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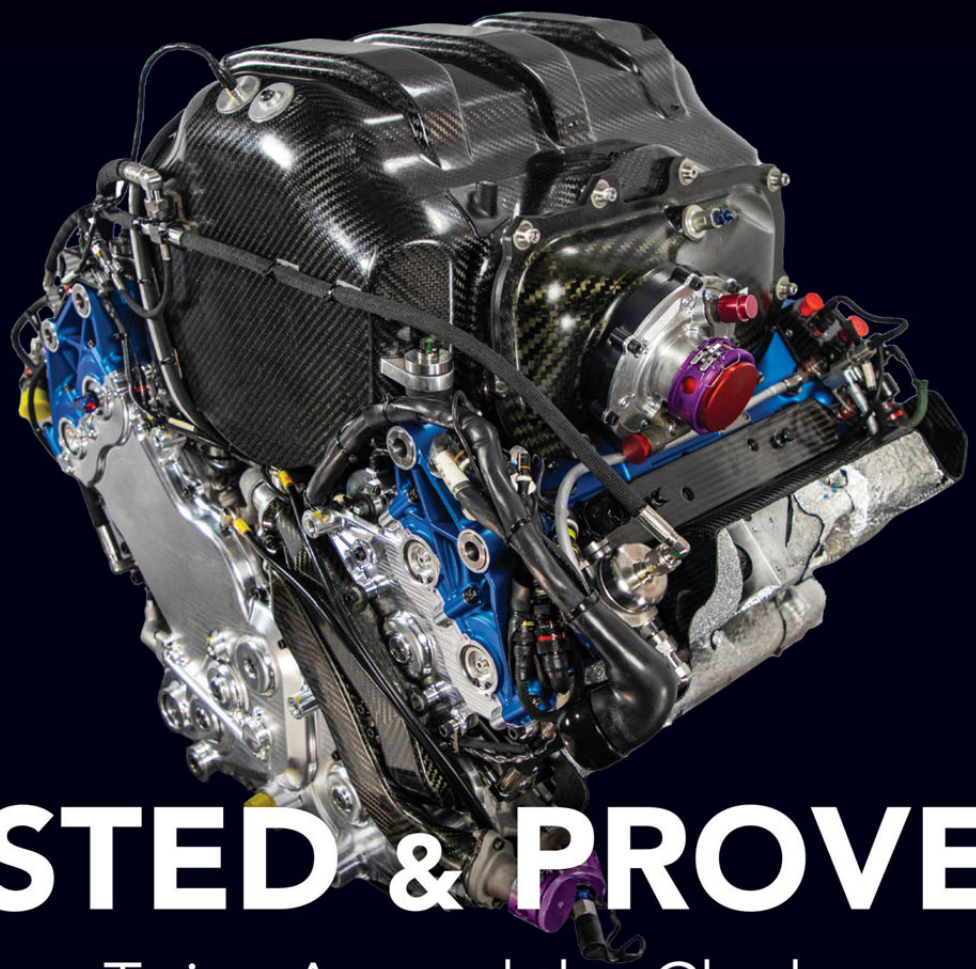

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NET ZERO TO HERO?

THE world is changing. Quickly.

I used to adore the build-up to the Australian Grand Prix. Boarding that plane was part of a ritual: the reawakening of the sport after its winter hibernation.

That's no longer the case, or course, and recent events make me wonder exactly who's been doing the sleeping. For Europe seems to have been almost sleepwalking towards its ban on the sale of new ICE cars.

Yet just as the F1 teams set up their garages in Melbourne, came some important news. The European Commission and the German government have reached an agreement that will allow combustion-engined cars to stay on sale after the planned 2035 cut-off, provided they only run on e-fuels.

German Chancellor Olaf Scholz, backed by carmakers and other members of the EU bloc, had called for an exemption for e-fuels and the Commission has now reached a deal.

For some time now, motorsport has been championing the switch to sustainable fuels. From rallying to endurance racing, and from IndyCar down to karting (see this month's news story), these fuels are the buzz. They are also a central part of the sustainability drive contributing to F1's resurgence in popularity.

Not that the EU news is universally popular. Environmental group Greenpeace branded the deal "a lazy compromise". Others countered that it causes uncertainty and undermines the march to electrification.

I appreciate that supplying a motorsport series with synthetic fuel, while complex, is not the great panacea when it comes to the scale of production required to satisfy larger fleets. But there are people far better qualified than me who will swear that every ICE being climate neutral is not a fantasy.

Net zero? The only thing we can guarantee is zero is the credibility of some of our politicians. After all, the mass electrification of vehicles sometimes appears to be motivated more by political posturing than it does science. There are an estimated 1.4 billion cars on the planet. Many in remote, underdeveloped locations. Are they really *all* going to be electric?

Carbon neutral fuels surely have a role to play? If only as an interim measure in some sectors where the ideal longer-term solutions, be they electrification, hydrogen combustion or fuel cell, have not yet matured?

The only certainty, is that there *is* no certainty when it comes to the future direction. But whichever route the politicians finally deign to converge upon, motorsport has the R&D capability to play a role in easing that passage. RT

Mark Skewis
EDITOR

THE TWO SIDES OF HYDROGEN

Extreme E weighs switch to fuel cells while Toyota's experiment with liquid hydrogen hits trouble. By **Mark Skewis**

EXTREME H

EXTREME E's hydrogen project, which was originally set to co-exist alongside the current battery-electric class, could become the off-road championship's sole focus.

The 'Extreme H' prototype remains on course to commence testing this summer. Given the growing political momentum behind the investigation of hydrogen as an alternative zero-emissions fuel solution across some sectors, Alejandro Agag, CEO and Founder of Extreme E, admits that the next-generation Extreme E cars could just run hydrogen fuel cells.

"We're using fuel cells and I think it's really relevant to create a platform for motorsport and hydrogen – there isn't really motorsport with hydrogen," Agag told media at the recent Desert X Prix in Saudi Arabia. "There's been some attempts – Le Mans, Dakar with a truck and so on – but I think the format is not the right one. Our format is the right one to test hydrogen. I think short races like the ones Extreme E does will be the perfect format for hydrogen."

"We still need to figure it out," he conceded. "We haven't decided yet if we're going to do both, if we're going to focus on hydrogen, if we're going to transition – both and then hydrogen only. We have ongoing discussions with the teams and then we will make a decision which way to go. They could even be different weekends.

"My feeling is that we will focus mainly on hydrogen. But we have to still make the decision."

Extreme E's sister series, Formula E, has just introduced its third-generation race car, which will promote fast-charging. The direction of the Gen2 Extreme E racer could similarly be a trail-blazer. "I think the Gen2 will be the hydrogen cars," Agag said. "Then, we may decide to do another battery.

"The thing is, with Formula E we needed to develop along the generations because in the first generation the cars couldn't finish the race – we needed two cars. Then with Generation 2 we finished the races but the cars were quite big. Then Generation 3 finally we finished the race with a smaller car. Then we're going to do ultra-fast charging next year.

