There's a huge amount of time that's not actually spent designing the car. Over the next 20 years I think we'll see AI

ABOVE One of the technology's big strengths is the ability to detect hidden patterns in data

LEFT The use of Artificial Intelligence is widespread in F1, ranging from data analysis and predictive analytics to simulation, strategy optimization and cyber security

> *"We could see some curious designs, which look strange, but work really well, where an aerodynamicist has been using AI tools"*

replace those menial tasks, but as long as people are willing to adapt, I think the humans in the process will still be there; they'll just be operating faster and able to explore more ideas."

Looking beyond motorsport, not all of the tasks that humans choose to supercharge with AI will be for the better. But – coming back to Skynet – Patterson believes we have little to fear from AI itself.

Genuine danger

"There's a genuine concern around what could happen if AI was more intelligent than us, but we're not anywhere close. And these systems only learn what we generate, so there's no real evidence to suggest that they ever would be," he comments. "But in my opinion those arguments detract from the real things that we should be worried about with AI. There's a genuine danger that if these models learn from biased data then that could perpetuate or even amplify that bias. For instance, if you have a job opportunity for a role that's traditionally been done by men, there's a risk that an AI algorithm automatically screening CVs might bias towards the male candidates."

AI in social media also has a tremendous potential to be harnessed by those looking to spread disinformation, he notes. Again, it's a tool to amplify human actions and not a self-aware force intent on enslaving humanity for its own ends. In the rather more benign world of motorsport, however, it seems likely that AI will only ever be a force for good.

BELOW World Endurance Championship powerhouse Toyota has been employing AI for years

Toyota GAZOO Racing

THE SECONDS WHERE LE MANS WAS WON AND LOST

Gary Watkins examines the events behind the scenes that influenced the way an epic duel played out between Ferrari and Toyota

VICTORY for any other manufacturer wouldn't have focused attention on the Le Mans 24 Hours in its centenary year in quite the same way as Ferrari's eventual triumph. The win for the Italian manufacturer in the double-points round of the World Endurance Championship brought a gigantic global gaze on the big race.

A marque returning to the prototype ranks as a factory after 50 years with the 499P Le Mans Hypercar garnered the headlines in the wider media. The back story to the success and a controversial run-up to the French enduro was inevitably overlooked.

A drama unfolds

The names of Alessandro Pier Guidi, James Calado and Antonio Giovinazzi are now written indelibly in the history of the world's greatest endurance race. What happened in the days leading up to the start of track action on the Circuit de la Sarthe will in time be largely forgotten, perhaps relegated to nothing more than a footnote of history. But the events of the week prior to the Le Mans Test Day on the Sunday ahead of race week undoubtedly played a part in overall Le Mans victory number 10 for Ferrari at the start of what the world expects to be a golden era for sportscar racing. The Balance of Performance – a foundation stone of the Hypercar class that incorporates cars built to two different rulesets, LMH and LMDh – was revised just three days before the pre-event test.

The significance of the change politically was that it came outside of the new guidelines laid down for the 2023 season. Its significance out ▶

Ferrari

LEFT The script demanded Ferrari's triumphant return after a 50-year absence

on the race track in the 24 Hours was that it shook up the order established over the opening three rounds of this year's WEC. Toyota was no longer the dominant force that it had been at Sebring in March and then Algarve and Spa in April.

Ferrari's 499P leapfrogged the Japanese manufacturer's GR010 HYBRID LMH as the fastest thing in the Hypercar class. It wasn't by a lot, certainly not the kind of margin the Toyota had enjoyed in the initial races of the season. But the Ferrari was the faster car over the course of the 24 hours.

What happened – and why?

A new BoP for Le Mans was issued on the Wednesday ahead of the Test Day. The minimum weight of Toyota was raised by 37 kg, the Ferrari was given an extra 24 kg, and the Cadillac V-Series.R and Porsche 963 LMDhs received 11 kg and 3 kg respectively. The BoP for the Peugeot 9X8 LMH and the non-hybrid Glickenhaus-Pipo 007 and Vanwall-Gibson Vandervell 680 LMHs was left unchanged. Those penalties, if you want to use that word, can be viewed against the backdrop of a clear pecking order in Hypercar over the opening races. Toyota led the way followed by Ferrari, Cadillac, Porsche and Peugeot.

The move was described in a perfunctory joint statement from Le Mans organiser and WEC promoter the Automobile Club de l'Ouest and the FIA, who together administer the series, as a "correction" that was necessary because the opening rounds of the WEC had shown "differences between different LMH-spec cars competing in the Hypercar class to be greater than initially anticipated".

The word correction was clearly deliberately chosen. That's because the kind of wholescale changes made to the BoP before Le Mans were not possible under the rules as they were written. A new system of BoP was introduced for 2023 – one based on simulation rather than track-data, that calculates the potential of each car – was more or less set in stone for the first half of the WEC up to and including Le Mans. Only the balance between the LMHs, which include the four-wheel-drive factory cars, and the rear-drive-only LMDhs could be tweaked. That is known as the platform as opposed to the manufacturer BoP.

A platform change would have balanced the best LMH to the best LMDh, with the same revisions to weight, power and energy allocation made to all cars within each ruleset. So if Toyota was handed 30 kg, so too would Ferrari, Peugeot, Glickenhaus and Vanwall.

A further explainer issued by the FIA/ACO added some meat to the bones of their original statement.

"Following the first three races of the

ABOVE Decisive moment: Ferrari's eventual race-winner snatches the lead from Toyota, setting up a thrilling denouement to the centenary race

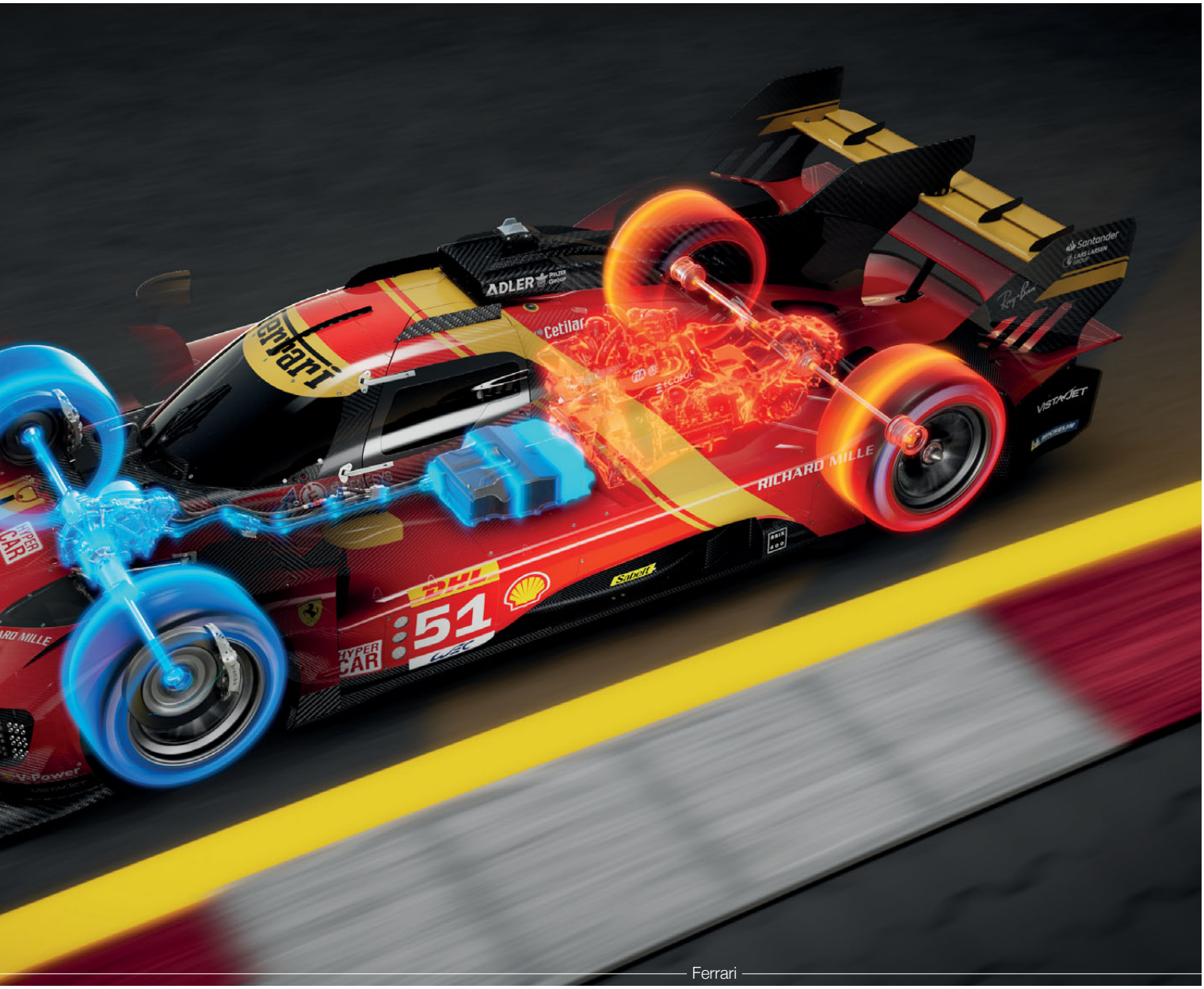
ABOVE RIGHT Ferrari's 499P was the fastest car, just, for most of the race but the conditions did favour the Toyotas at some stages

RIGHT The ability to develop its own hybrid powertrain, rather than adopt a spec component as in LMDh, was a guiding principle throughout the negotiations which led to Ferrari's Le Mans return after a 50-year absence

season it turned out that performance differences within the LMH group are greater than initially anticipated, therefore balancing out only the two platforms wouldn't be sufficient to fulfil the ultimate goal that the BoP is meant to achieve, and that is to ensure a level playing field for all competitors," it read. "Therefore, corrections were made between, but also within, the LMH and the LMDh platforms – BoP changes and balancing out between the platforms in this case happened simultaneously."

The FIA/ACO stressed that the new system as written remains in place, though there still seems there is no intent to place it in the public domain. That means there could be another manufacturer change ahead of round four of the 2023 WEC at Monza on ▶


Ferrari



Ferrari

July 9, the only time changes could originally be made across the whole Hypercar field during the season.

The idea of a fixed BoP was conceived to ensure that a manufacturer couldn't sandbag in order to get a favourable BoP for the 'big one' in mid-June. All the participants in Hypercar were signatories to the guidelines, which had been thrashed out over the course of a reputed eight technical working group meetings during the final months of last year.

If there was any contention it centred on exactly when the one pre-Le Mans platform BoP could occur. The rules are believed to state that this could happen after two WEC rounds. Toyota claimed that meant before and only before round three at Spa at the end of April. Porsche, or at least its head of motorsport Thomas Laudenbach, argued that "after two races" could mean any time up to Le Mans. The sporting rule introduced for 2023 barring manufacturers, teams and drivers from talking in public about the BoP had long since been disregarded as Le Mans approached.

Backtrack a month or so. What happened in the run-up to the Spa 6 Hours on 29 April isn't entirely clear, though it appears that a platform BoP change in favour of the LMDhs was floated, only for it to be shouted down. It appears that Toyota was not the only marque to put up a fight. It is understood that other entrants with LMHs who were facing the prospect of losing out to the two LMDh manufacturers in Cadillac and Porsche who were already faster than them were equally vocal.

It is known that there was a meeting between the rule-makers and the manufacturers – virtual or otherwise – ahead of Spa. What is clear is that when it came to the pre-Le Mans change there was no debate. The seven makes involved in Hypercar were summoned onto a Zoom-type conference call and told by ACO president Pierre Fillon and his opposite number on the FIA's Endurance Commission, Richard Mille, that there was going to be a change. The revisions themselves weren't communicated during the call; the manufacturers only learnt of their extent that afternoon when sent the new BoP table.

Vehicles		Mass			Energy		
		Min. Dry Weight (Kg)			Maximum Stint Energy (MJ)		
Manufacturer		prev	adj	current	prev	adj	current
CADILLAC	V-Series.R	1035	+11	1046	904	+1	905
FERRARI	499P	1040	+24	1064	899	+2	901
GLICKENHAUS	007	1030	0	1030	913	0	913
PEUGEOT	9X8	1042	0	1042	908	0	908
PORSCHE	963	1045	+3	1048	910	0	910
TOYOTA	GR010 - Hybrid	1043	+37	1080	904	+4	908
VANWALL	Vandervell 680	1030	0	1030	901	0	901

ABOVE Manufacturers only learnt of their fate when sent the BoP table

It was a *fait accompli*. The ACO and the FIA acted unilaterally, and as the ultimate arbiters of the WEC they reserve the right to do so. Bulletins from the Endurance Committee have a subheading reading "Period of Validity". There's a box with the words "until further notice" next to it. It is always ticked.

How did the BoP affect the race?

Only Toyota driver Kamui Kobayashi put a figure on how much the BoP changes hurt Toyota. He also holds the position of team principal of the Toyota ▶

> *"The 13 kg differential in the weight increase between the GR010 and the Ferrari 499P was worth 0.4 sec a lap"*

BELOW The synchronised finishes on the racetrack (here Cadillac earns a well-deserved podium) contrasted with the jostling for position in the boardroom before the race week had even started. More than one LMH team lobbied against LMDh rivals being handed a performance break

Richard Prince/Cadillac

Toyota GAZOO Racing

LEFT Weighting game: the Toyotas carried an extra 37 kg, the Ferraris 24 kg

GAZOO Racing WEC squad, so presumably he was speaking with some authority and knowledge when he suggested on his Twitter account in the immediate aftermath of the publication of the new BoP that the addition of 37 kg cost 1.2 sec around the 8.47 miles of the Circuit de la Sarthe. He subsequently suggested after the race that the 13 kg differential in the weight increase between his GR010 and the Ferrari 499P was worth 0.4 sec a lap.

Senior management at Toyota GAZOO Racing Europe in Cologne didn't go public with any figures prior to the race. Technical director Pascal Vasselon then suggested upon its conclusion that the net loss caused by those 13 kg was two and half minutes, a figure he explained that was corrected to take into account the three full safety cars and the five of the virtual kind, known as Full Course Yellows in the WEC, as well as the many so-called Slow Zones in which the FCY speed limit of 80 km/h is enforced over set areas of the track.

That amount of time is just under double the winning margin of the Ferrari. Pier Guidi, Calado and Giovinazzi finished 1m 21.793s up the road from the surviving Toyota shared by Sebastien Buemi, Brendon Hartley and Ryo Hirakawa. Vasselon's comments could be viewed as code for "the BoP changes cost us the race".

The 80-odd seconds by which Ferrari prevailed makes the centenary Le Mans among the closest Le Mans finishes in history: Race Tech's reckoning makes it the seventh closest of the 91 editions of the great race, though this is not an exact science. That's because until the 1980s, the ACO gave the winning margin when less than a lap in metres rather than minutes and seconds.

Ford

ABOVE The return of manufacturers such as Ferrari, Porsche and Cadillac made for an unforgettable atmosphere

LEFT The battle had media scrambling to look up the closest finishes the race has ever produced. None have topped Ford's botched formation finish in 1966, when the lead car won by dint of the 20-metre staggered start positions

Toyota

The closest finish, without doubt, is Ford's stage-managed – that should probably be mis-managed – finish in 1966 when the two Shelby American Ford MkIIs were officially separated by 20 metres. The narrowest margin when the stopwatch was involved came in 2011 when the winning Audi R18 e-tron quattro with Andre Lotterer at the wheel crossed the line 13.854 sec ahead of Simon Pagenaud's Peugeot 908. That is reckoned to be the fourth closest finish in Le Mans history after the 401 metres that separated a pair of Alfa 8C-2300s in 1933. This year's margin sits just behind the 40 sec in 2004 between the Goh and Veloqx Audi R8s in 2004 and the 16 sec that separated the pair of Toyotas in 2019.