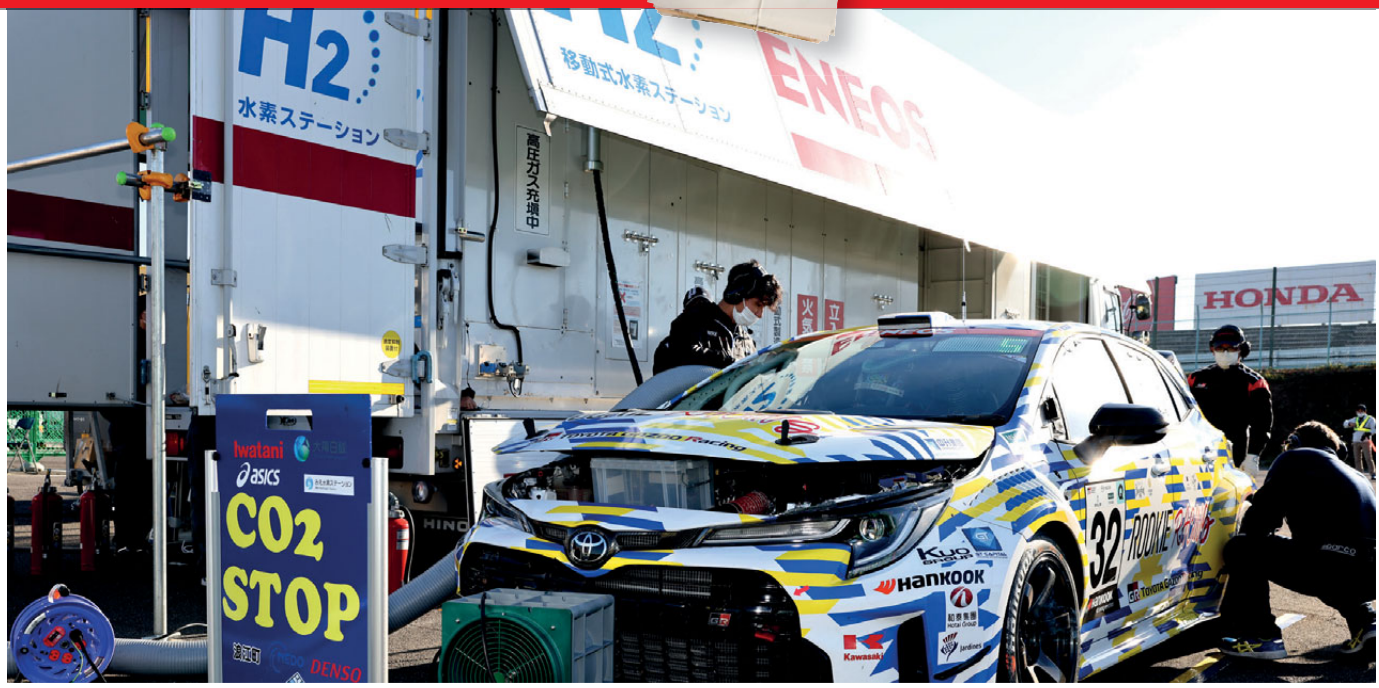
"In Extreme E these cars are perfectly capable of racing as much as we want. For our format, these cars are perfect."

The Le Mans Mission H24 project, very much the poster child of hydrogen race technology, will use a fuel cell. Elsewhere, though, hydrogen combustion is increasingly on people's radar.

"We need to explore hydrogen combustion," Agag acknowledged. "Fuel cells have an advantage with absolutely zero emissions; combustion of hydrogen has certain emissions.

"We have to analyse exactly how much the emissions are, NOx for sure. But they have certain advantages: for example, combustion makes noise. Some people find that obviously exciting for motorsport."

RIGHT The next-generation Extreme E machines are likely to showcase hydrogen



ABOVE Toyota's ambition is to race on liquid hydrogen fuel

TOYOTA'S COROLLA H2 CONCEPT

TOYOTA'S pioneering hydrogen-powered Corolla was forced to miss the recent Super Taikyu Series race at Suzuka, following a fire caused by a hydrogen leak during private testing at Fuji International Speedway.

The incident occurred while experimenting with liquid hydrogen. However, the team insists that the fire was not directly caused by the fuel change from gaseous hydrogen to liquid hydrogen. The leak has been traced to the loosening of a pipe joint, caused by vibration. As the piping joint is located near the engine, the leaked hydrogen ignited when heated.

> *"We're fighting to create a future for the internal combustion engine by tackling a technology deemed unfeasible for cars, in the uncharted territory of -253°C"*

The Rookie Racing-entered team found that the hydrogen leak sensor fail-safe functioned properly so that the hydrogen supply was shut off, avoiding a significant spread of the fire. As a result, the cockpit was protected from the blaze.

The hydrogen-powered Corolla has run on gaseous hydrogen since its first entry in the Super Taikyu Series in May 2021. Over the past two years, it has evolved with each race in areas such as output, torque, cruising range, and filling time.

The next stage of the project was to explore liquid hydrogen, which offers higher energy density than compressed hydrogen gas, potentially reducing the volume and weight of the fuel tanks. However, the need for cryogenic storage presents its own challenges in areas such as developing fuel pump technology that can function in a low-temperature environment, preventing hydrogen from naturally evaporating from the tanks, and establishing regulations for vehicle-mounted hydrogen tanks.

In February, a GR Corolla fuelled by liquid hydrogen was given a Super Taikyu test run at Fuji Speedway in Oyama, Shizuoka. The car ran three sessions on the day. This test simulated real race conditions, including sharing the track with other cars and refuelling within designated times.

"We're fighting to create a future for the internal combustion engine by tackling a technology deemed unfeasible for cars, in the uncharted territory of -253°C," explained driver Masahiro Sasaki, referring to the cryogenic storage. "While various hurdles still remain, as with gaseous hydrogen we hope that our agile development on the racetrack will feed back into everyday cars."

For gaseous hydrogen, tanks are filled at high pressure and must therefore be cylindrical. When the fuel is in a liquid state, however, there is no need for tanks to be pressurised. In the future, fuel tanks could be shaped conveniently for under-floor mounting, offering the potential to improve packaging efficiency.

Switching the fuel from gas to liquid also allows for more compact mobile hydrogen stations. Liquefaction reduces the required size of transport trucks and eliminates the need for facilities that boost pressure up to 70 MPa. This shrinks the footprint of a station to about one-quarter of that needed for gaseous hydrogen. As with gasoline vehicles, refuelling could also be done in the pit area. What's more, since refuelling no longer needs to be done at pressure, multiple cars can be filled up in succession.

The fire occurred during a further, private, test at Fuji. Nevertheless, the team remains committed to its goal of becoming the first squad to race with liquid hydrogen fuel.

Moving forward, Toyota will focus on challenges such as maintaining the ultra-low temperature of -253°C during refuelling and storage, and dealing with natural vaporization as tanks heat up, as it strives to pick up the pace of technological development.

US$ 2.25 million prize pool for Abu Dhabi Autonomous Racing League

ASPIRE has announced the launch of the world's largest autonomous racing league, in line with its vision of building a world-class research and development (R&D) hub in Abu Dhabi.

The league will kick-off with a race at the Yas Marina Circuit in Abu Dhabi, United Arab Emirates, in Q2 of 2024.

With a prize pool of up to US$ 2.25 million, the Abu Dhabi Autonomous Car Race will feature the Dallara-built Super Formula cars, the usage of which has been enabled by Japan Race Promotion, Inc. (JRP). The Super Formula cars will be specially equipped with an autonomous technology stack.

A core goal of the Abu Dhabi Autonomous Racing League is to push the boundaries of autonomous mobility by hosting challenges to advance R&D in autonomous racing and artificial intelligence (AI). It is hoped the applied research executed in preparation for the League will help develop cutting-edge and low-risk solutions to significantly reduce fuel consumption and carbon emissions.

Race viewers will be invited to experience the head-to-head autonomous car racing with live updates from Augmented Reality (AR) and Virtual Reality (VR) infographics and real-time displays shown on screen.

His Excellency, Faisal Al Bannai, Secretary General, Advanced Technology Research Council, said: "Abu Dhabi is a rising hub for STEM empowerment and envisioning a decarbonized economy, which is why we are proud to launch the Abu Dhabi Autonomous Racing League. Autonomous racing is continuing to gather steam, given its significant potential to disrupt the future of transportation and mobility.

"We will set new benchmarks for autonomous vehicles and help them pre-empt and prepare for unknown challenges as they become more mainstream. In addition to creating a community platform for motorsports fans, the Abu Dhabi Autonomous Racing League will feature an open development model, supporting faster progress, faster testing, and greater innovation. Machine learning and reinforcement learning will be key to collecting data and developing the technology of these vehicles."

The Autonomous Car Race will be the first among a series of autonomous vehicle races in the Abu Dhabi Autonomous Racing League, which will include autonomous off-road racing, autonomous drone racing, and more. They will be open to all teams from previous autonomous racing challenges, teams from universities around the world, and public and private research institutes.

Andrea Pontremoli, CEO of Dallara, added: "The Abu Dhabi Autonomous Racing League will set the pace and drive new levels of performance, safety, efficiency, and importantly, sustainability, in autonomous technologies. Watch this space."

Dallara already has some experience of autonomous racing through its work with the Indiana-based Indy Autonomous Challenge (IAC), which transitioned the Italian constructor's Indy Lights cars into autonomous racecars. RT

BELOW The SF23 Dallaras will be run with an AI stack

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"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"

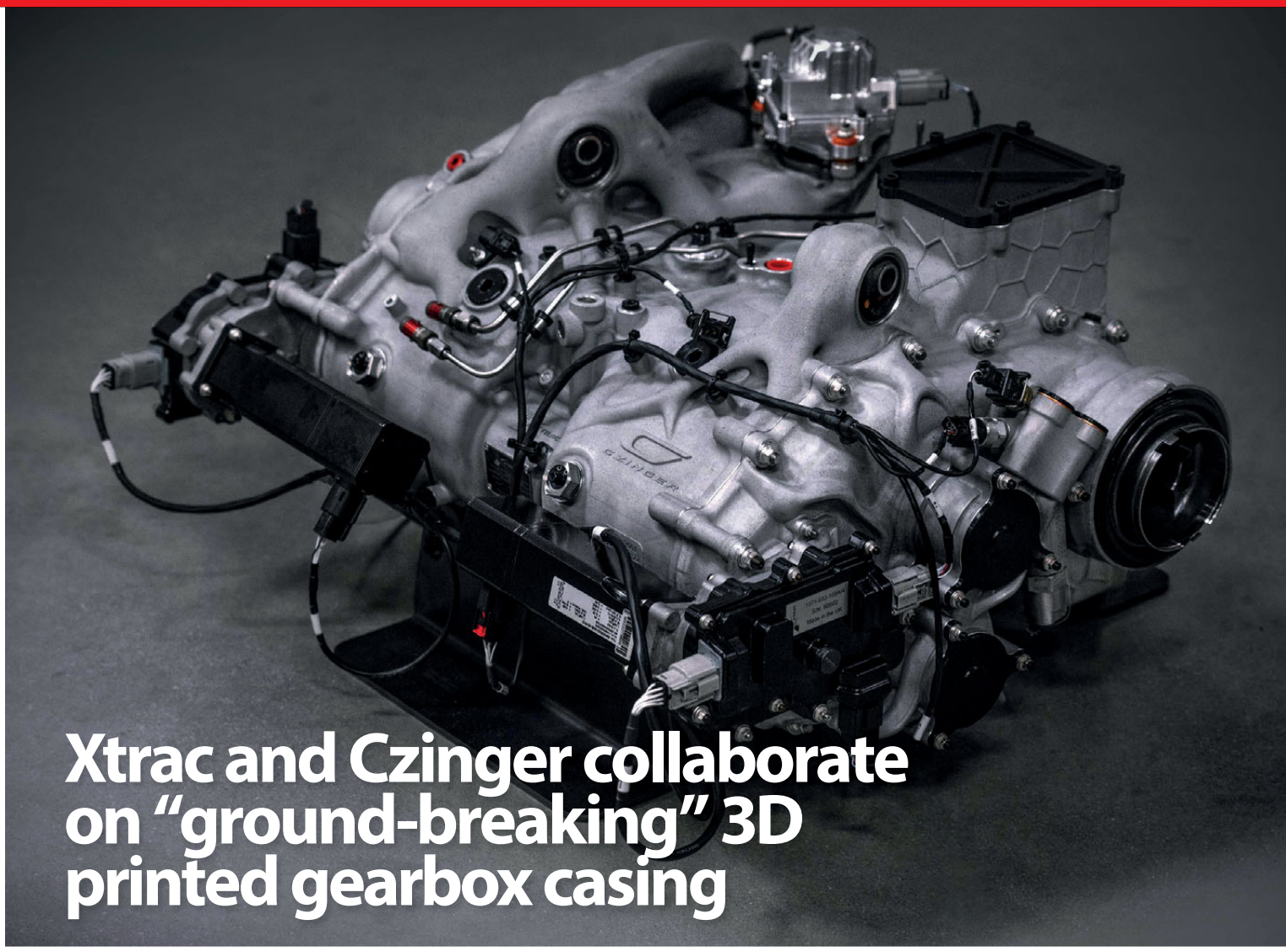
ERIC JACUZZI, Managing Director, Aerodynamics/ Vehicle Performance, R&D Center, NASCAR

"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

"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



Xtrac and Czinger collaborate on "ground-breaking" 3D printed gearbox casing

A 3D printed gearbox casing created by a collaboration between Czinger Vehicles and Xtrac has been hailed as "ground-breaking".

The two companies partnered to pioneer the first topology-optimized and additively manufactured gearbox case.

The production of the gearbox uses a unique printing process and proprietary aluminium alloy, resulting in significant mass savings, outstanding structural performance, production quality, and efficient printing times. Furthermore, the partners report that this approach eliminates the need for tooling, achieving a substantial reduction in development time, and the ability to make real-time design improvements.