Ferrari's great escape

So for all the furore over the BoP, it was exceptionally close, close enough for the vagaries of endurance racing in the modern era of ultra-reliability to decide the outcome of the race. It can be said with some certainty that the last-hour electronic glitch for the Ferrari would have been enough to hand Toyota victory had not Hirakawa lost time with an hour to go courtesy of an off at Arnage. He clouted the barrier front and rear, the damage resulting in the loss of two minutes in the pits.

The Ferrari lost in the region of 30 sec when Pier Guidi had to recycle the electronics – essentially reboot the car – with approximately 25 minutes of the race left on the clock. Hirakawa was just 15 sec behind at the time of his off and had a car that looked at least a match for the Ferrari at that time.

There was no criticism of Hirakawa from within the Toyota camp. Hartley had been closing on the leader before handing over to the Japanese, who is in only his second season with Toyota's WEC squad, and had got the lead down to under 10 sec, before a few seconds were lost during the handover. He insisted that the message to his Japanese team-mate as he climbed aboard was "maximum attack".

Toyota might just have had the faster car for the run to the flag as the temperatures rose. The 499P was the quicker car over the full distance, but there were segments of the race when the GR010 was ascendent. A portion of the night when the Toyota went onto the soft compound Michelin slick was one of them. Buemi was able to get the car into the lead as the Toyota came into the window.

But the fact remains that the Ferrari was quicker. On a 150-lap average, the winning car had just under three tenths on its pursuer, while the second Ferrari that ended up fifth in the hands of Antonio Fuoco, Nicklas Nielsen and Miguel Molina was a further three tenths up the road. It owed its lowly finishing position, five laps in arrears, to the time loss in the pits resulting from a stone piercing the radiator for the car's Motor Generator Unit.

Ferrari had an undoubted edge at Le Mans, but it was a race that could have gone either way. The action was befitting of such an important race in Le Mans history. In years to come, no one will remember that the rules were changed to achieve that. RT

"GOOD PERFORMANCE, RELIABILITY AND RESPONSE – WITH AN EMOTIONAL CONNECTION"

With the Le Mans hydrogen category now opened to hydrogen combustion, Bosch Engineering and Ligier Automotive have joined forces to explore the frontiers of the technology. **Chris Pickering** reports

IN September 1860 the magazine Scientific American confidently proclaimed that the steam age was over. It was in response to Belgian inventor Etienne Lenoir who had built a motorised tricycle using a single-cylinder internal combustion engine.

The Hipmobile, as it was known, was a crude machine compared to that of Carl Benz who'd swoop in 20 years later and be pronounced the father of the automobile. But it had one interesting feature. Lenoir's car ran on hydrogen.

More than 160 years later, hydrogen combustion is very much on the agenda again. The technology has skirted the periphery of motorsport for a decade or so, but suddenly interest is ramping up.

Among the hydrogen announcements at this year's 24 Hours of Le Mans was the unveiling of a joint project between Bosch Engineering and Ligier Automotive. The Ligier JS2 RH2 uses a 3-litre twin turbocharged V6 that has been converted to run on hydrogen. Bosch Engineering led the development of the engine, fuel system and safety systems, while Ligier Automotive was responsible for the vehicle dynamics, the chassis integration and the development of an all-new carbon fibre monocoque.

This, then, is far more than the JS2 R track car with a few engine mods. But for both parties it represented an opportunity to demonstrate their ability to take an existing platform and convert it to hydrogen.

"As a manufacturer, a new series with hydrogen combustion engines is clearly a possibility for us, but we also wanted to show that we are able to do the same for other manufacturers that are looking to integrate a hydrogen solution," explains Julien Jehanne, site manager for Ligier Automotive.

Bosch already had hydrogen engines running on the test bench and was looking for a partner to develop a demonstration vehicle for motorsport. Ligier Automotive has a long history in endurance racing and was already working with the German company on other projects, so it was an ideal match.

High power

As is so often the case in motorsport, the first challenge was the timescale. The project was only given the go-ahead in October 2022, and the team wanted to be out on track by September this year. They'd also set an ambitious target of 500 hp – significantly more than the hydrogen engines that Bosch had run on the dyno up to that point.

"We wanted an engine that would provide good performance, reliability and response, along with an emotional connection," comments Pierre Humbert from Bosch Engineering. "We thought 500 hp from an engine of this size with ▶

DPPI Images

LEFT The JS2 RH2 is already producing 570 hp, a specific output of 190 hp/litre similar to the outgoing GTE cars and into the LMDh ballpark

relatively little optimisation would make a good argument for the use of hydrogen. Below [that power level] we weren't sure if it would have the impact we wanted."

In the end, they comfortably surpassed both targets. We catch up with the engineers in June, the week after Le Mans. Both have just returned from the JS2 RH2's first high-speed test at Magny-Cours, with the engine now producing 570 hp and more apparently left to come. That gives a specific output of 190 hp/litre, which is about the same as the outgoing GTE cars and into the right sort of ballpark for an LMDh entry.

From a powertrain perspective, the first challenge is getting the hydrogen into the engine. Injecting the gas into the ports is comparatively straightforward, but due to its very low density, the hydrogen can displace some of the intake air and reduce the engine's volumetric efficiency. To counter this effect, Bosch also uses a direct injection system.

This is where things start to get complicated, Humbert explains: "Being a gas rather than a liquid, you need a very high mass flow to get the fuel into the combustion chamber quickly enough if you want to maintain flexibility in the injection timing window. That means you need a very big injector. And it needs to be able to run dry – without any lubrication."

> *"It uses water injection to control the combustion temperatures, allowing the engine to run in the high power zone around lambda one"*

Hydrogen ignites very easily – it takes about 10 times less ignition energy than gasoline and burns across a wide range of lambda values. In some respects, this is a good thing, but it also brings its own challenges.

"Depending on pressure or temperature, hydrogen can auto-ignite. For example, a hot spot could also make it ignite without the spark. And you can also get what we call a ghost spark, where there's a little residual energy left in the coil that causes a very small spark," comments Humbert. "Overall, you need less energy, but it needs to be very finely controlled."

Another useful property of hydrogen is that it's capable of being burnt at extremely lean equivalence ratios. Maximum power is achieved around lambda one, but in this region, hydrogen burns very quickly and releases a lot of heat – far more so than gasoline. Consequently, some applications run the engine lean, even at full loads, to limit temperature.

Bosch Engineering has taken a different approach. It uses water injection to control the combustion temperatures, allowing

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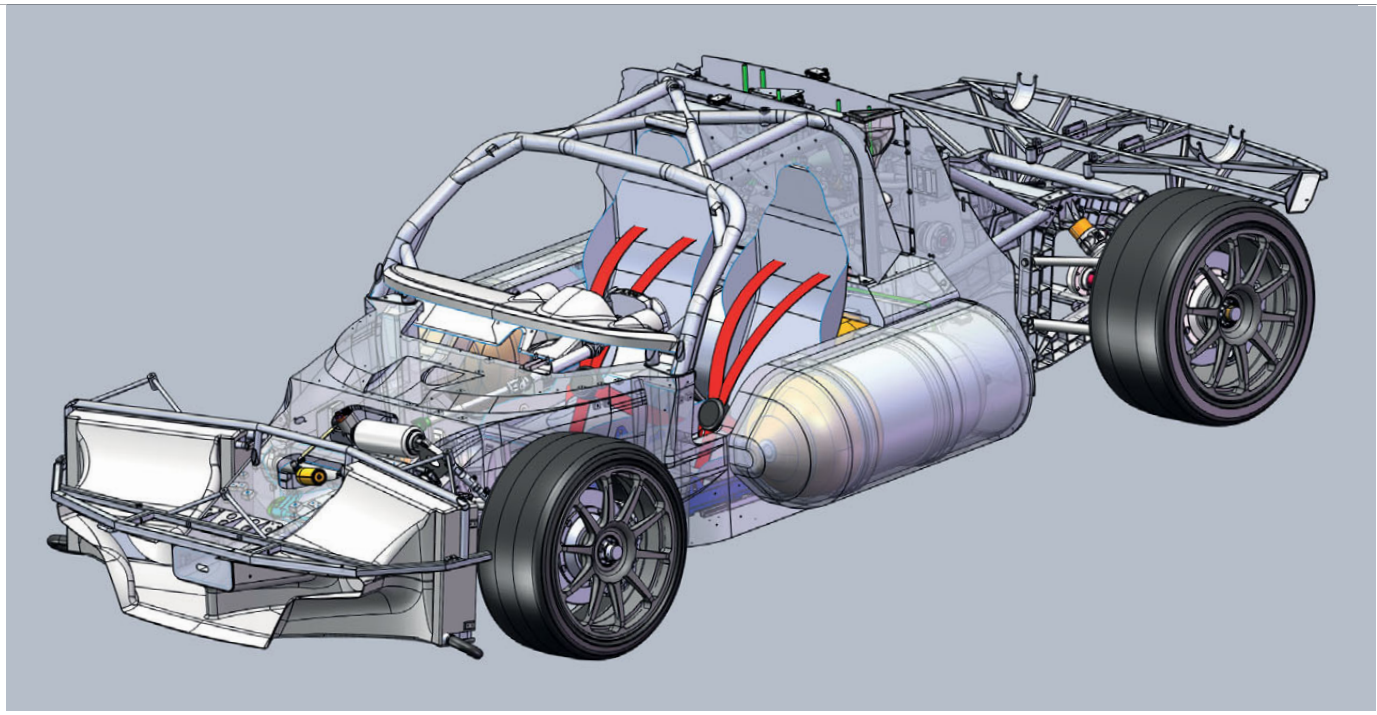
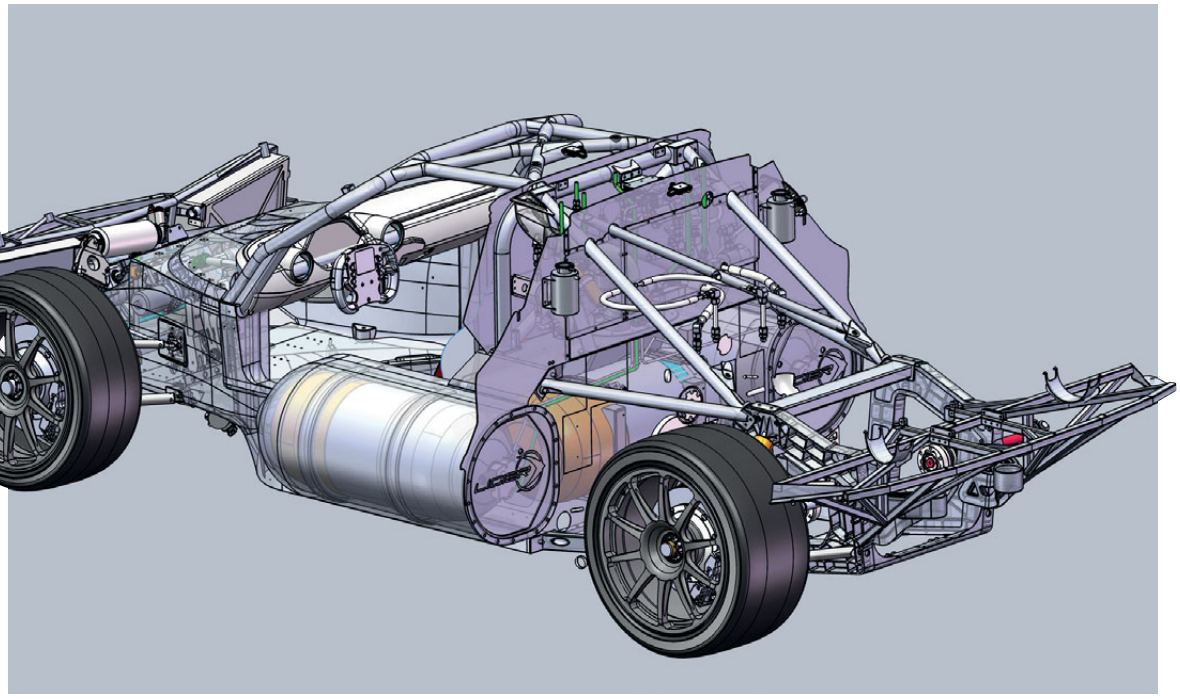




ABOVE & RIGHT The JS2 RH2 seen in CAD. The most pressing issue was how to package the three 700-bar carbon fibre hydrogen tanks

the engine to run in the high power zone around lambda one. This also means it can retain the original turbocharger hardware, whereas a lean burn concept would have required a bigger turbo and a bigger intercooler to restore its output.

Quick fix

"We knew that the engine would need more cooling [than its gasoline equivalent] from the water system point of view, but also in terms of charge cooling. Cool intake temperatures are particularly important for the combustion in a hydrogen engine," notes Humbert.

"The water injection provided us with a quick fix to mitigate the combustion – it's an easy way to get a lot of performance in a short period of time. But with further optimisation it may be possible to achieve the same sort of performance with much less or even without using a water injection system."

Getting the fuel, air and water safely into the cylinder is only part of the challenge. The combustion also needs to be carefully managed.

"In general, it's a lot like a standard spark ignition combustion engine," comments Humbert. "The ignition, the air path and the lambda control would all be familiar to someone who's worked on gasoline engines. We also have knock control and pre-ignition detection. If you're not after high performance, I'd almost dare to say it's easier than controlling a standard gasoline engine. But where it gets complicated with hydrogen is if you're after ▶

LEFT The new car predictably attracted a lot of attention at its Le Mans launch

maximum specific power, and then you really need to look at the details."

An example of this is the injection timing. Hydrogen is generally very tolerant to where in the cycle it's injected and ignited, but this becomes far more critical if you're looking to maximise power. Similarly, the broad range of equivalence ratios that can be used, from rich to very lean, adds further complexity – so much so that Humbert describes it as a whole additional torque path.

Pre-ignition detection is one of the hardest points to master on a hydrogen engine. It's further complicated, in the case of the V6 engine used, by the interactions between the port injection, direct injection and water injection systems. The wide range of injection strategies open to a hydrogen engine also gives the engineers plenty of options when it comes to calibrating transient response and anti-lag systems.