Czinger is best known for its 21C, a 1,233 bhp hypercar complete with a turbo V8 revving to 11,000 rpm, a 1+1 layout and $1.7m price tag. Large sections of the car's chassis are 3D printed. Partnering with Xtrac to engineer and develop the 21C's 3D-printed gearbox is further evidence of Czinger's commitment to additive manufacturing.

The seven-speed semi-sequential gearbox features a 48V-electrically actuated twin barrel system, resulting in what the two companies claim is the fastest automated single clutch synchromesh gearbox in existence.

Dual barrel gear actuation allows for seamless EV-to-Rear Drive blending for smooth city driving in the 21C, while sub-100ms shifts combined with blending of front-axle EV power allows seamless shifts for high performance driving. The companies claim the highest torque transmitted per mass of gearcase for any road-legal vehicle.

Czinger Co-Founder and SVP Operations, Lukas Czinger, said: "We are proud to team Czinger's world-class engineers with those at Xtrac; together, we have developed an incredible, industry first, gearbox that is truly at the pinnacle of performance. We can't wait to shatter more track records as we utilize this system in the 21C."

"What our Xtrac engineers have accomplished in tandem with Czinger and Divergent is ground-breaking," commented Xtrac CEO Adrian Moore. "Xtrac is pleased to be at the forefront of cutting-edge gearbox manufacturing by creating these 3D printed casings. It has been extremely interesting and very stimulating for our engineers working closely together to bring this cutting-edge innovation to life." RT

ABOVE Czinger's hypercar will feature a 3D-printed gearbox casing

Getty Images/Red Bull

Red Bull Powertrains chooses Convergent Science CFD for 2026 engine reset

RED Bull Powertrains has joined forces with computational fluid dynamics company Convergent Science, utilising the firm's CONVERGE CFD software in the design of its 2026 Formula 1 power unit.

Established in 2021, Red Bull Powertrains was created to develop power units for Oracle Red Bull Racing and Scuderia Alpha Tauri. The company's first power unit is set to make its debut in 2026 when new F1 regulations specify the use of 100 percent sustainable fuels.

Red Bull Powertrains' partnership with Convergent Science will see the US software firm support the design of the engine's combustion system, working to optimise fuel spray and combustion chamber parameters. CONVERGE's detailed combustion models will be used to predict the performance of various ICE designs, while the ability to quickly set up new simulations with different geometry configurations will allow the teams' engineers to rapidly evaluate design options.

ABOVE Convergent Science CFD will aid Red Bull Powertrains' work on the new engine's combustion system

CONVERGE's flexibility has led to its adoption by not only engine makers and F1 teams around the world, but also manufacturers in a variety of industries, including electric vehicle systems, rotating machinery, and renewable energy infrastructure.

Christian Horner, Oracle Red Bull Racing Team Principal and CEO, said: "The development of our power unit for the 2026 season is evolving day by day. We continue to invest in people and facilities to bring competitive power units to the grid, and to achieve that target we need the best tools in every area. CONVERGE CFD undoubtably meets that need and will help us to build a race-winning ICE. Their highly detailed combustion models enable us to visualise and simulate the inside of the cylinder during combustion, a process that will accelerate our development of a more powerful and efficient engine for the next generation of F1."

Kelly Senecal, co-founder and owner of Convergent Science, added: "We work hard to keep CONVERGE on the cutting-edge of simulation technology and it's exciting to see Red Bull Powertrains take advantage of our software's advanced capabilities to design a best-in-class power unit in a few short years." RT

End of fossil fuels moves closer with kart switch

MOTORSPORT moved a step closer to freedom from fossil fuels last month when FIA karting competitions switched to a 100 per cent renewable fuel solution.

The fuel is a 100% renewable product made from second generation bio-based components and synthetic fuel produced by German manufacturer P1 Racing Fuels. The company, which also supplies the World Rally Championship, is the official fuel supplier for the FIA Karting Championships, Cups and Trophies from 2023 to 2025 (with the exception of Superkart).

The move to sustainable fuels for karting is in line with the FIA's commitment to leading motorsport into a low carbon future to reduce its environmental impact and contribute to a greener planet. The FIA is targeting net zero carbon by 2030.

By 2026, all FIA championships will be required to be powered by 100% sustainable energies – from advanced, sustainable drop-in fuels to battery and hydrogen technologies.

With the adoption of the 2020-2030 Environmental Strategy, the FIA has set bold ambitions to align itself with climate science and its vision to promote safe, sustainable and accessible motorsport and mobility for all. Its ambition is to strengthen its position in sustainable innovation and to have a positive impact on the sustainability agenda in motorsport and mobility.

"The move to 100% carbon neutral fuel is a very important step in the evolution of all FIA Karting championships. It ensures alignment with the FIA's overall environmental strategy and allows us to continue racing in a sustainable manner," said CIK-FIA President Akbar Ebrahim. "The introduction of P1 Racing Fuels in 2023 allows us to make concrete progress in this direction, alongside other motorsport disciplines, while retaining the usual running of our competitions and their appeal."

ABOVE The FIA's kart series have moved to 100% carbon neutral fuel

P1 Fuels' new approach to producing carbon neutral fuels combines several innovative production processes that rely exclusively on non-fossil sources. These fuels are derived from the conversion of alcohols into synthetic hydrocarbons.

Martin Poplika, Managing Director of P1 Racing Fuels, said: "As a pioneer in its field, P1 Racing Fuels has always strived to bring cutting-edge innovation to its products, using new processes, components and technical know-how to formulate sustainable, high-performance biofuels that are produced and delivered in a cost-effective manner. We believe that the future of racing is free from fossil fuels, and we are very pleased to support FIA Karting in this important step towards a more sustainable future for the sport." RT

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Photos: Ford Performance

Ford's all-electric SuperVan 4 to tackle Pikes Peak

FORD Performance is to compete in the 101st running of the legendary Pikes Peak International Hill Climb (PPIHC), held just outside of Colorado Springs, Colorado, this June, with its all-electric SuperVan 4.

"The Pikes Peak International Hill Climb is the perfect next stop for Ford Performance, and is the perfect place to take SuperVan 4, as both have long, storied histories that ignite the imagination of racing fans all over the world," stated Mark Rushbrook, global director, Ford Performance Motorsports. "Both have evolved over time, and it's time to take our electric vehicle technology and put it to the test on the mountain against some of the most impressive performance vehicles in the world."

In 100 instances of the PPIHC, Ford vehicles have competed prominently with a variety of nameplates ranging from a 1916 Model T to current generation Mustangs, including a Ford Mustang Shelby GT500SE campaigned by Shelby American in 2022.

Over the years, several iconic drivers have piloted Fords up the mountain, from Stock Car Division records set by Curtis Tanner and Parnelli Jones in the 1960s, to the late and former action sports driver, Ken Block, piloting the Hoonicorn to create a Climbkhana spectacle.

For 2023, SuperVan 4 will be piloted by PPIHC record holder Romain Dumas, who among other notable accomplishments is also a three-time Le Mans winner and holds several EV-powered lap records.

"Ford's latest generation of electric vehicle technology is the perfect match for America's Mountain," said Dumas of the event, which winds up 156 turns and 4,725 ft to a finish line sitting 14,115 ft above sea level. "With high altitudes cutting power in traditional ICE powered vehicles, the electric powertrain of SuperVan 4 has no loss at elevation and will be a healthy competitor in this year's race."

SuperVan 4 takes to the mountain sporting an all-wheel drive system powered by a 50 kWh ultra high-performance battery. Other key features include a lightweight carbon composite body, an FIA specification roll cage, and adjustable regenerative braking.

ABOVE & TOP Ford's all-electric SuperVan 4 is the latest in a long line of wild concepts. The second iteration of the transit (above, in 1984) was based on a C100 Group C car

The project will rely on a number of well-known motorsport suppliers. They include EV and R&D specialist STARD, which provides the powertrain, and Alcon, which memorably provided brakes for Sébastien Loeb's record-breaking run in Peugeot's mighty 875 hp 208 T16 Pikes Peak in the 91st edition of The Race to the Clouds.

This marks STARD's most recent project with Ford Performance over a five-year relationship, including other high-performance EV powertrains found in vehicles such as the Fiesta ERX, the first line of FIA-certified EV rallycross vehicles.

"SuperVan 4 is equipped with one of the world's most powerful electric powertrains ever developed," said STARD CEO Michael Sakowicz. "It's also one of the most versatile electric racecars ever built. It has gone up the hill at Goodwood, rallied over WRC tarmac stages and more. Now, to send it to the Pikes Peak International Hill Climb, is very exciting. A lot of work has gone into this effort."

This will be Dumas' eighth appearance at the Pikes Peak International Hill Climb, originally starting his time on the mountain back in 2012. He is no stranger to the EV ranks, having previously smashed the outright record with VW's ID.R.

"We're always excited to see what Romain is racing next in the Pikes Peak International Hill Climb. He consistently arrives in unique builds that are serious contenders and fun to watch," said Melissa Eickhoff, PPIHC Executive Director. "This year is no different. The Ford Performance SuperVan 4 is sure to be a crowd-pleaser."

Continental reveals more sustainable Extreme E tyre

CONTINENTAL has supplied a more robust and sustainable version of its CrossContact Extreme E tyre for the new season of the pioneering series.

The 2023 campaign began in NEOM, Saudi Arabia, last month with a new tyre that featured an even higher proportion of sustainable materials.

The CrossContact Extreme E tyre now consists of around 43 per cent recycled and renewable materials. Among these is silica obtained from the ash of rice husks, a waste material of agriculture. Alongside processed steel and carbon black, Continental is again integrating polyester yarn from recycled PET plastic bottles into the tyre's construction.

As well as increasing its use of new, more sustainable solutions, the tyre manufacturer has reduced the overall weight of the tyre by two kilograms. The development results to emissions savings in the transportation process.

Continental is a founding partner of Extreme E and exclusive tyre supplier to the championship, which is now in its third season.

Nels von Schnakenburg, Technical Manager for Extreme E at Continental, said: "We have focused even more strongly on the use of sustainable and recyclable materials with this tyre and are extremely well prepared for the challenges of the 2023 season.

"We've also made further gains with handling performance and have therefore improved drivability. The performance and robustness of the tyre mean it will be able to withstand the full range of challenges Extreme E can throw at it."

The third-generation CrossContact Extreme E also employs the ContiRe.Tex technology developed by Continental. This includes polyester yarn produced without any intermediate chemical steps from used PET bottles that are not recycled elsewhere. The bottles used for this technology are sourced exclusively from regions which do not have a closed recycling loop.

Continental will supply 30 tyres to each of the 10 teams competing in the third season of Extreme E, and each of those tyres will contain polyester from around 60 processed PET bottles. The company currently offers road car drivers three series-produced tyre models with polyester from recycled PET bottles, each in five dimensions.

Together with rubber, fillers like silica are also an essential part of a tyre's construction. Silica helps to significantly improve characteristics such as grip, rolling resistance and mileage.

In the CrossContact Extreme E, rice husks provide the base material for the sustainably manufactured silica. Rice husks are a waste product of rice production and cannot be used as food or animal feed.

The manufacture of silica is more energy efficient when it is obtained from the ash of rice husks than when conventional materials like quartz sand are used.

The size, diameter and width of the tyre are unchanged at 37 x 12.50 R17 – a diameter of 37 inches, width of 12.5 inches and 17-inch wheel rims.

Continental's tyre sector is pursuing a holistic approach to sustainability across all phases of the tyre value chain. Its circular economy solutions represent an important route to achieving its ambitious goal of carbon neutrality throughout its value chain by 2050 at the latest. RT

ABOVE The new season began in Saudi Arabia

IndyCar adopts new telemetry system

THE NTT IndyCar Series will adopt a new telemetry system in 2023 that will introduce a host of new features to help teams improve the performance of their cars and better inform medical response crews.

Provided by EM Motorsport, supplier of electronic safety devices to Formula 1, MotoGP, the 24 Hours of Le Mans and other championships, the new system will stream hundreds of data channels from an array of onboard sensors to the teams and race control. Particularly important to monitor are the safety systems on the car. With the new telemetry in place, feedback and tracking of these systems has been streamlined, providing additional critical data to the IndyCar Safety Team and response crews in the event of an incident.

"EM Motorsport has become a valued partner to IndyCar and our teams," IndyCar President Jay Frye said. "Their work to implement the course marshalling system was flawless and extremely well received by our paddock, promoter partners and fans. Incorporating the EM Motorsport telemetry system with our growing paddock is the natural next step as definitive data is key to our race teams' ability to make split-second decisions."

Operated in full for the first time during the pre-season test last month at The Thermal Club, the new telemetry system works in conjunction with the pre-existing electronic marshalling in what is billed as a never-before-seen unified solution.