Bespoke chassis

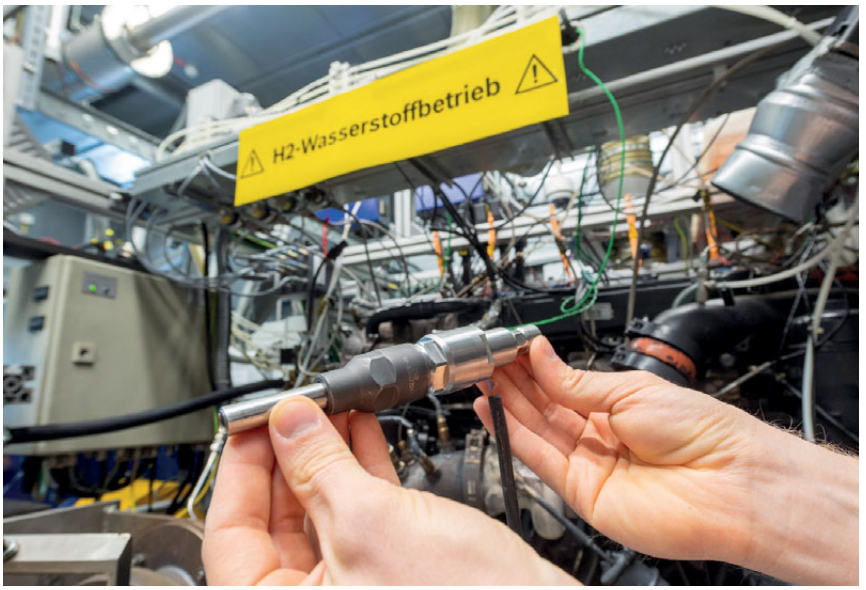
The JS2 R was chosen as a base car to get the project up and running as quickly as possible. However, this didn't turn out to be quite as simple as you might expect. The most pressing issue was how to package the three 700-bar type IV hydrogen tanks from Norwegian green tech firm Hexagon Purus. Although these are among the smallest and lightest designs on the market, they still take up a considerable amount of space.

"We understood that there wasn't enough time to develop a custom storage system, so we had to look at what was out there on the market. You have big tanks for heavy duty applications, but smaller tanks aren't easy to find, so we looked at several different solutions," explains Jehanne. "We considered using one tank, two tanks or three tanks, and how that would impact the design."

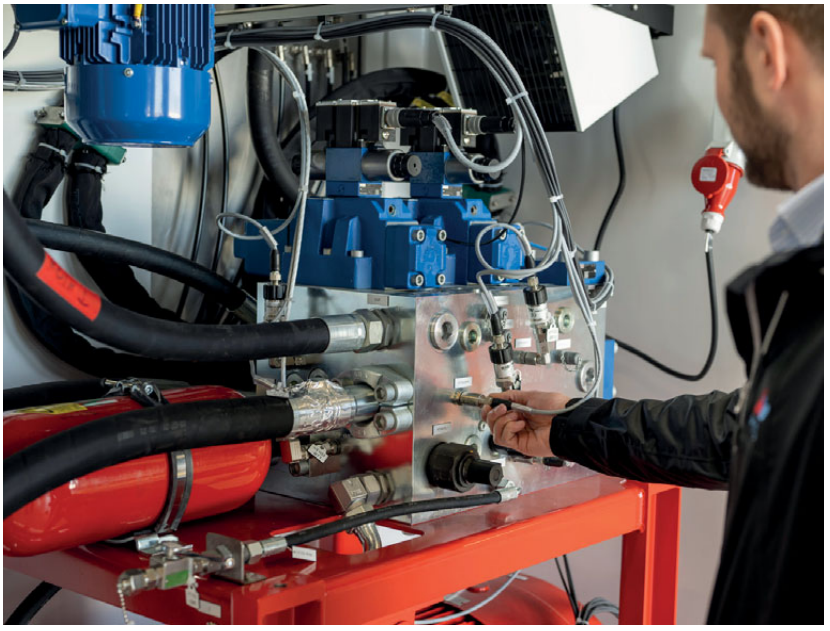
One issue is that the high-pressure carbon fibre tanks are quite thick. This means that the material itself takes up a significant portion of the volume in a small tank, leaving less room for the hydrogen. In the end, the configuration that was chosen was three small tanks: one behind the cockpit and two on the sides. "This gave us the best compromise between storage capacity and packaging volume," notes Jehanne.

Bosch Engineering had already carried out extensive simulation work before the project kicked off. Thermal management was a major topic, with the temperature of the hydrogen inside the tanks increasing rapidly as they're pressurised during refuelling and then falling to well below zero by the time they're empty. This work had shown that multiple tanks would make it easier to manage the temperature, and it had also helped Humbert and his colleagues to devise control strategies that were later applied to the car.

Initially, Ligier considered using the standard JS2 R's tubular steel spaceframe, but this was rapidly discounted in favour of a carbon fibre monocoque, which offered inherent safety advantages and more packaging options. A modified version of the carbon tub from the JS P3 and JS P4 prototype racers was also considered, but it proved easier to start from scratch. ▶



ABOVE Bosch is involved in more than 100 technical trials with customers around the world as it explores the use of hydrogen



BELOW Bosch Rexroth and Maximator Hydrogen have developed a solution for compressing hydrogen for filling stations, storage tanks, and pipelines. By 2030, the two companies want to make this technology available to 4,000 hydrogen filling stations. One in three hydrogen filling stations worldwide would then be equipped with Bosch components

> *"Mechanically similar to gasoline engines, and you still have the same noise and emotion"*

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Safety first

Safety was paramount from the start of the project, Humbert explains: "We didn't want to do something that was quick and dirty. Right from the start we wanted to achieve very high quality standards based on the road-going regulations for hydrogen engines and the rules laid down by the FIA."

One of the key aims was to package each of the three tanks in its own leak-proof compartment, which could be integrated into the design of the monocoque. Each of these compartments uses a high-strength carbon sandwich construction, with Zylon anti-intrusion panels providing additional protection on the sides.

"The tricky point for us was that we had to define the monocoque design really early in the project," recalls Jehanne. "We started in October, and we had to freeze the design of the monocoque by early December, if we wanted to meet the deadlines for tooling and production."

In theory, this gave the engineers a completely clean sheet, but they were reluctant to stray too far from the existing template. In particular, they wanted to retain the JS2 R's comparatively compact wheelbase to demonstrate that a hydrogen powertrain could be accommodated in a wide range of vehicles.

Another integral feature of the design concept was a passive ventilation system. The team had looked at using an active system, but found that some of the required parts weren't yet on the market. This comes down to simple yet fundamental issues such as finding a fan that's deigned to work with hydrogen.

The passive system ducts air in from the front of the car. Two separate streams of air pass the side tanks and then merge together around the third tank before being vented out the top of the car. A separate air flow system passes around the pipework. There's also an individual leak detection system in each tank, so if any loss of hydrogen does occur, the control unit can automatically pinpoint its location and set off an alarm.

Feeding the air in and out of the bodywork is relatively straightforward, says Jehanne, but the packaging of the hydrogen tanks still introduces challenges in the aerodynamic design.

"The tanks are 370 mm internal diameter, so the biggest challenge from an aerodynamic perspective is that they take up a lot of space on the side of the monocoque," he comments. "You end up having to put all the cooling at the front of the car but there's not much space anywhere else. So, in the near future, we believe we will see some kind of new cooling concepts for hydrogen."

Due to the short timescale, all of this had to be considered as the project was progressing. Alongside the design of the vehicle itself, the specifications were continuously refined for the gas tanks, the pipework and the valves.

"We kept challenging Ligier," comments Humbert. "Every time we spoke to them we were saying, 'We've found a new component, you need to find a place for it, it needs to be in a compartment that's separated from the cockpit and separated from the engine…' And all of this needed to be done very

ABOVE The car's comparatively compact wheelbase demonstrates that a hydrogen powertrain could be accommodated in a wide range of vehicles

quickly, so the parts had to be freely available. That means that several of the components we're using at the moment are quite big and heavy, and not really optimised for motorsport. Ligier did a fantastic job of integrating them."

On track

The first shakedown runs took place at Bosch's verification road at its Abstatt site in southern Germany before Le Mans. However, the recent two-day test at Magny-Cours was the car's first high-speed outing. This gave the team a chance to finish its debugging, and the car will now be fine-tuned back in Germany at Bosch's test track in Boxberg ahead of some events in September. At present, there are no plans to race the car, which is essentially a development prototype and demonstrator, but the recent unveiling at Le Mans is already said to have stimulated many interesting conversations with fans and manufacturers alike.

"We think that hydrogen combustion has a very good future within motorsport," comments Jehanne. "It's mechanically similar to what we know already with gasoline engines, and you still have the same noise and emotion. The drivers still love the car. It's

> *"Ultimately, liquid hydrogen could be the way forward"*

a promising alternative to electric cars, which we've seen can struggle to attract privateer interest."

Another benefit of hydrogen is that it's a relatively mature technology in some respects. Bosch Engineering and Ligier Automotive may be in the early stages of their project, but Toyota has been running hydrogen-fuelled cars in the Japanese Super Taikyu series on and off for several years and Aston Martin kicked things off in 2013 with the dual-fuel Hybrid Hydrogen Rapide S that successfully raced at the Nürburgring 24 Hours.

Jehanne is certainly optimistic: "From what we've seen so far, hydrogen seems like a realistic option from the vehicle side. There's a bit of a question mark over the refuelling facilities at the circuits, but there are solutions out there for that already."

The current fuel system holds 6.3 kg of hydrogen. Although the team has yet to test the car's full range, we're told that simulations suggest it would run for around 30 minutes on a typical track and possibly slightly less at somewhere like Le Mans or the Nürburgring.

Ligier Automotive and Bosch Engineering are already looking ahead to the future. Ultimately, Jehanne believes liquid hydrogen could be the way forward, as it dramatically increases the volumetric energy density of the fuel, which will equate to more range and quicker pit stops. With liquid hydrogen stored at a chilly -253 deg C this brings its own thermal challenges, but he believes these could be overcome with bespoke tanks.

Bosch

ABOVE & BELOW Having been instrumental in the introduction of the first hybrid racecars in North American racing (below), Bosch Motorsport has entered a technology and marketing partnership with the ACO for the new Hypercar category (above)

Toyota agrees. The latest of its Super Taikyu racers is a GR Corolla that uses liquid hydrogen, although it was withdrawn from its first race back in March after a fire. Undeterred, the GR H2 Racing Concept that was launched at Le Mans also uses this technology.

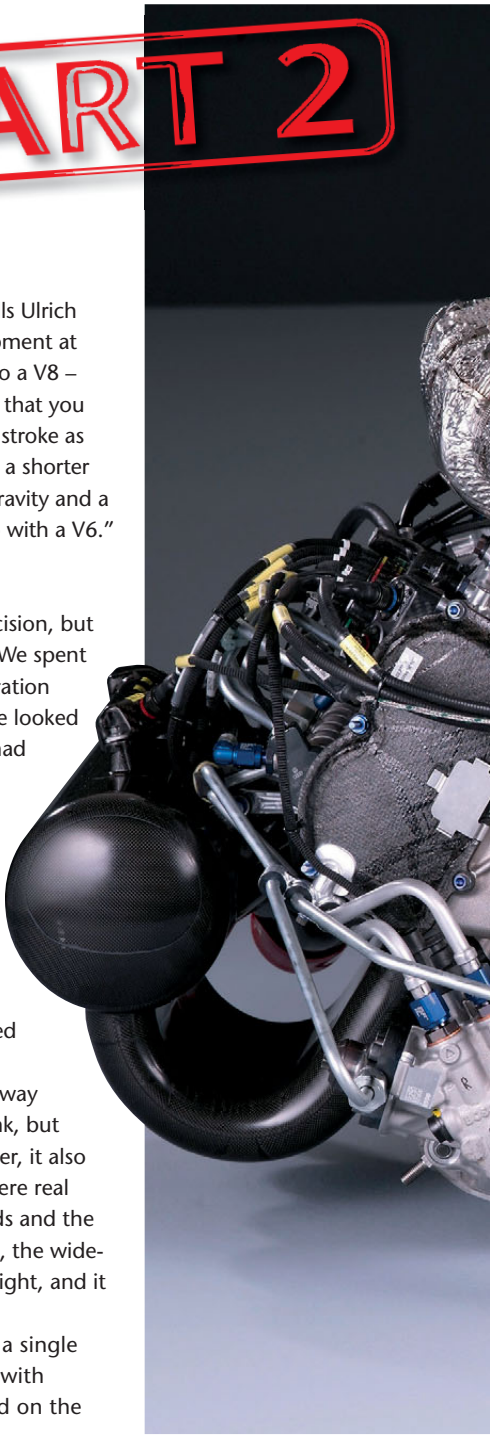
There's a question mark over how relevant liquid hydrogen would be to road car applications, where most of the work at the moment is focused on gaseous fuels. However, it seems likely that further refinement and the adoption of liquid hydrogen could bring the JS2 RH2's range in line with current gasoline engines, with the one crucial exception that it would produce no tailpipe CO2 whatsoever. There's plenty of work yet to be done, but the thought of a grid full of rumbling V8s and sonorous V12s emitting barely anything other than water vapour is certainly a very appealing one. RT

Bosch

HELLO HYBRID! *DANKE* DIESEL

PART 2

In the second of our articles with Ulrich Baretzky, the former head of engine development at Audi Sport reveals the philosophy that shaped the last of the German giant's pioneering diesel Le Mans engines. By **Chris Pickering**



AUDI'S audacious foray into the world of diesel-powered race engines revolutionized the Le Mans 24 Hours endurance race.

Defying convention, the German automaker took on the formidable challenge of proving that diesel could compete at the highest level of motorsport. Its pioneering work not only shattered records but also left an indelible mark on the history of motorsport. It won first with a V12 engine, then with a V10. But, just as changing trends in the wider automotive industry had been the catalyst for the development of diesel race engines in the first place, those forces also shaped the last of Audi's diesels.

In 2008, the ACO and the manufacturers began discussing the next step for the engine regulations. Passenger car engines were starting to downsize, and it was agreed that the race engines needed to be smaller, lighter and more economical as well.

The new regulations eventually arrived for the 2011 season. For diesel engines, the rules allowed a maximum displacement of 3.7 litres – a reduction of more than 30 per cent – and no more than eight cylinders.

"We started to think what an engine produced to these regulations might look like," recalls Ulrich Baretzky, the then-head of engine development at Audi Sport. "It was definitely possible to do a V8 – Peugeot proved that – and it would mean that you could use more or less the same bore and stroke as the 5.5-litre V12. But we wanted to go for a shorter engine to give the car a better centre of gravity and a lower polar moment, so we decided to go with a V6."

> *"The diesel project was like the moon landings. We knew what we wanted to do, but we didn't know how we were going to do it, and we didn't know if we were going to succeed"*

Hot vee configuration

Conceptually, it was a straightforward decision, but the devil was in the details, he explains: "We spent weeks thinking about the engine configuration and the turbo arrangement. First of all, we looked at putting them on the outside like they had been in the V12, V10 and the V8, but the aerodynamics and cooling system would be handicapped. Therefore, we looked at putting the exhaust on the inside to run a hot vee configuration like Ferrari had done in Formula 1 in the 1980s."

A wide-angle 120-degree configuration was chosen for the cylinder banks. This lowered the centre of gravity and increased space for the turbocharger installation (as Baretzky points out, it's only 30 degrees away from a boxer engine on each cylinder bank, but avoided the problems of a boxer). However, it also results in a lot of lateral load, and there were real concerns that the block, the cylinder heads and the sump might slide. After careful simulation, the wide-angle configuration was given the green light, and it proved to be a success.

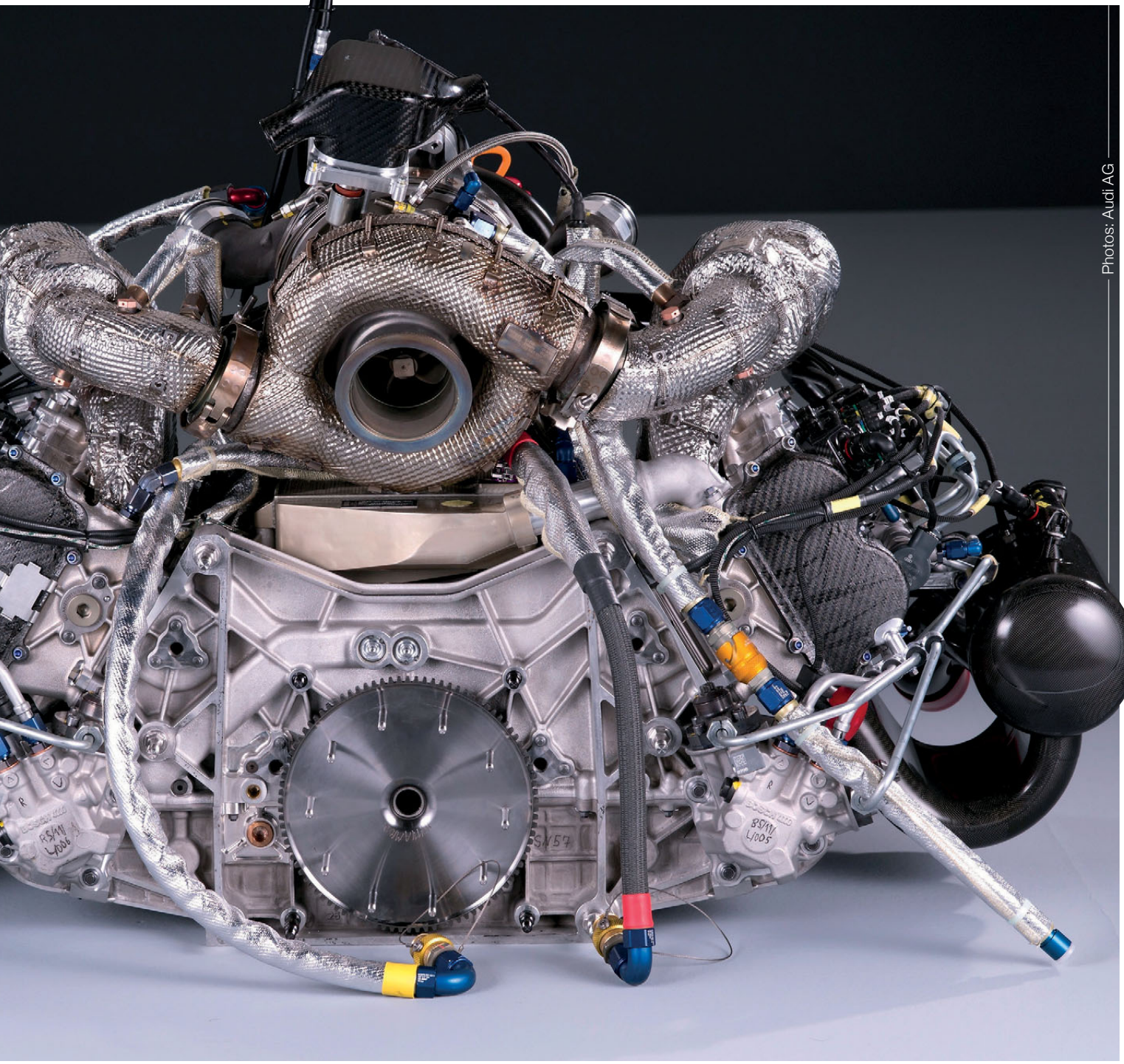
Another significant step was the use of a single turbocharger, developed in conjunction with Garrett, in place of the twin turbos found on the

R10 and the R15. This two-stage design utilised Garrett's variable geometry nozzle technology (VNT) to deliver around 600 hp from a 3.7-litre engine running a single turbocharger.

"Garrett was a fantastic partner – over the years, we came to the engineers there with a lot of difficult requests and they never said, 'We can't do that', it was always just, 'This is how long it will take'," comments Baretzky. "At the beginning, the turbocharger was a little heavier than we would have liked, but we went on the safe side to ensure it worked. Then we changed things, like switching to magnesium for the compressor housing and the central housing. In the end, we reduced the weight by about 40 per cent."

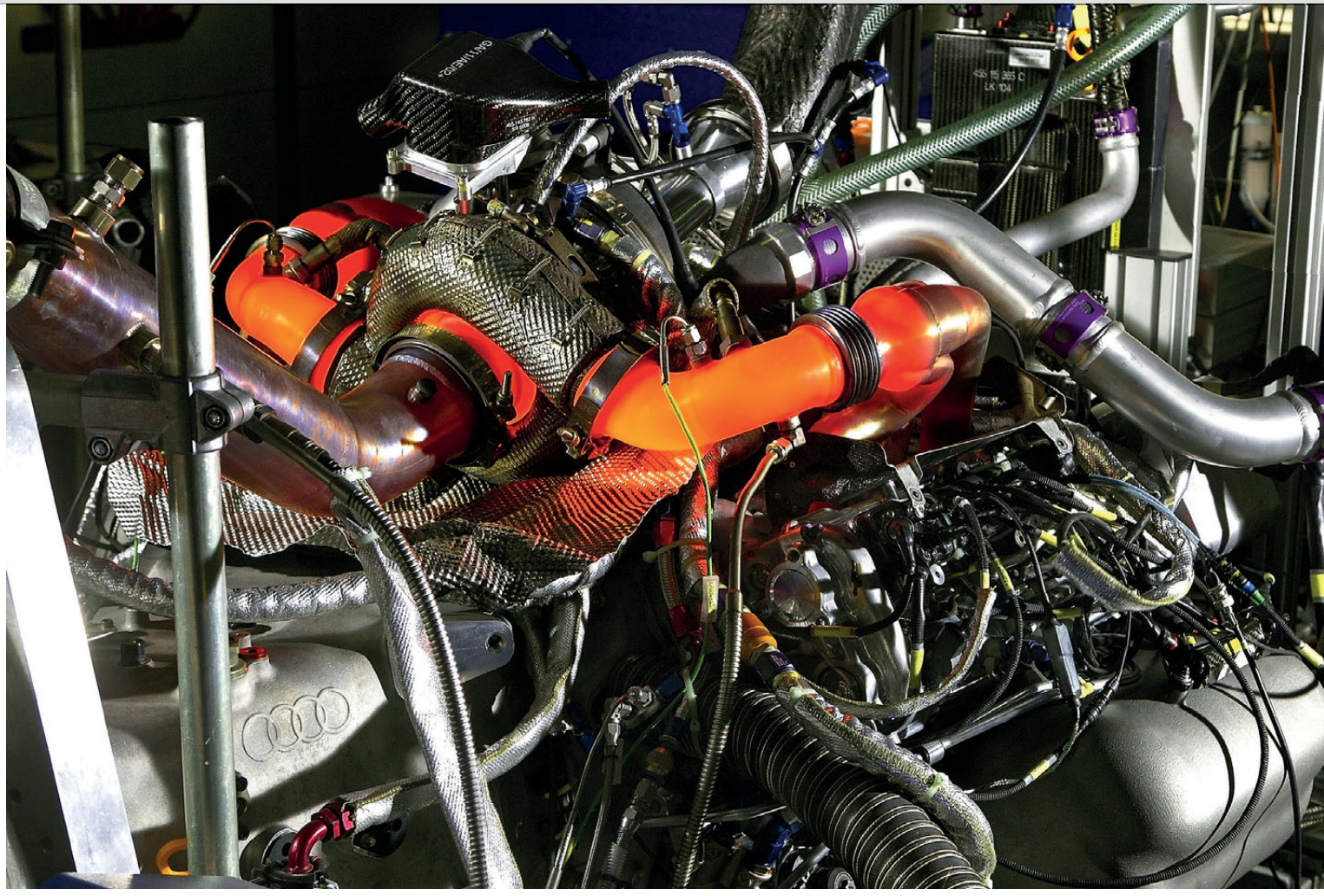
Turbocharging has been a recurring theme for Baretzky, who began his motorsport career working on BMW's spectacularly powerful 1.5-litre Formula 1 engines in the early eighties. Beyond his own projects, he admits that one of the engines that inspired him along the way was the 3.6-litre twin turbo V6 in the Toyota GT-One of the late nineties.

"I've always been a fan of turbo engines, and when we started talking about the development of ▶



BELOW The wide-angle 120-degree cylinder banks enabled the exhaust to be run on the inside of a hot vee configuration in Audi's 3.7-litre V6 diesel

Photos: Audi AG



the R8, the performance of the Toyota was proof to me that we should go down this route," he reveals. "Not a V6 and not naturally aspirated, but a twin-turbo V8. If efficiency is important as well as performance, it has to be a turbocharged engine. And the same applies to diesels."

Hybrid era

In 2012, the LMP1 rules were changed to allow the use of hybrid systems. Much like diesel engines, first seen at Le Mans in the 1940s, hybridisation was not strictly a new thing at the event. Panoz had entered the hybrid Q9 in 1998, while a hybrid version of the Ginetta-Zytek GZ09S had run with moderate success in the ALMS in 2009 and the concept returned to Le Mans with the ORECA Swiss HY Tech-Hybrid in 2011.

Peugeot had left endurance racing unexpectedly at the start of the 2012 season, having already prepared a hybrid version of the 908. Instead, the main opposition to the new R18 e-tron quattro at Le Mans that year came from newcomers Toyota with the gasoline-engined TS030 Hybrid.

Two R18 e-tron quattros were entered, alongside two non-hybrid R18 ultras. The hybrid version used a motor generator unit on the front axle combined with an innovative electro-mechanical flywheel energy storage system from Williams Hybrid Power with 500 KJ energy. It changed the chassis concept of the car, but had little direct impact on the design of the combustion engine.

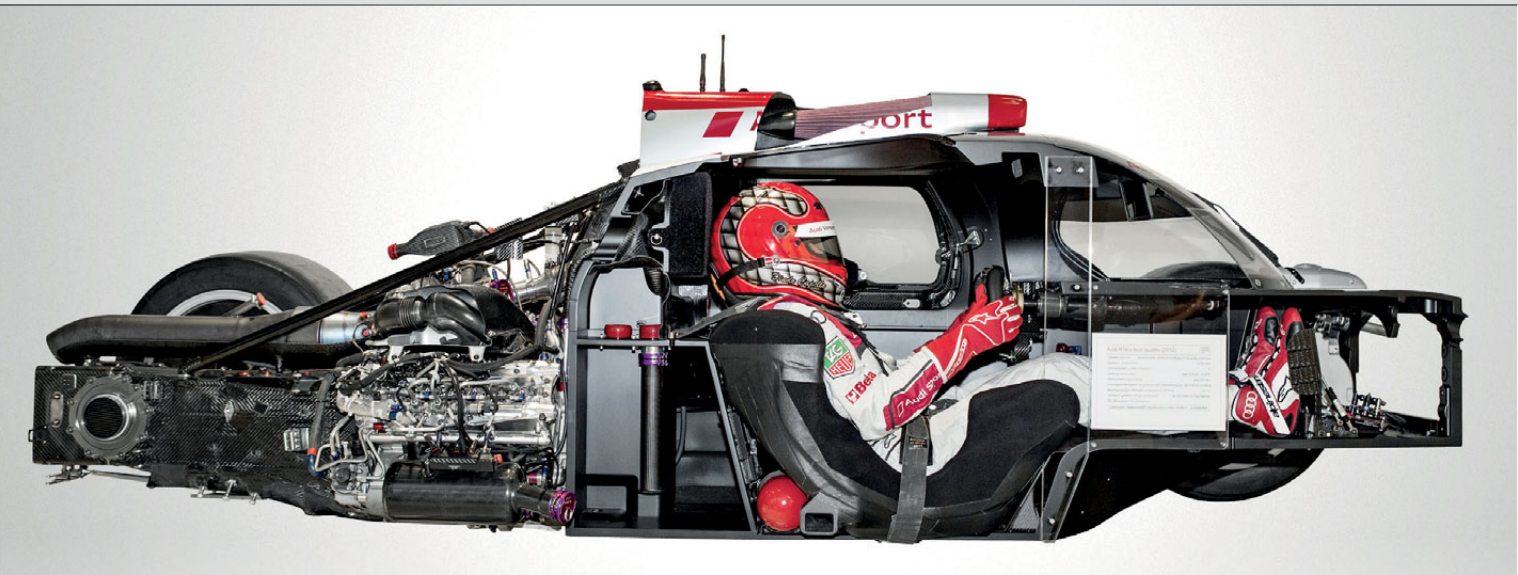
> *"When we started with the R8, we only needed two people to run it; by the end of the R18, we needed five laptops just to start it up!"*

It's fair to say that Baretzky wasn't a fan: "For me, hybrids have always struck me as the wrong approach in motorsport. They cost an awful lot of money and they make the car terribly complicated and heavy.

"When we started with the R8, we only needed two people to run it. By the end of the R18, we needed five laptops just to start it up – one for the hybrid system, one for the battery, one for the engine, one for the gearbox and one for the sensors. And that extra workload continued through the race – if you exceeded one of the limits, you had two laps to correct it before you were disqualified."

However, the concept of hybridisation was here to stay. In 2014, after two more back-to-back victories from the R18, the system of air restrictors was

ABOVE With the V6 diesel engine subject to a lot of lateral load, the wide-angle configuration was given the green light only after careful simulation



abandoned in favour of an energy-limited formula. In response, Audi enlarged the V6 to 4 litres and upgraded the flywheel system.

"It was a very different story under the 2014 regulations. Suddenly you could have as much air as you wanted to use, but energy was restricted per lap and in total," comments Baretzky. "It was an incredibly complex calculation to ensure that the combined energy of the combustion engine and the hybrid system didn't exceed the limits.