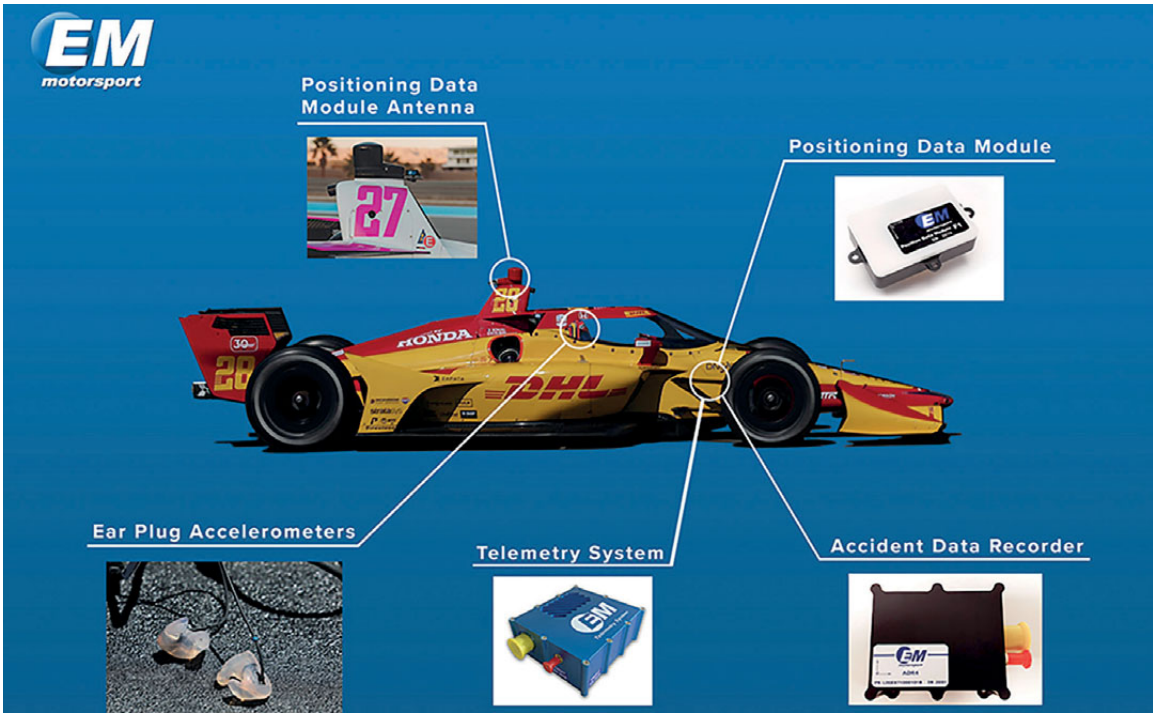
The all-in-one system means both the telemetry and marshalling systems come from the same source, therefore is managed locally with no data being sent off-site. This not only increases reliability with less risk of interference between different operators but also ensures the security of the data being transmitted.

Combining the two pieces of software also means fewer in-car components and wiring looms are required, offering a lighter and more sustainable solution that is easier to install, configure and maintain. Altogether, it creates a much more cost-effective package.

The combined system was chosen for its development potential and, as part of its growing partnership with IndyCar, EM Motorsport will continue to explore avenues for improvement and expand the quality and quantity of information shared to and from the cars.

The partnership began with supplying Accident Data Recorders and Ear Plug Accelerometers in 2021. EM Motorsport's Electronic Marshalling System, which connects race control and the local marshal flag panels directly to the cars on track, was introduced last season and won the Louis Schwitzer Award for Engineering Innovation and Excellence.

"The NTT IndyCar Series will be the first to run this revolutionary all-in-one system of telemetry and electronic marshalling," said Luca De Angelis, EM Motorsport deputy manager. "This has been an ambition of EM Motorsport for many years and to achieve this with America's premier single-seater series makes us extremely proud. The championship is leading by example of how other series can run a more cost-effective and elegant solution. We are greatly looking forward to working alongside IndyCar to expand the capabilities of the combined systems."



LEFT The system offers a unified solution

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IMSA and Bosch strike deal

A FIVE-year partnership between Bosch and the International Motor Sports Association (IMSA) was announced at the Mobil 1 Twelve Hours of Sebring in the USA.

Through the collaboration, the partners aim to use Bosch's knowledge within the fields of electronics and mobility to improve vehicle performance while enhancing safety and making racing a fairer, more competitive sport.

To help motorsports transition to become a more sustainable sector that conserves resources, Bosch is continuing to work on the development of components and systems designed for use within electrified drives. The new LMDh cars competing at Sebring were the embodiment of that ambition: Bosch Motorsport is one of the exclusive partners for IMSA's Grand Touring Prototype (GTP) class – North America's first hybrid-powered prototype racecar.

To adhere to the current LMDh regulations, the system has a permanent output of 50 kW in drive mode and up to 200 kW in recuperation mode. The hybrid system is capable of higher performance levels for future scalability, enabling Bosch to meet the power and torque demands of different racing series.

"Bosch has played a passionate role in motorsports for more than a century," said Jacob Bergenske, director of Bosch Motorsport, North America. "From our ABS systems allowing for unbeatable braking performance, to our collection of electronics and telemetry systems that allow for data-driven performance on and off the track, to our new LMDh technology for electrified racing, Bosch helps set that pace."

"Our new hybrid-electrified era of IMSA GTP racing would not have been possible without the substantial contributions of Bosch," commented IMSA president John Doonan. "This is the newest chapter in a decades-long partnership between Bosch and IMSA. We have worked together in lockstep as technology has advanced over the years, and the best is yet to come with our ultimate showcase of relevance, technology and sustainability in the GTP class."

BELOW The deal will see IMSA further leverage Bosch's electronics and mobility expertise

Levitt/LAT Images

Daytona winners penalized for manipulation of tyre pressure data

IMSA has penalized Meyer Shank Racing, winner of the new GTP class at January's Rolex 24 At Daytona, for the potential manipulation of tyre pressure data.

Although the victory has been retained, the WeatherTech SportsCar Championship levied six penalties against the team for running below the threshold set by official tyre supplier Michelin.

The drama-laden event was hailed as a big success for the introduction of the GTP class, with Honda Performance Development's Acura ARX-06 GTP model prevailing in the hands of Tom Blomqvist, Colin Braun, Helio Castroneves, and Simon Pagenaud. However, after weeks of reviewing its findings, the series found that MSR applied offsets to the information being transmitted by the tyre pressure monitoring systems affixed to each wheel that was being seen and received by IMSA.

According to IMSA, HPD found and brought the matter to the series.

"The tyre pressure data manipulation was discovered by Honda Performance Development (HPD) and reported to IMSA after the official results were released," IMSA said. "No changes will be made to the official race results. The No. 60 team and drivers retain credit for the race victory, trophy, and race-winner watches. All other teams and drivers will retain the points and prizes commensurate with their finishing positions as shown on the official race results. There also will be no change to GTP manufacturer points."

In addition to the loss of 200 team and driver IMSA WeatherTech SportsCar Championship points, the team loses its prize money and has been fined $50,000. Team and Entrant representative Mike Shank has been placed on probation through to June 30, 2023 and IMSA has revoked the annual credential of team engineer Ryan McCarthy, indefinitely suspending his IMSA membership.

MSR accepted the decision, took responsibility and apologised to its partners, saying it had dealt with the matter internally and that the team member responsible was no longer with the organisation.

ABOVE Maserati is returning to GT racing with its GT2

Maserati gears up for GT comeback

MASERATI'S return to GT racing has moved a step closer with track testing of its new GT2 model at the Autodromo Varano de' Melegari.

The shakedown at the Parma circuit is the precursor to a series of events marking the run-up to the official unveiling of the car at the end of June in Belgium, at the 24 Hours of Spa.

The car rekindles memories of the brand's success with the legendary MC12 and the initial runs were conducted by Andrea Bertolini, who won four titles with its GT1 predecessor.