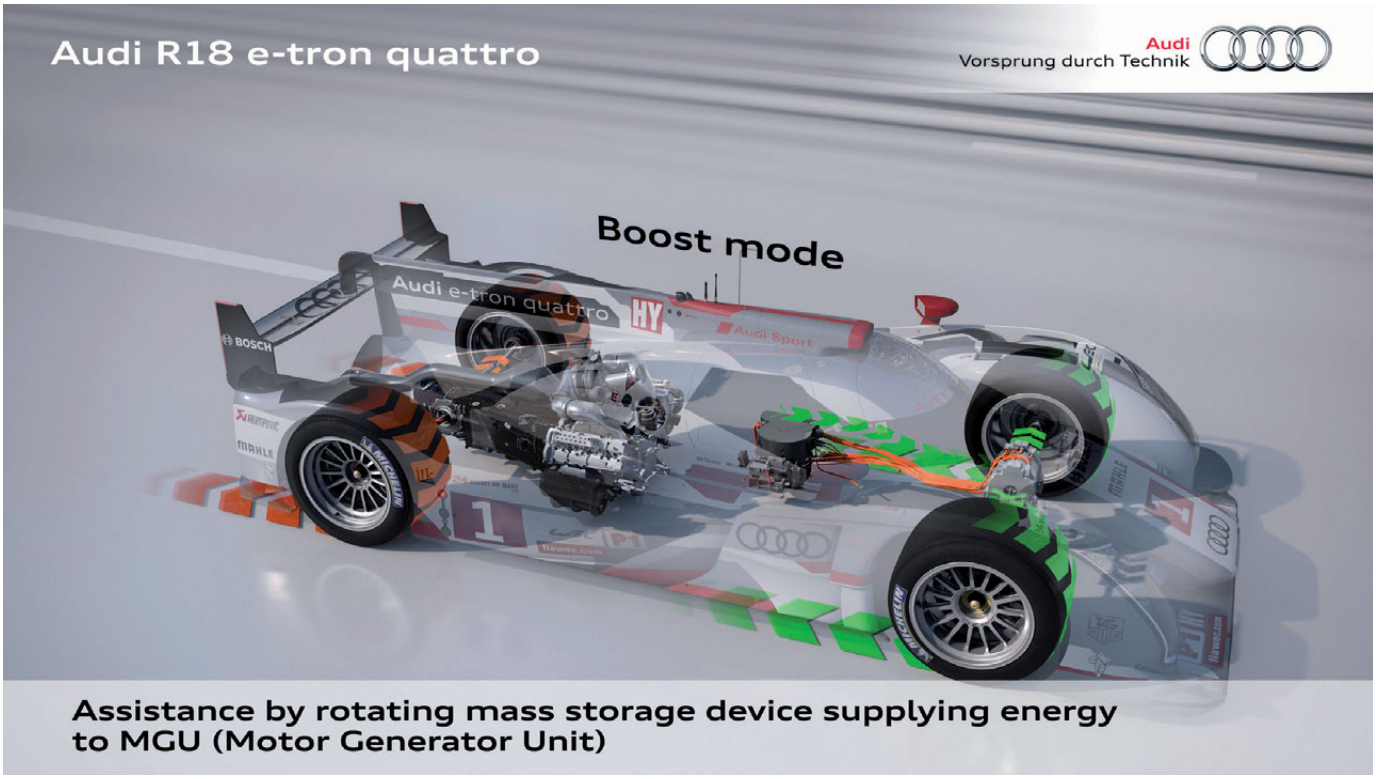
"You couldn't use the engine flat-out and the hybrid flat-out: it was far too complicated to ask the drivers to do that while they were driving, so it was all managed automatically. But it took us to specific fuel consumption levels that were in the same sort of range as large marine engines. Something like 170 g/kWh. At the time, I was on the supervisory board for a company (MAN Diesel and Turbo in Augsburg) that builds two-stroke ship engines – 16 metres high, 30m long and weighing 2,000 tonnes – and they were around 157 g/kWh. It was incredible that we could achieve this sort of performance and consumption with a race engine."

ABOVE The hybrid changed the chassis concept of the R18 e-tron quattro, but had little direct impact on the design of the combustion engine

BELOW The Audi R18 e-tron quattro's V6 hybrid consumed 40 per cent less energy than its V12 diesel predecessor had used when it first conquered Le Mans in 2006

This 'efficiency formula' also resulted in extremely high cylinder pressures. Previously, the engines could consume as much fuel as they were able to supply oxygen for, but now the focus was on using the readily-available oxygen to release as much energy from the fuel as possible. Every drop had to be mixed and burnt as efficiently as possible, which meant higher temperatures and higher pressures. However, the structural design of the V6 – still underpinned by the 'long stud' concept from the R10 – proved more than up to the task.

"The only area where we started to struggle when the loads got really high was the point where the ▶



studs screwed into the cylinder heads," notes Baretzky. "The material was still aluminium, and we found we had to reinforce that with steel inserts around the thread. To do that, we had to find a steel material that had the same heat expansion characteristics as the aluminium, which was a real challenge."

During 2013, Audi had also developed an exhaust heat energy recovery system – similar to the MGU-H devices in Formula 1 – with the intention of campaigning it in 2014. Once they were finalised, the rules stated that any energy harvested upstream of the turbocharger wastegate would be added to the energy allowance for the engine, whereas energy harvested downstream of that point did not. This was a critical distinction between the Audi system and that found on the Porsche 919 Hybrid, which arrived on the scene the same year.

"The drivers were very enthusiastic about the electric turbocharger, because it increased the back pressure and added an engine braking effect, which you don't normally have on a diesel with no throttle valve," Baretzky points out. "They also loved the electrical assistance on the turbocharger, which meant we had no turbo lag at all. It was hard work to develop – it cost me a lot of grey hairs – but it was a fantastic system."


Ferdi Kräling Motorsport-Bild GmbH

LEFT The Audi R18's hybrid system battery, seen in 2016

In the end, with extra energy added to the combustion engine's allowance being of limited use, it was decided that the benefit of running the system was outweighed by the risks of something going wrong. As such, it never raced.

Final evolution

By the start of the 2016 season, diesel engines had won nine out of the last 10 Le Mans races, and the rules were starting to tilt in favour of gasoline. In response, Audi set about stripping as much weight out of the V6 as possible. This included dropping one of the two high pressure pumps previously used to feed the fuel system. The end result was a 4-litre diesel engine producing 600 hp that tipped the scales at just 155 kg. This reduction was an attempt to allow a Li-Ion battery with 2 MJ and to keep the weight of the car on the limit allowed.

The diesel era was drawing to a close at Le Mans. For 2015, the R18's flywheel energy storage system was upgraded to 700 KJ to allow entry to the 4 MJ ERS class; the following year it was replaced by a lithium ion battery system to support a step up into the second-highest 6 MJ ERS category Audi continued to pick up wins in the World Endurance Championship over these two seasons, but Porsche would scoop the championship crown and the Le Mans victory both years.

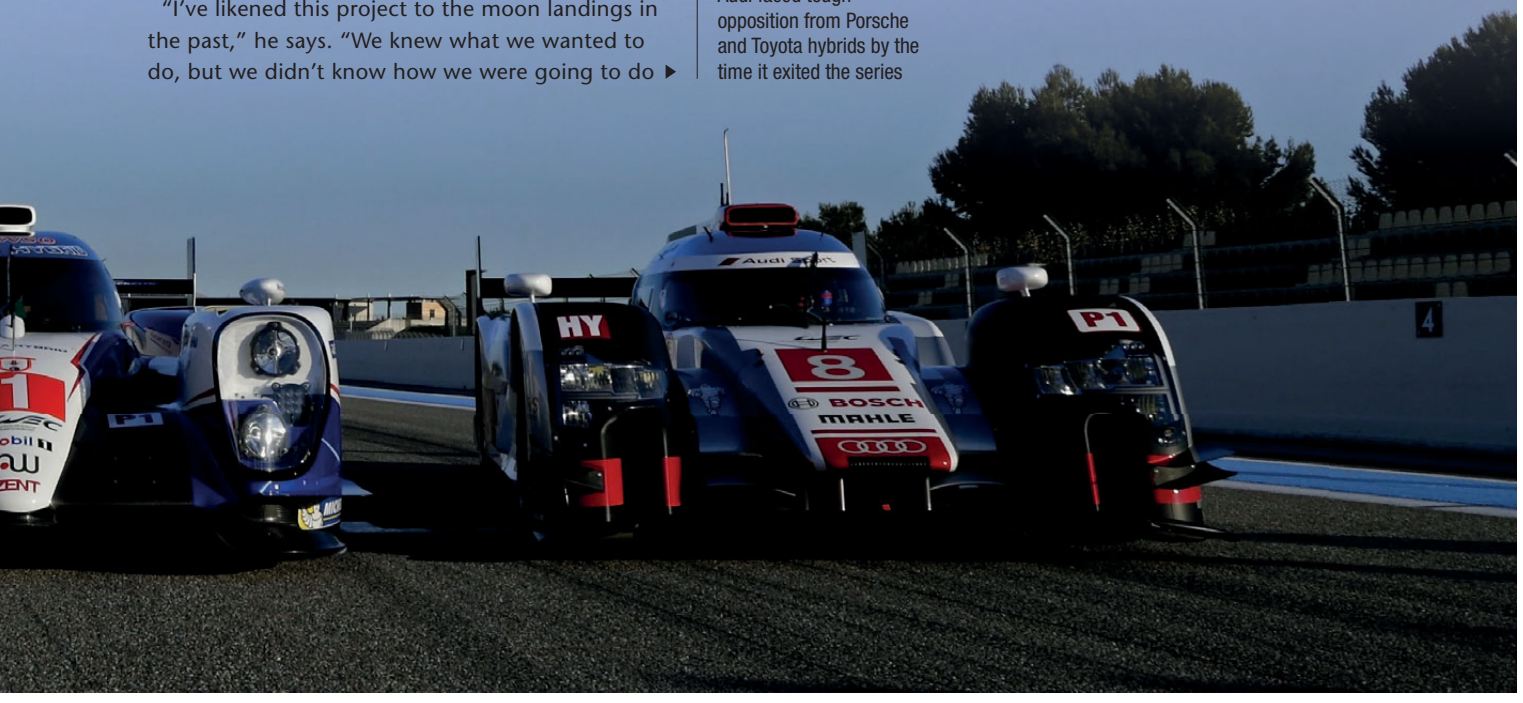
> *"If efficiency is important as well as performance, it has to be a turbocharged engine"*

Looking back, the rate of progress over Audi Sport's diesel decade had been phenomenal. By the time the energy-based formula was introduced in 2014, the R18 was achieving similar lap times to the R10 on 40 per cent less fuel. Even at its introduction in 2011, the V6 weighed 25 per cent less than the V10 it had replaced. But the biggest achievement, says Baretzky, was simply getting there.

"I've likened this project to the moon landings in the past," he says. "We knew what we wanted to do, but we didn't know how we were going to do ▶

ABOVE The 2012 Le Mans win showcased the growing importance and performance of hybrid technology

BELOW Having given hybrid technology a foothold in the World Endurance Championship, Audi faced tough opposition from Porsche and Toyota hybrids by the time it exited the series



The early days

THE Audi R10 TDI may have been the first diesel car to make a major impact on Le Mans, but it was by no means the first to compete.

In the modern era, it was the Volkswagen-based V10 in the Lola B2K/10 of Taurus Sports Racing that first showcased the concept. However, the history of diesel racing cars goes back further still.

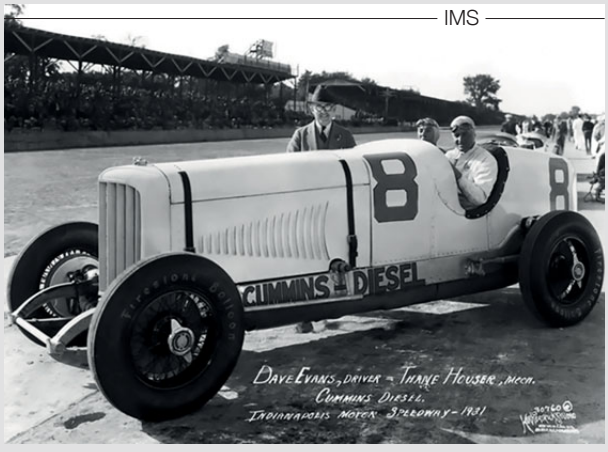
Cummins fielded several diesel racers at the Indy 500 during the 1930s, including a supercharged two-stroke. Perhaps inspired by the moderate success of these cars in America a decade before, brothers Jean and Jacques Delettrez entered a car based around a 4.6-litre GMC straight six diesel at Le Mans in 1949. It covered 123 laps ("plodding steadily along" according to a contemporary report in MOTOR SPORT) and retired after 20 hours.

The Delettrez brothers returned with an evolution of the same car in 1950 and this time made it to 120 laps. But this time they weren't the only diesel competitors in the race. French tractor manufacturer MAP (Manufacture d'Armes de Paris) was eyeing up the possibility of road car production, and it entered a fascinating prototype at Le Mans.

Driven by Francois Lacour and Pierre Veyron (winner of Le Mans in 1939 and the man who gave his name to the Bugatti hypercar), it used a Delage V12 chassis paired with a 4.9-litre supercharged two-stroke. The engine featured a highly unusual opposed-piston layout with two pistons in each of the four cylinders. These days, however, it's best remembered as being the first mid-engined car to race at Le Mans, with a chunky silhouette that could be charitably compared to the far more-elegant Auto Union grand prix cars of the 1930s.

MAP never returned, but the Delettrez special made one final outing in 1951 – lapping a full two minutes slower than the Jaguar C-Type that eventually won the race. It may have been an ignominious end to diesel's first chapter in endurance racing, but the torque and efficiency benefits that those early pioneers had identified would later go on to define a decade. RT

IMS



ABOVE Cummins explored the diesel concept at Indianapolis as early as 1931

it, and we didn't know if we were going to succeed. But we tried.

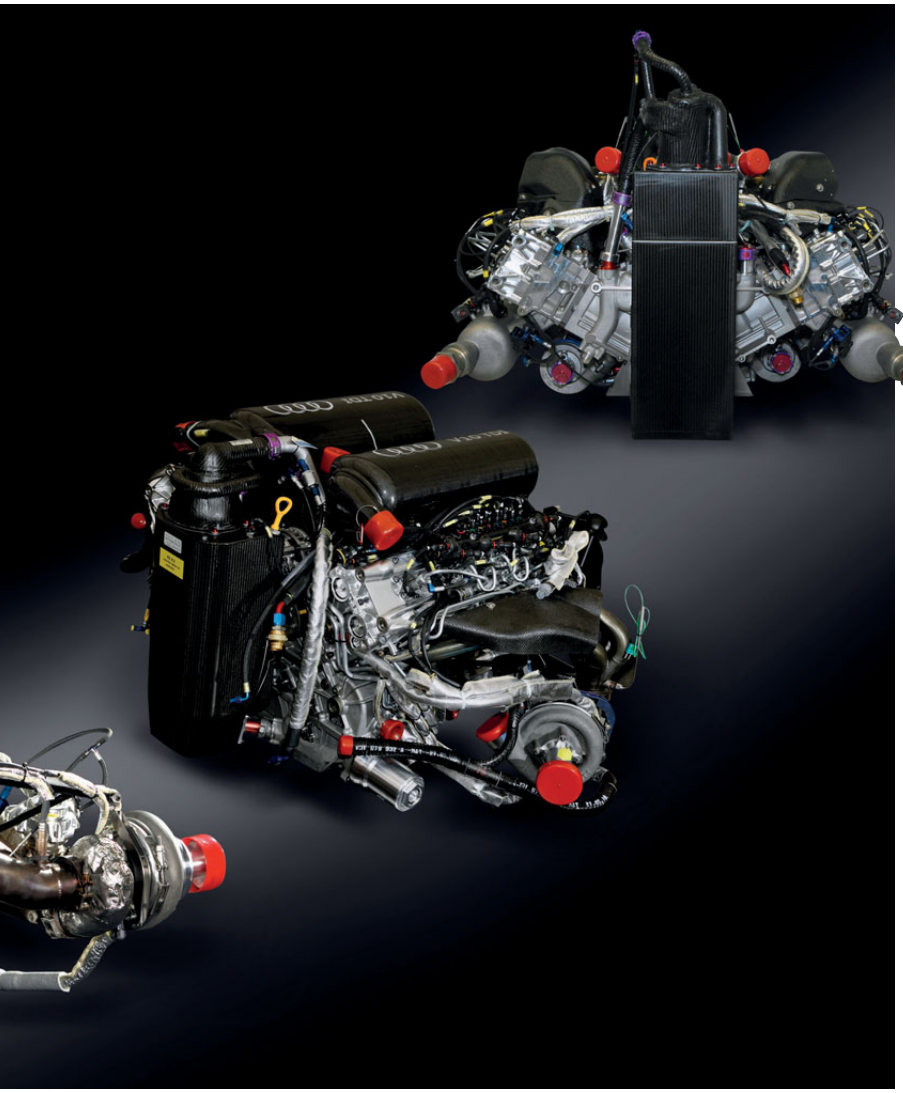
"Even more than the direct injection gasoline engine [in the R8], it felt like a step into the unknown. Things we'd taken for granted in our gasoline engines for many years like oil pumps no longer worked in the diesel engine, so we had to completely re-learn those things. For example, diesel engines are much more sensitive to air bubbles in the oil, so we had to look at ways to get the air out otherwise, under high loads, it could destroy the engine in minutes."

Race against time

It wasn't until that historic first race at Sebring in 2006 that it really became clear that all the hard work on diesel had paid off: "That was a really special race, even with all the problems we had. We'd had to change an engine every evening during the test days beforehand,

RIGHT Audi Sport's victory at the 12 Hours of Sebring in March 2006 was one of those moments that defined motor racing history

BELOW Audi made phenomenal progress with its engines across its diesel decade, winning nine out of 10 Le Mans races with its V12, V10 and V6



> *"Things we'd taken for granted in our gasoline engines no longer worked in the diesel, so we had to completely re-learn those things"*

because we were losing oil pressure. It took us two days to discover that the pipe going into the oil tank, which should have been glued in place, had been fixed with tape, which was disintegrating in the hot oil and blocking the intake of the pump."

The team were down to their last spare engine when one of the cars came back from practice on the morning of the race close to overheating. The problem was traced to an assembly error in the water and oil cooler, so it became a race against time to swap the part over.

"The complete system had to be removed, and we did that between the end of practice and the beginning of the race," he recalls. "We took a cooler from one of the old engines. We had 13 people working on that car and on the other engine – no shouting and no panic, it was as if they'd done nothing else for years – and it was fantastic to watch."

Dindo Capello made it out to the exit of the pitlane with seconds to spare. And the rest, as they say, is history. RT

THE RACE-WINNING ADVANTAGE NOBODY CAN SEE

BELOW Reflecting its success in the market, the PMP4300 Series Pressure Sensor, Druck's most customisable motorsports sensor, has been providing accurate and reliable pressure measurement data for more than 25 years

In a sport that's all about marginal gains, the ingenuity and accuracy of sensor technology can make the difference between victory and defeat. By **Chris Pickering**

MODERN motorsport is driven by data. And in more ways than one. There's the information that race engineers pore over in the pits and which championship organisers use to monitor legality and apply balance of performance. Beyond that, there's an even more critical flow of internal data without which a modern racing car wouldn't even fire up – manifold pressures, fuel pressures, crank position signals and so on.

The sensors that capture this information face a pretty brutal task. They're often found in some of the harshest environments on the car, where space and weight are at a premium. And, in many cases, if they stop, the car stops too.

"Motorsport sensors are all about robustness," comments Jonny MacGregor, global technology leader at sensor manufacturer Druck, a Baker Hughes business. "Part of that is obviously the temperature and the vibration – particularly for powertrain sensors – but they need to be robust in other ways too."

He gives the example of a pressure sensor in a hydraulic power steering system. Here, the normal operating range can be relatively consistent, but if the driver hits a kerb it can create a sudden pressure spike measuring many hundreds of bar that the sensor also needs to withstand if it's to function reliably. Another example he points to are crash loads – particularly in motorcycle applications where the bikes can end up cartwheeling through the air.

It's an area that Druck's senior electronics engineer Neil Sands knows about all too well. Aside from his role at the sensor manufacturer, he's also a data engineer for Hawk Racing in the British Superbike Championship.

"Many times, we've had situations where we basically sweep the bike up into a dustpan and salvage what parts we can," he notes. "We very rarely have any issues in the sensors, which are rated for shock loads of up to 1,000g."

New trends

Druck carries out the majority of its manufacturing in-house – much of it at the company's headquarters in Leicester. Founded in 1972, Druck has always

been based in the UK, but its name comes from the German word for pressure – chosen by the company's founders as they believed it was synonymous with German engineering's reputation for quality. These days, the company also has offshoots in China and India.

"We're quite unusual in that we design and manufacture our own sensing elements here on-site, we don't buy them in," notes Sands. "That gives us complete control of how they're manufactured, but it also means that we can respond to changes very quickly. If a new application comes along, for instance, we can tailor the designs to its requirements."

One such trend is the demand for sensors that can run in hotter environments. MacGregor points out that this is particularly important in hybrid categories such as LMH, where complex electrical systems and high output turbocharged engines are packaged in a very tight space.

"To some extent that's offset by the standard of the development tools that the manufacturers are using these days," he notes. "They now have a much better idea of the temperatures in the engine bay and how to manage those than they did, say, 15 years ago. Nonetheless, things are still getting hotter."

> *"Highly accurate data allows engineers to use as much of their energy allocation as possible without breaching the limits"*

It's not just durability that becomes harder to engineer as the temperatures rise, he points out. As with the rest of the industry, many of Druck's sensors are based around what's known as a Wheatstone Bridge. This is a tiny piece of silicon with an array of four resistors ▶

embedded on it. When pressure is applied to the silicon, it flexes, causing a change in the resistance, which can be measured and calibrated.

The sensing element is insulated and isolated from the fluid – be that air, oil, water or fuel – by a diaphragm behind which sits an oil-filled cavity. The silicon is immersed in this cavity (unlike engine oil that will have trace quantities of metallic particles, pure oil won't short out the sensor). Temperature changes will cause that oil to expand and contract, and the sensor has to correct for these changes as part of a process known as linearisation. As MacGregor notes, this becomes harder to do at elevated temperatures.

Temperature also impacts the mechanical properties of the sensor material and can lead to a degree of 'drift' over time. Plus, there are other potential challenges, such as solder softening at high temperatures, which can make the part more susceptible to vibration.

"We put a huge amount of effort into the qualification electronic components and circuit boards to make sure that they're robust at those temperatures. Likewise, we undertake a lot of vibration testing and qualification in-house," notes MacGregor.

ABOVE Michael Dunlop hustling the Hawk Racing Honda at the Isle of Man TT. The accuracy of Druck's sensors allows confidence in monitoring pressures and temperatures when racing close to the limit

Accuracy

Another key trend is sensor accuracy. Clearly, this has always been a high priority, but it's become particularly critical as powertrains have evolved. Faced with the growing use of energy limits and fuel flow restrictions, highly accurate data allows engineers to use as much of their allocation as possible without breaching these limits.

> *"Trench-Etched Resonant Pressure Sensor technology holds a huge amount of promise"*

"If you have very accurate information for the air flow into the engine and the fuel pressure, which directly correlates to the fuel flow into the combustion chamber, you can control the engine vey precisely," comments MacGregor. "That's not just a question of power output. If you can reduce the fuel consumption, maybe you can do one less pit stop than the next team. Better quality information gives you a higher confidence in those decisions."

In highly transient situations, the speed of response becomes a key factor in delivering an accurate measurement. The sampling rates on datalogging systems regularly go up to 1 KHz (reading 1,000 times a second). By harnessing sensor technologies that are able to respond at that sort of rate, MacGregor says it's possible to capture phenomena that would otherwise be lost.

"One thing that we can do if we employ that level of speed and accuracy to, say, the oil pressure readings is that we can start to see pump 'ripple'," he comments. "So instead of being a steady 60 psi, you can actually see the variation in pressure as the pump rotates and the vanes go past ▶

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the outlet. What you can then do is monitor how that signature changes through the engine's rebuild life, which can give you an idea of the health of the oil pump or maybe even the engine itself. It's possible that level of insight might allow you to do an extra session or an extra race before changing the engine."

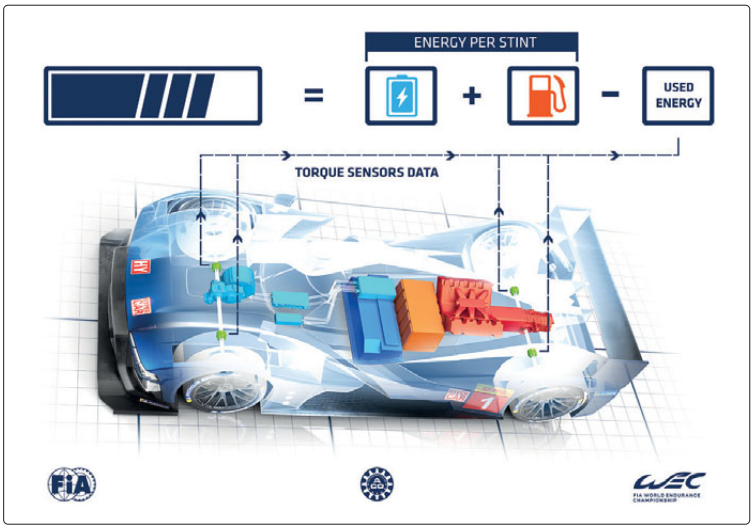
Sands has experienced a similar issue on the bike side: "We've changed motorcycle manufacturers recently, and we had an issue that cost us an engine and a race. Looking at the data, we were able to see there was an oil pressure spike under heavy braking and another under acceleration as the oil moved away from the pickup. That information allowed us to develop and optimise a baffle that's since cured the issue."

Another interesting development within Druck is the application of the company's TERPS sensor technology. Short for Trench-Etched Resonant Pressure Sensor, it no longer relies on the embedded resistors to measure strain on the sensing element, like those in the conventional piezoresistive sensors. Instead, the etched structure of the element is driven at its natural frequency by the electronics. As the pressure changes, the resonant frequency shifts, and this effect is used to generate a very accurate frequency output that remains very stable over time.

Druck already uses this technology in its high-end calibration devices and controllers. It's currently too bulky to use on-vehicle in motorsport applications, but MacGregor and his team are investigating ways to miniaturise it onto a chip.

"The challenge isn't the sensing element itself, it's the associated electronics," he explains. "We use a feedback loop to ensure that the element is always driven at the resonant frequency, and there's some

BELOW The growing use of energy limits and fuel flow restrictions, such as the WEC's use of a Virtual Energy Bank, is also driving the ever-improving accuracy of sensors



LEFT There is a demand for sensors that can run in hotter environments, such as those found in hybrid categories

quite significant drive circuitry involved. But it's a technology that holds a huge amount of promise. The level of accuracy is at least 10 times that which you'd get from a standard piezoresistive product, and in reality, it's probably more like 100 times better on our high-end products. It's so sensitive that you can easily measure the difference in air pressure due to the altitude change between your head and your feet."

New challenges

New powertrain technologies also bring new challenges. Thermal management can be extremely critical on electric and hybrid vehicles, where the cooling system needs to be carefully managed. Likewise, pressure and temperature measurement within the battery pack itself is a rapidly-growing area that can provide vital data for the battery management system (BMS). In both cases, the quality and reliability of that data could potentially be a race-winning advantage if it allows the race engineers or the vehicle's own control systems to take better-informed decisions.

Hydrogen powertrains – either with combustion engines or fuel cells – also rely on careful monitoring and control. Not only do the various powertrain systems on the car need to stay within the right temperature and pressure ranges, the tanks also need to communicate with the external refuelling system, particularly if time is of the essence in a pit stop.

> *"A level of insight that might allow you to do an extra session or an extra race before changing the engine"*

Here, one of the challenges for sensor manufacturers is that of hydrogen embrittlement. This occurs in metals where the hydrogen atoms are small enough to permeate into the internal structure of the material, causing it to become brittle and crack. It's a potential issue for any metal component that comes into contact with the hydrogen – including sensors.

The diminutive size of the hydrogen atom and its ability to permeate through solid materials can also create issues elsewhere. With conventional technologies, there's a danger that hydrogen can make its way into the cavity that contains the sensing element, causing the output to drift over time. However, the technology already exists to deal with these problems.

"Industrially, there's already a huge focus on hydrogen when it comes to markets like power generation. We've got the technology that we use in those markets and we could apply that to our motorsport range of sensors as well," says MacGregor. ▶

BELOW Druck's Neil Sands and Jonny MacGregor, seen here during the company's announcement of its partnership with Hawk Racing for Superbikes

"This is essentially a series of special coatings that can be applied to the diaphragm to prevent the hydrogen permeating through it. Those coatings can be employed on high-stress areas like welds, and that actually stops the embrittlement issue as well."

Pit lane possibilities

There are other, rather more prosaic applications for temperature and pressure sensors that can nonetheless yield a worthwhile advantage. MacGregor's GT racing team, for instance, has taken to using Druck's 705E handheld pressure indicator in place of a conventional tyre pressure gauge.

"It's just so much more accurate than a regular tyre pressure gauge," he comments. "So we're confident that when we put, say, 22 psi into the tyres we are actually getting 22 psi and not 22.5 psi. That just gives us a little more confidence in the setup, in a competition that's all about marginal gains."

Similarly, he emphasises the benefits that can come from precisely calibrating gauges and regulators on other bits of equipment using Druck's pressure calibrators. One example that might easily be overlooked is the air jack system that's used to raise the car during pit stops.

ABOVE & BELOW Druck designs and manufactures its own sensing elements on-site. Silicon processing and the Clean Room are glimpsed here

"The air jacks are fed from a bottle and they have a maximum safe operating pressure," notes MacGregor. "We've gone through all the gauges with our calibrator and adjusted them so we can run as much pressure as possible in the system, while being within the safe operating limits. That means the car

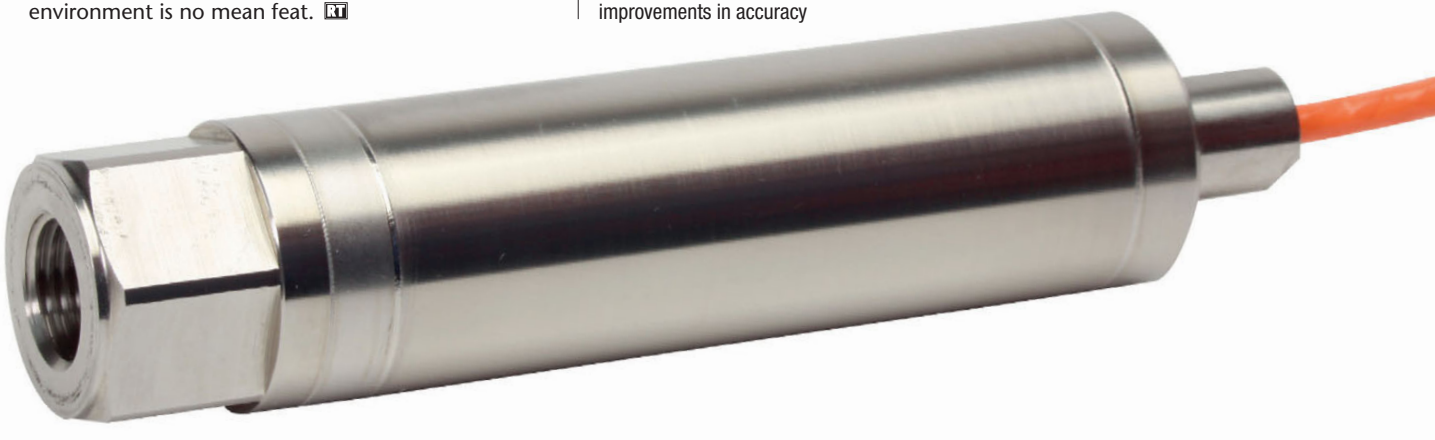
lifts as quickly as possible. It might not sound like a big thing, but it can save a couple of seconds at a pit stop, so it's well worth spending 20 minutes with a portable calibration system before the race."