"Early feedback is positive," he commented. "We've focused on developing a product that not only stands up to its competitors but is also an ideal car for our gentleman drivers in terms of handling, comfort and performance. We want them to experience a unique feeling in this car. In the last few months, we've been working intensively in the simulator. Now we're making it all a reality."

The chassis features high torsional and bending stiffness. The GT2 inherits the 463 kW/630 CV Nettuno V6 engine from the Maserati MC20, featuring the all-new patented MTC (Maserati Twin Combustion) technology. RT

F1 reports record growth

FORMULA 1 revenue for the year ending 2022 increased by 20 per cent compared to the previous year, rising to US$2.6 billion.

The Liberty Media-owned series enjoyed record growth in attendance in the grandstands and in the Paddock Club, with numbers well above pre-COVID-19 levels. F1 was, once again, the fastest-growing motorsport on social media.

The main sources of revenue are from race promotion, media rights and sponsorship fees. All three areas saw increases in 2022. These revenue streams comprised 28.6%, 36.4% and 16.9%, respectively, of total F1 revenue.

With three additional races held outside of Europe compared to 2021 and the return of full capacity crowds, race promotion saw a big increase – especially compared to the pandemic-disrupted chase around the globe in 2021.

Media rights revenue also increased, with prominent deals including Sky's extension across the UK, Germany and Italy and Disney-owned ESPN paying up to US$90 million per year for the US TV rights.

Global sponsorship deals were also agreed with the likes of MSC Cruises, Salesforce and AWS. The Paddock Club, which operated at 19 races in 2022 as opposed to just 11 in 2021, also contributed to the increase in revenue.

That growth saw team payments increase to US$1.2 billion for 2022. RT

Getty Images/Red Bull

LEFT Expansion in North America is proving lucrative for F1

NEWS

Radical Motorsport to establish corporate HQ at Donington Park

ABOVE The new facility could be completed by Spring 2023

RADICAL Motorsport, the UK's largest race car manufacturer, has announced the opening of a new customer-facing facility within Britain's oldest motor racing circuit, Donington Park.

Located at the main entrance to Donington Park, just 100 metres from the circuit itself at the Melbourne Hairpin entry, the facility will be known as Radical Motorsport's corporate headquarters (HQ).

The move into the former Formula E headquarters comes after Radical Motorsport's most successful year in its 25-year history, and marks a historic moment for the company, moving the customer-facing sales and marketing teams away from its manufacturing and production base in Peterborough for the first time since its incorporation.

Joe Anwyll, Radical Motorsport CEO, said: "We looked at a number of non-circuit-based locations in the UK to host our expanding commercial team. However, with British motorsport tracks widely known as being some of the best in the world, we had to take this opportunity, as a British motorsport manufacturer, to be right on the doorstep of the action.

"As well as our expanding team and record production numbers this year, this move to Donington Park will allow us to pursue ventures we've been unable to from our factory. Our cars belong on track, so it's only fitting we be present there too."

Jonathan Palmer, Chief Executive of circuit operator MotorSport Vision (MSV), commented: "I'm delighted that Radical Motorsport has decided to move its corporate headquarters to Donington Park. Since MSV took over the running of the venue in 2018, it's been our ambition not just to create an improved competitor and spectator experience, which we've already achieved through numerous venue improvements, but also to elevate the circuit's standing as a major national hub of motorsport businesses.

"Radical Motorsport is a much-admired and globally recognised manufacturer of sports racing cars, and I'm delighted it's recognised the significant benefits of being based at one of the UK's leading race circuits. With the addition of Radical Motorsport alongside a growing portfolio of businesses, and further developments planned at the estate, including the renovation of Donington Hall as an incredible mansion house hotel, the future for the site is looking very bright indeed." RT

Hankook joins quest for future rally stars

HANKOOK, supplier of tyres to the FIA Formula E World Championship, has added the FIA Junior European Rally Championship to its expanding motorsport portfolio.

Part of the FIA European Rally Championship, the series features front-wheel drive cars with around 210 hp. The cars of this Rally4 category are kept visually very close to the production model.

The FIA Junior ERC was launched in 2014 as a platform for talented youngsters, on which young drivers can develop and gain valuable experience. This season it will be contested over six rounds, beginning in May. The prize awaiting the winner is a start in next season's FIA Junior World Rally Championship.

Manfred Sandbichler, Hankook Motorsport Director Europe, said: "With this new cooperation, we are consistently continuing our approach of supporting youth in all areas of motorsport. The FIA ERC is the strongest rally series in Europe and has produced many stars. Against this setting, the FIA Junior ERC offers young drivers the unique opportunity to prove themselves at the highest level and in professional conditions.

"I look forward to following the development of the individual drivers on our high-end rally tyres, which have been tried and tested in all conditions, and to an exciting season together." RT

F1 champs feel the heat in NASCAR scrap

EX-Formula 1 champions Jenson Button and Kimi Raikkonen both suffered from the intense heat in the cockpit during a NASCAR Cup Series outing at Circuit of the Americas (COTA) in Austin, Texas.

The two qualified in close proximity, split by only 0.03s, with Raikkonen in 22nd, Button 24th, and often ran at close quarters throughout the 68-lap race around the 3.426-mile, 20-turn road course. So close, in fact, that Button later revealed that a bump from the Finn had contributed to his race setup deteriorating.

Both admitted to finding it hard to race in a pack.

"It was an emotional rollercoaster. At first, it was terrible," admitted Button, who drove the No. 15 Mobil 1 Ford Mustang. "I was just like, 'Everyone, go. I just need to drive and find a rhythm.' I've never gone through a corner two wide, so often. And trying to place my car in the right place – I just got it wrong every time.

"Normally, if you're a little bit slow through a corner, nobody tries to overtake you from the outside – because they're not going to make it all the way on the next one. But here they do, because they get a wheel inside for the next one, and if you turn in, you turn around.

"The first stint was really bad. It was embarrassing for me. I was like, 'Alright guys, we need to pit, freshen the tyres and I need some air. I need some fresh air.' I got that."

The heat took a big toll amid the "mayhem", however, with Button confessing that he came close to retiring with heat exhaustion.

"It was so hot, I thought I was going to faint in the car," he said. "So, I stopped twice for a minute. They put ice on me, gave me loads of water, and I went back out. I was so close to getting out of the car because I thought I was going to faint. I must've drunk eight-nine bottles of water during the race. The team kept me calm."

Raikkonen similarly struggled, especially when his cool suit failed.

In the end Button hung on to finish 18th.

Raikkonen, driving a Chevrolet Camaro, even jumped to as high as fourth at one point, during some chaotic restarts which he described as "a bit intense". He fell to 27th at the flag after a spin, and was demoted to 29th with a post-race 30-second penalty for short-cutting the esses on the final lap.

Tyler Reddick won the EchoPark Automotive Grand Prix to score his fourth career NASCAR Cup Series victory, his first of the season and his first at COTA. His margin over second-place Kyle Busch was 1.411 seconds.