Sands points to a similar example in the motorcycle world: "We have an on-grid regulation in Superbikes that stipulates a minimum tyre pressure. There can be a performance advantage to running very low pressures, but there's a danger of the tyre coming off the rim if they're too low, so the bikes are randomly checked on the grid prior to the race, and if they're below the limit they'll be removed by the organisers. The closer you can get to your ideal pressure on the starting grid – which might be right on the limit of what's allowed – the more performance you'll gain, but you need that confidence in the equipment."

It's this level of confidence that Druck and companies like it are striving to provide. Achieving that in a device that's small enough, light enough and robust enough to operate in a motorsport environment is no mean feat. RT

ABOVE & RIGHT Pressure calibrators are increasingly being used in new areas. Above, Druck's Genii Pressure Calibrator is used by the company's global technology leader Jonny MacGregor

BELOW The company's TERPS (Trench-Etched Resonant Pressure Sensor) technology offers tantalisingly impressive improvements in accuracy



HOW *GREEN* IS MY GRAND PRIX?

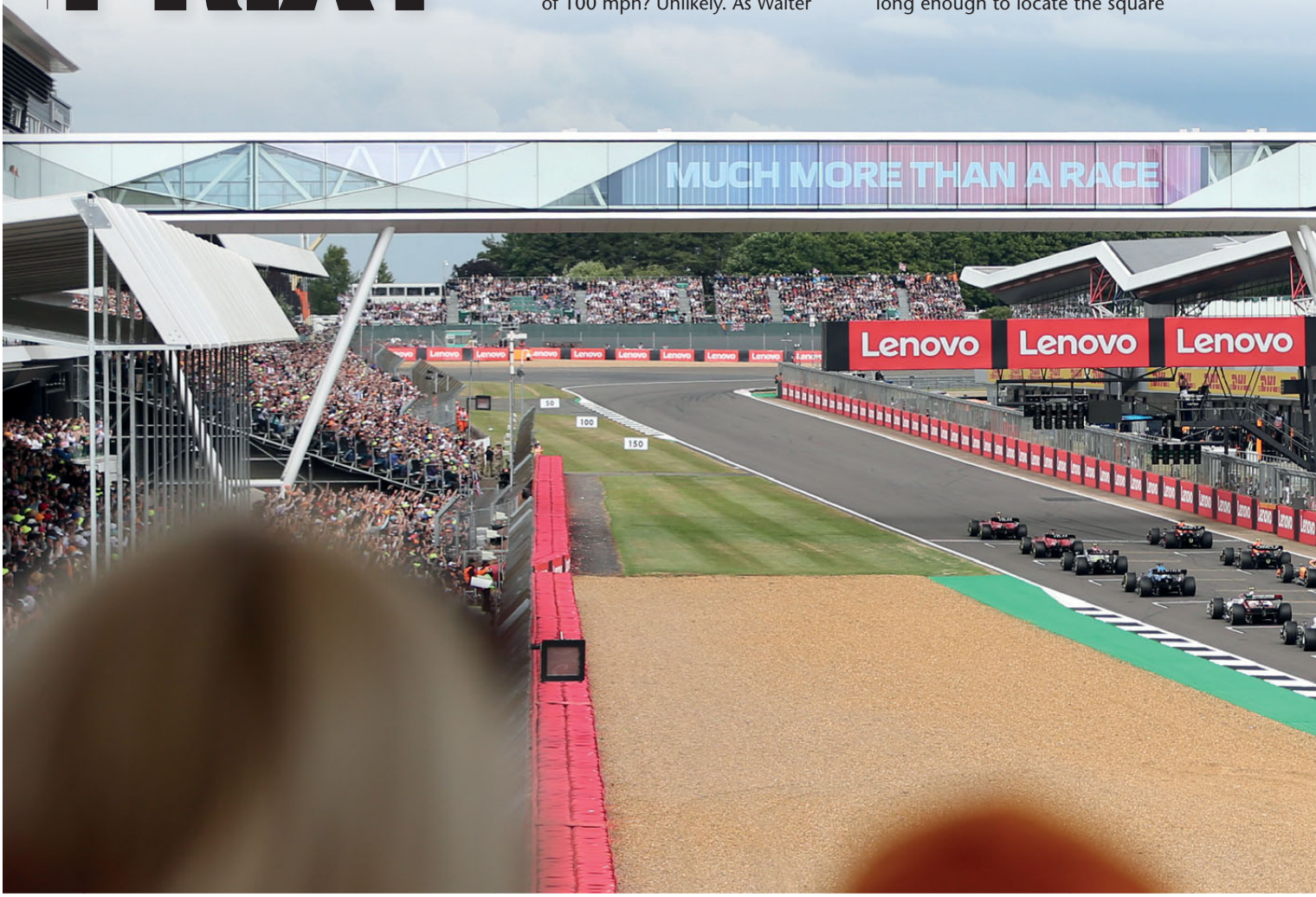
Mirroring F1's drive to be Net-Zero Carbon by 2030, Silverstone has placed sustainability at the heart of ambitious new plans. **Peter Innes** talks to the man tasked with re-imagining how the home of the British GP operates

SUSTAINABLE? Motorsport? Surely some mistake…

At first glance the very idea of blending these two words seems to lie somewhere between an oxymoron and an exercise in futility. Ever since the motor car first arrived on the planet, the whole essence of the sport it inspired has been about speed, exhilaration, pushing to the limit at all costs – and guzzling gas. Lots of gas.

Was Stirling Moss thinking about the local flora and fauna as he stormed round the Italian countryside to win the 1955 Mille Miglia at an average speed just shy of 100 mph? Unlikely. As Walter Röhrl blitzed the foggy Arganil forests of the 1980 Rally Portugal four minutes quicker than anyone else, was he musing on the well-being of the trees he could barely see? No, his sole focus was on staying the hell out of them.

Similarly, will the drivers, teams and race fans visiting Silverstone for this month's British Grand Prix be there to stare at the butterflies, bees and birds that bring shimmering life to the summer meadows and hedgerows of deepest Northamptonshire? Somehow, I doubt it. At best, they might study the grass just about long enough to locate the square



> *"Eighty-one percent of Silverstone's carbon emissions are related to fan travel"*

yard with the clearest view of the 5.9 km-long strip of tarmac that flows through it.

For the weekend of July 7-9, the only wings that will matter to 480,000 people at Silverstone will be those attached to a grid full of the finest racing cars on the planet. And, despite all the recent advances in hybrid engine technology – with promises of much more to come in 2026 – Formula 1 remains a sport where fuel unavoidably, unashamedly rules.

Sustainable motorsport? Pah. And yet… and yet… there is a battle going on. Unless you've spent the last decade facing the rear wall of a cave on top of a mountain screaming at the top of your voice with your fingers in your ears, you might just have heard about it. The enemy? Carbon – and its dastardly sidekick carbon dioxide.

Silverstone has now put itself firmly in the frontline, becoming the first racetrack to join the United Nations Framework Convention on Climate Change (UNFCCC) Sports for Climate Action programme. With the 2022 launch of its Business Sustainability Strategy, Silverstone committed to the goal of zero carbon by 2030 – plus zero single-use plastic and 100 percent of its waste reused, recycled and composted by 2026. Promoted as 'Shift to Zero', the concept was prompted by F1's own push to hit Net Zero Carbon by 2030 and the UK government's stated policy of banning new combustion engines by 2030 and reaching Net Zero by 2050.

No illusions

Leading the charge is Stéphane Bazire, who was appointed as the circuit's Head of Business Sustainability and Partnerships in 2021 after a career in sports management and marketing that took him all over the world. And the Frenchman is under no illusions about where the challenges really lie when it comes to reducing the environmental impact of a ▶

BELOW Almost 480,000 fans are expected to flock to the British GP to support some of the best drivers on the face of the planet. Can their behaviour contribute towards saving that planet too?

space that hosts such huge events as the British Grand Prix.

"You've got 20 F1 cars going around the track during a grand prix, but you've got around 20,000 cars each day bringing spectators to the venue," says Bazire. "So it's not hard to do the maths."

So far, so simple. But the sums get a bit harder when you try to calculate the overall carbon footprint of a venue like Silverstone. That's because there are so many different sources for the emissions – some direct, some indirect – and they are divided up into three areas: Scope 1, 2 and 3.

"Scope 1 means direct emissions from everything your own activity generates," says Bazire. "So if we have a test drive at Silverstone on a Sunday with Maserati or Aston Martin, having those cars going round the track has a direct carbon emissions implication for us, as it is a direct result of our activity. Scope 2 is the energy we use to power our facility – whatever we get from the grid, and the fuel we put in our generators.

"Then comes Scope 3, which is our supply chain, because every product we purchase and every service we contract has its own carbon footprint and emissions. This includes things like staff commuting to Silverstone every day, people commuting to work for the big events, and all the products we buy – such as water, meat, vegetables and everything we offer in our catering. Scope 3 also includes our fans' travel emissions. So during an event like the grand prix, 99 percent of the carbon emissions are Scope 3. That means the effect of all the activity on the track, related to the running of the sporting event itself, is almost nil."

The figures get complicated further by the fact that the British Grand Prix is technically run by Formula 1, but hosted by Silverstone. So there is a shared responsibility for whose carbon footprint

> *"He asked me: 'Would you like to lead our organisation into becoming the most sustainable racetrack in the world?'"*

Darren Heath

RIGHT Previously Chief Strategy Officer for Barcelona Circuit, Bazire was fired up by the challenge of transforming Silverstone

LEFT Free water refill stations are estimated to have reduced waste by 600,000 plastic bottles

BELOW A total of 2,764 solar panels installed onto the roof of The Wing contribute significantly to Silverstone's net-zero by 2030 pledge

belongs to who. But what the numbers do spell out is that Silverstone's chunk of the carbon footprint from that weekend is three times higher than the total emissions the circuit generates for the whole of the rest of the year – not including the MotoGP and Silverstone Festival. And all of it now comes under the remit of Bazire and his team.

Bazire hails from Normandy, where he was first introduced to environmental issues by his grandfather, whose company provided fertiliser to golf courses, parks and gardens in Paris and other French cities. A former tennis coach, Bazire arrived in the world of sport via the WTA tennis tour, travelling the world for four years on behalf of its sponsor Sanex. After he moved to Barcelona to run a tennis tournament, he travelled to Brazil to work at football's FIFA Confederations Cup in 2013. That's when he had his epiphany.

"I visited all the stadiums – in places like Recife, Belo Horizonte and Rio de Janeiro," he recalls. "And I saw the fragility of the way those events are organised, in terms of people, staff and the waste they generate. I thought: 'Oh my God, these mega-events that move millions of people and millions of dollars have such a big impact. So much waste…'

"That was the trigger. I said: alright, I want to do something positive. My work has to have a positive impact in the world. So how can I do that, following my passion for sports and my background in sports and events management? I decided to go into sports sustainability and make sure the world of sports and leisure could showcase good practices, and educate all the stakeholders on how to run those events in a more sustainable way."

Making sustainability visible

Bazire promptly completed a Master's degree in sustainability, development and corporate social responsibility at a Madrid university, before launching the consultancy, WeGreen. That's how he ended up joining the Circuit de Barcelona-Catalunya in 2018, eventually becoming its Chief Strategy Officer. As a public company run by the local region, the track already had an established culture of sustainability, and Bazire's contribution brought him to the attention of Silverstone managing director Stuart Pringle.

"Stuart asked me: would you like to lead our organisation into becoming the most sustainable racetrack in the world?" smiles Bazire. "When you've got the most emblematic racetrack in the world asking you that, you cannot say no."

Since Bazire's Silverstone arrival two years ago, the biggest – and most obvious – inroads his team has already made focus on Scope 2 emissions: where the power comes from, and how. This includes covering the Wing building at the main paddock in 2,764 solar panels, which now generate 13 percent of Silverstone's annual grid consumption.

"This was a big investment for us," admits Bazire. "But these solar panels will have a return on investment in less than five years. Given that solar panels usually have a 25-year lifecycle, we know we probably have 20 years of free electricity. That means we will save money – and on top of that it's good for the environment. So it's a no-brainer… do it!

"This is part one of our 10-year plan to modernise our venue, making sustainability visible at Silverstone. By reducing 13 percent of our electricity consumption from the grid, we are also reducing our carbon emissions by 13 percent, so that's a good tick. Next we've been working to make sure our electricity coming from the grid is green; since April 1 we've been powered by 100 percent green electricity."

Hang on a minute… how does that work? Renewable energy may be on the up in the UK but if a sizeable ▶

Getty Images/Red Bull

chunk of the grid's power still comes from fossil fuels, how can anyone know whether or not they are getting the 'clean' bit?

"Obviously any renewable energy producer ends up feeding the grid with that electricity, then mixing it in with the coal, oil, nuclear, whatever energy generation is available in the UK," he adds. "But what we do is buy our electricity directly from a producer of green electricity, and we've got a certificate to show that what we use is actually produced.

"Yes, it might cost slightly more than 'normal' electricity, but I would almost say price is not an issue. This is a strategic decision. We are happy to have signed that agreement because it is very important for us to tell the world we are 100 percent powered by green electricity."

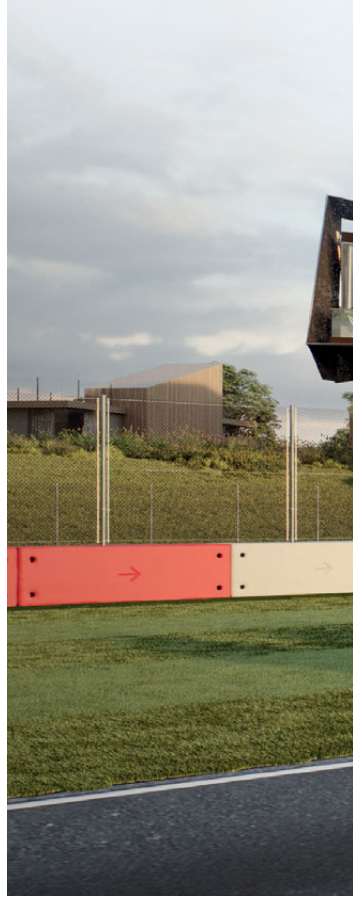
Another step in this great shift of power around Silverstone involved switching the venue's generators in 2022 to run on the biofuel Hydrotreated Vegetable Oil (HVO) rather than the industry standard diesel. Again, these changes are costly, but Bazire reckons it is worth it.

"This switch has reduced the carbon emissions of our generators by 90 percent," says Bazire. "It has an extra cost: the HVO litre is probably 15p to 20p more than diesel. But it mattered to us, and the good thing is that our decision has now influenced other stakeholders. From 2023 onwards, our food concession Freemans will be running the generators for their food trucks and food courts on HVO. Even Formula 1 themselves, who have a broadcast centre and team merchandise areas, have now switched to HVO to follow our example.

Leader of the pack

"It shows the behaviour you decide to have as a venue, running your own activities, can be extended to other stakeholders following your path. We want to be a platform for innovative solutions, leading the pack and showing other UK event organisers it is possible to run your venue or your event in a sustainable way that is profitable."

Bazire is keen to stress the balance between sustainability and profitability is



ABOVE F1 has discovered that the impact of the cars themselves is dwarfed by that of the logistics and fans

key in all these ventures. One of the factors that led to Silverstone's efforts to become more self-sufficient came about because of a calculation at the height of the energy crisis that its electricity bill would top £100 million over the next 20 years.

This is, though, one of the areas where arguments over benefits and costs to the environment get fuzzy. If suppliers feel they have to throw away working diesel generators to replace them with new ones that run on HVO, isn't that akin to the wider public being encouraged to scrap older cars to replace them with 'eco-friendlier' machines? Who, exactly, decides which waste is acceptable and which isn't?

It can seem that such initiatives focus on cleaning up 'our bit' while sweeping the problems somewhere else. And, just as electric cars cause environmental problems of their own down the chain thanks to their reliance on mining rare metals such as lithium and cobalt, HVO has courted controversy too, with much of the global supply derived from palm oil. Working out the 'right thing to do' these days is enough to give anyone a headache.

But if we're talking pure numbers, Bazire reckons the changes at Silverstone outlined above will reduce its Scope 2 carbon emissions almost down to the magic 'zero'. He also believes Scope 1 could follow suit, especially if electric cars take over, way ahead of the 2030 target.

That just leaves the big one: Scope 3. And that basically means the rest of us…

> *"It is possible to run your venue in a sustainable way that is profitable"*

"Eighty-one percent of Silverstone's carbon emissions are related to fan travel," says Bazire. "So Scope 3 will be very hard to bring down to zero – unless everybody starts doing their bit. Are the cars coming to Silverstone for the grand prix becoming electric? Are people switching to buses or trains? Why not buy a rail and ride ticket or use park and ride – as the last mile in traffic is the one that generates the most carbon emissions? Your journey will be much better and, on top of that, you are making a gesture for the environment.

"We need to communicate more alternatives for travelling to Silverstone, working with local suppliers like Stagecoach, National Express and Megabus to offer more destinations across the country for people to use public transport," acknowledges Bazire. "We also need to encourage people to stay for all four days, enjoying the atmosphere like a festival. This year we have Calvin Harris doing the Thursday launch party and Black Eyed Peas on Saturday night. That cuts down carbon emissions by four instead of coming back and forth…" ▶

ABOVE & BELOW The Escapade, a motorsport-themed resort, will feature 60 residencies

One of Silverstone's eternal problems is that the closest mainline railway stations at Milton Keynes and Northampton are over 10 miles away. And, let's face it: this isn't Japan, where trains run reliably and on time. So the idea of attempting a trip to the British Grand Prix by rail doesn't top many to-do lists, and might require much more carrot than stick.

Battle against waste

Silverstone is meanwhile making sustainable strides in other ways, pushing to eliminate plastic from single-use items. It hasn't quite been able to reach 100 percent, though: while fizzy drinks are available in cans, some fruit drinks don't yet have that option.

Last year the venue also donated 11 tonnes of surplus food to local Towcester food charity TowFood – although again Bazire admits there are limits. With such huge numbers of visitors it's hard to predict how much will be eaten, and they can only donate food that is guaranteed to be safe for consumption. The target remains to hit 100 percent of waste recycled, reused or composted by 2026. In 2022 it only managed 12 percent but Bazire estimates it will triple that to 35 percent this year.

"The good thing about our waste is that since 2018 nothing has gone to landfill," he adds. "Whatever waste is not properly recycled goes to energy-from-waste facilities, such as incinerators. This is probably the best solution here in the UK – after you've recycled as much as you can."

At last year's British Grand Prix, fans were asked to support these initiatives by recycling rubbish, refilling water bottles or opting for a vegan or plant-based meal. On recording their action via a QR code, they were entered into a competition to win hospitality at the event in 2023. It leads to the biggest question: do Silverstone's punters really give a monkey's?

"Actually 25,000 people responded," says Bazire. "You may say that is not many compared to the 400,000 people who came. But it gives us a good understanding of how people behave during the grand prix. We've estimated that because we offered water refill stations we've probably reduced the waste by 600,000 plastic bottles. Free water is clearly a huge incentive, but we know that the moment you start offering people alternatives, they tend to use them."

> *"The effect of all the activity on the track, related to the running of the sporting event itself, is almost nil"*

It does indeed help that it's free; no one will argue with that. Nor will anyone quibble over giving food to those who really need it. But one reason why the words 'net zero' as pushed by global governments are increasingly cursed in some quarters is that the costs – in terms of time, money and energy – tend to be absorbed by (and inflicted on) the population at large. It begs the question: how much of the hit should the general public have to take for the

RIGHT Understanding and modifying fan behaviour is crucial to the drive for sustainability

LEFT Fans staying on-site helps cut emissions. A 197-room hotel is now run by the Hilton

greater good? And can anyone really be sure what that greater good is?

Whisper it, but when an agenda seems to be railroaded through everywhere without debate, let alone a vote, it invariably leads to questions – especially when the original arguments are based on scientific consensus rather than fact. There are growing numbers of people asking why we even need a war on carbon at all? Isn't it all a bit harsh on an element that comprises 18 percent of every human body and a compound we all produce with our every breath, one that brings life to the trees in the forests and the grass in the meadows?

"Yes, everyone's crazy about measuring the carbon footprint, and there is lots of estimation and lots of assumption," says Bazire. "It's never going to be 100 percent accurate. But we know that climate change is a reality and we know climate change is definitely accelerated because of human being behaviour; there is no doubt about that.

"Obviously things like the British Grand Prix have an impact, so you could say: let's just stop organising events at Silverstone. I don't think this is the bottom line. Our concern is how can we make sure we can keep running this activity in the most sustainable way. How can we make sure all our different stakeholders – suppliers, visitors, teams, the automotive industry in general – end up cutting down their carbon emissions? But it's not just counting carbon. It's helping people make sure this is the most environmentally friendly behaviour to have."

Either way, given that carbon savings are often illustrated by their plant-based equivalent (72 trees a month for the Wing's solar panels, apparently) and given Silverstone's abundance of green space… wouldn't it be simpler and cheaper just to plant more trees instead?

Taking responsibility

"We all know offsetting carbon footprint is not a solution until you are reducing your own footprint to the maximum of your capacity," adds Bazire. "So we're trying to measure our carbon emissions better, then making a plan to reduce them to the maximum. For what is still unavoidable to generate, we could start a potential offset programme, which will be focused on reforestation and biodiversity conservation. But we're not there yet. The people coming to Silverstone have the biggest carbon footprint, so we need to work on asking every individual to take responsibility for their carbon emissions."

As for the future, Bazire is keen for Silverstone to become more of a year-round venue, using the Wing building for corporate events, weddings, even stag parties – with a kart track due in the spring of 2024. The circuit already has a museum and a 197-room hotel now run by the Hilton. Also coming next year is the all-new Escapade, a motorsport-themed resort featuring 60 residencies of between two and four bedrooms.

"We want to become a sustainable business and leisure destination, with motorsport clearly at its heart," says Bazire. "This is our vision. We will keep having race events, track days, test drives and all that. But we want to start having other things too: product launches, festivals, music events. If we are prepared to have half a million people here for the grand prix, we can host any kind of event at Silverstone.

"We have a great facility with lots of green space, lots of parking and green energy. Now we want to make sure we offer the best practice for any event organiser, providing them the best solution for them to run a sustainable event. We want to be chosen for our green credentials. That's going to be our way of being different from other venues in the UK. So if you want to organise your events in a sustainable way, come and do it here. Even though there is no train station nearby…" RT

FERRARI'S VICTORIOUS RETURN... *WORTH THE WEIGHT?*

Sergio Rinland enjoyed a Le Mans classic but how much did a controversial late BoP alteration influence the race?

LAST month I had the privilege of witnessing what must rank as one of the most epic Le Mans 24 Hours battles ever. How fitting a celebration it was of the one hundredth anniversary of the first event in 1923. This was a race that will go into the history books as the triumphal return of the prodigal son, Ferrari.

Who, in my generation, does not remember the gorgeous 330 P2/P3/P4 (Forghieri's masterpiece)? Or the 512 S and M? Or the fabulous 312P?

That was 50 years ago, and they have been absent ever since, mainly engulfed by the ever-resource-hungry Formula 1. Until now…

Even though the powers-that-be at Ferrari deny that the Formula 1 budget cap has anything to do with their return to Le Mans, it *is* a coincidence difficult to ignore. Whatever the reason, welcome to the Ferrari 499P.

In spite of the fact that the ACO, IMSA, and FIA have created a great formula combination with commendable parity, it was somehow not a surprise that an LMH car would win the 24 Hours race. But until a few days before the event, all bets were on Toyota, the most experienced LMH team with more miles under its belt than all the others put together.

Ferrari, the newcomers to LMH, have surprised everybody with their pure pace from the beginning of the season, but lacked in tyre management for long-distance stints. It was particularly during the second stint on the same tyres where Toyota had, understandably, the upper hand: until the ACO decided to intervene with Balance of Performance, the hated – by some, me included – BoP.

Basically, after the test day, it was decided unilaterally that Toyota had to carry an extra 37 kg of ballast during qualifying and the race. Those 37 kg equate to some 1.0 to 1.2 seconds a lap around Le Mans, so if Ferrari were already faster on a single lap, those 37 kg added to their advantage.

Where Toyota were hit hardest was on race pace. Where before they had the advantage of being able to manage tyre wear and performance better than anyone else, 37 kg meant that advantage evaporated.

Unfair timing

But what was worse than the application of the BoP to penalise excellence, was the way it was done with only a few days' notice. It left Toyota no time at all to adjust their car to the extra weight, beyond a few ▶

Photos: Ferrari

BELOW & RIGHT
The very presence of the works Ferrari 499Ps added to the celebratory feel of the whole event. But did the late BoP change take the edge off that victory?

Stellantis

days of simulation. I know life is not fair, but in my opinion, this was beyond fairness.

Hence, only reliability issues or team errors on the part of Ferrari would have handed Toyota the victory. But the AF Corse team worked faultlessly during the 24 hours to give Ferrari a well-deserved triumph at the 100th Le Mans 24 Hours. The car made history and vindicated the marque's decision to return, bringing with it that great historical background at Le Mans in the process.

We all celebrated this success – even though my heart was elsewhere. But it left a sour taste, due to the intervention in the rules. Would Ferrari have won if not for that 'unfair advantage' (to quote the great Mark Donohue)? Perhaps not.

Not if, but when

Of the other participants, the performance of the LMDh Porsches, particularly the private Jota team earlier in the race, showed that the Equivalence of Technology regulations worked very well. Porsche had great pace, which was probably masked to some extent by accidents and some reliability gremlins. But Porsche being Porsche, it is not a case of 'if', but 'when'…

Cadillac made a fantastic race. They were consistent and with no errors, with a very reliable car, managed to be on the podium. Hats off to GM and the Chip Ganassi Racing team.

My biggest disappointment was Peugeot. After making a bold interpretation of the LMH rules, as they were written when the car was conceived, Peugeot then found that LMH underwent a massive rule change. They were left as the only works team running on equal size tyres front and rear, with a concept unlike everybody else and unable to change it that late in the programme.

ABOVE Peugeot's 9X8 led the race for more than four hours during the night

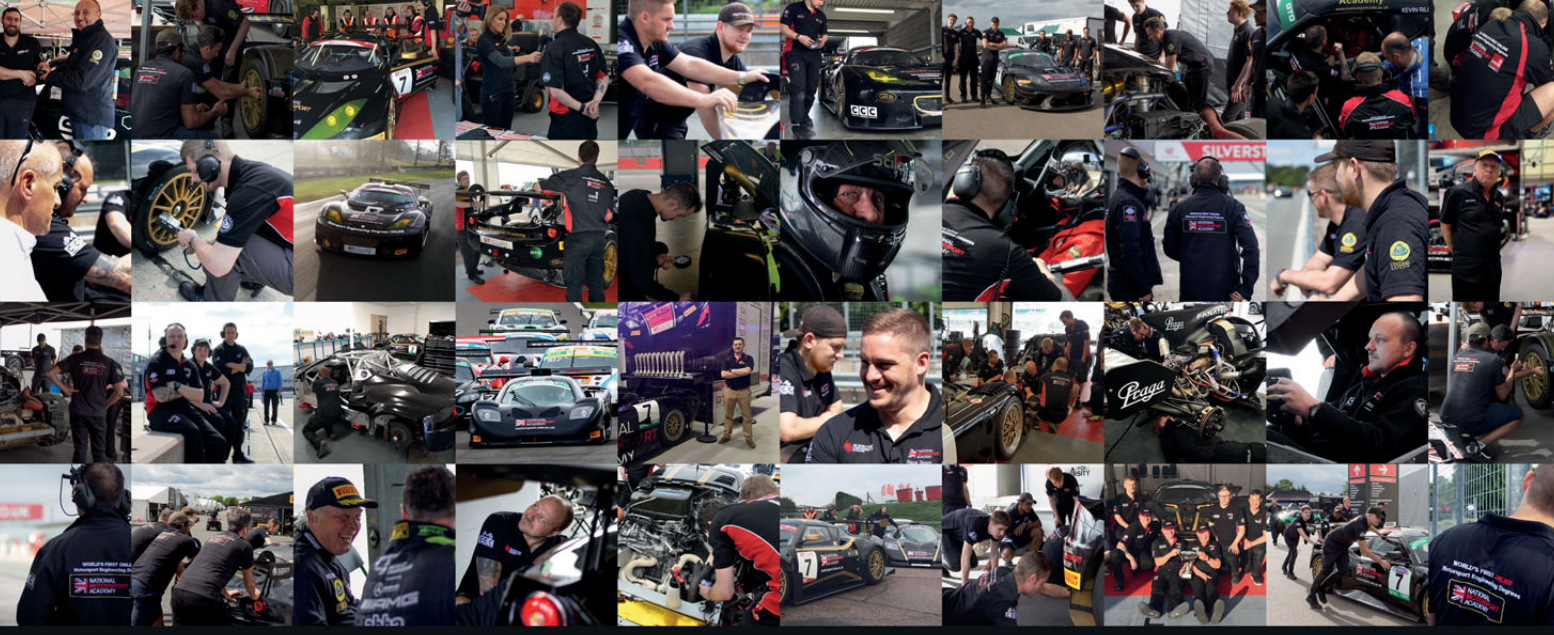
Hence, even if it had a theoretical advantage with the original rules, that evaporated when the ACO/FIA made the change to accommodate the cars using smaller tyres at the front, as do Ferrari and the revised Toyota.

> *"Worse than the application of the BoP to penalise excellence, was the way it was done with only a few days' notice"*

The accompanying rise in the hybrid activation threshold, i.e. governing the minimum speed where the front power could be deployed, meant that Peugeot no longer had an advantage of applying the power better out of slow corners. So the concept of higher weight and aero downforce in the front might have a small advantage on drag, but not sufficient to outweigh Toyota or Ferrari with cars designed specifically for the rules as they are now.

We understand the reasons why the rules were changed – mainly financial from the tyre manufacturer's point of view – to equalize tyre sizes for LMH Hybrid and non-hybrid, and for LMDh. But it prevented the success of a concept well thought out for the LMH architecture and philosophy. Even so, Peugeot managed to run at the front at some point during the race: well done!

So, we had a fantastic race with most teams leading at one point and a popular winner. What else could we ask for to remember the 100th Le Mans 24 Hours as a real 'classic'? RT



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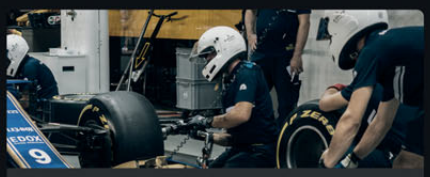

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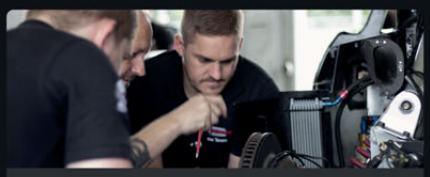

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