Button will also compete in the inaugural Chicago Street Race on July 2 before culminating his three-race Cup Series slate on Aug. 13 at the Indianapolis Motor Speedway Road Course.

Upon retiring from F1 in 2017, the British driver has taken on a variety of challenges. It began with sports cars in the Japanese Super GT Series' GT500 class, where he won the 2018 championship. He then ran a five-race stint in the 2018-2019 FIA World Endurance Championship, a drive that included the 24 Hours of Le Mans. He will return to Le Mans in June as part of the NASCAR Garage 56 driver squad. RT

RIGHT 2009 F1 champ Button found his NASCAR debut an intense affair, with his Mustang struggling with oversteer

Controversial start to Supercars Gen3 era

A NEW chapter in Supercars' history has opened, with a fresh generation of rivalry between Chevrolet Camaro and Ford Mustang commencing under the Gen3 regulations.

The opening round of the Repco Supercars Championship, in Newcastle, marked the start of the Gen3 era: the biggest architectural change in Supercars history.

The homologation of the cars from General Motors and Ford took place with over 2200 km of running, undertaken across both brands, during the VCAT validation testing in the build up to the season-opener.

The process required a significant effort to ensure that technical parity is maintained as a fundamental cornerstone of the success of the sport.

Supercars CEO Shane Howard said: "As part of upholding the integrity of the Championship, all parties will continue to work together to review data and the relative performance of our new vehicles. This is a pre-requisite for the ongoing success of the category, which falls under the parity review system which has been in place for more than 20 years."

Unfortunately, the re-energised racing wasn't the only talking point of the weekend, as the inter-team collaboration was tested by an argument culminating in the disqualification of the Triple Eight Race Engineering Camaros of Shane van Gisbergen and Broc Feeney, who had crossed the line first and second in the Thrifty Newcastle 500 opener. The decision, which revolved around the positioning of a secondary cooling system, was appealed but upheld during a hearing before the Supercars National Court of Appeal in Melbourne ahead of the second event. RT

BELOW The Triple Eight Camaros were excluded

Sabelt collaborates with Bcomp for natural fibre seats

SABELT, a specialist in lightweight seats for high-performance cars, is developing a seat made 100% from Bcomp's flax fibre solutions.

This development is part of the Italian company's "Carbogreen Project" initiative, which represents Sabelt's environmental mission, one of its priorities. The initiative aims to develop seating systems for sports cars made of newly designed, renewable and/or low environmental impact materials.

Its Carbogreen Project, which commenced in 2019, targeted a reduction of the company's environmental impact. Three years on, it continues thanks to the financing of Finpiemonte and the support of the European Fund for Regional Development.

Thanks to the collaboration with Bcomp, Sabelt is currently validating the use of flax fibres to make a seat with natural materials. The use of flax can be considered a new beginning of this project as it means replacing carbon fibre or fibreglass with renewable materials, significantly reducing CO2 emissions, without compromising performance.

Momentum is growing for automotive OEMs taking action to move towards weight reduction, recyclability, and sustainability through the use of natural fibres. Sabelt, having followed this course of action for years, can now boast of being among the leaders in this commitment.

Thanks to a collaboration with Bcomp – a leading solutions provider for natural fibre reinforcements in high-performance applications ranging from race to space – Sabelt is currently validating the use of flax fibres to make a seat with natural materials.

The Carbogreen Project is an important initiative for Sabelt as a first step, to be followed by the implementation of natural fibre reinforced thermoplastic materials, which are more easily recyclable at the end of the vehicle's life and helps reduce environmental impact from the seat system production.

Founded in 1972 by Piero and Giorgio Marsiaj, Sabelt specializes in the development and production of car seats for performance road cars, products for motor racing and seatbelts for aerospace. From the world of motorsport, Sabelt has developed a range of premium sports seats for the world's leading car manufacturers and counts Ferrari, McLaren, Alpine, Abarth, Alfa Romeo, Jaguar, Maserati and Aston Martin among its partners. RT

Pirelli makes Climate A List and confirms interest in new F1 tyre deal

PIRELLI has confirmed that the FIA's tender process for Formula 1's exclusive 2025 tyre supply contract "is of great interest", aligning with its desire for relevance to technology transfer from track to road, putting a particular emphasis on sustainability.

The FIA's tender process highlights the growing focus on sustainability that all tyre manufacturers are currently working hard to meet.

Pirelli has set its sights on achieving group Carbon Neutrality by 2030, underpinned by its goal of using 100% renewable electric energy by 2025.

Its ambitions were underlined by the recent news that for the fifth consecutive year it has been confirmed as a global leader in the fight against climate change, obtaining a position in the *Climate A list 2022* of the CDP (Carbon Disclosure Project), the international non-profit organization that gathers, disseminates, and promotes information on environmental questions.

The "A" rating, assigned to Pirelli at the conclusion of the analysis process, is the highest score. It was awarded to only 294 companies of the more than 18,700 participants, evaluated based on the effectiveness of the actions implemented to reduce emissions and climate risks and to develop a low carbon emissions economy, as well as the completeness and transparency of the information supplied, and the adoption of best practices associated with environmental impact.

"The recognition of the CDP confirms once again our commitment to sustainable development through the fight against climate change. It's what we try to do every day through our research, developing processes and products that are always more sustainable, safer and better performing," said Marco Tronchetti Provera, Executive Vice Chairman and CEO of Pirelli.

Pirelli has been Formula 1's exclusive tyre manufacturer since 2011, the Italian company supplying its product through several regulation changes, the most significant of which was Grand Prix racing's switch to 18-inch wheels in 2022.

The F1 tender involves a three-year contract that will run for 2025 to 2027, with an option extending into 2028. The winning manufacturer will also supply tyres to the FIA Formula 3 and Formula 2 Championships.

The FIA says the targets and specifications of the future tyre supply contract remain similar to the current contract, although bidding suppliers will be required to demonstrate the increased environmental sustainability of their product throughout its life cycle.

"These targets have been agreed through consultation with the Commercial Rights Holders and the Teams, and are designed to ensure a wide working range, minimise overheating, and have low degradation whilst also creating the possibility for variation in strategy," the FIA said.

Other technological updates will include the requirement for tyres to be fitted with electronic identification to improve the efficiency of the scrutineering procedures.

The FIA is expected to announce the selected winning bidder around mid-June.

Pirelli

BELOW F1's sustainability targets are attractive to Pirelli

Recycled Extreme E tyres to make basketball court

CONTINENTAL Tyres, a founding Partner of Extreme E, has opened a cutting-edge and sustainably built basketball court in the Linden-Süd district of Hanover, Germany.

This is no ordinary court – the innovative new build has been constructed using 200 recycled racing tyres from the first season of the Extreme E electric racing series, which Continental supports as a main sponsor.

Since its inception, a core value of Extreme E and its supporting partners has been sustainability, which has been actioned through examples such as electrification, legacy programmes, and a Scientific Committee. Being able to give new life to these old racing tyres is a further impactful development to this goal and demonstrates the significance of a major manufacturer adapting to match a purpose driven mission.

Ali Russell, Chief Marketing Officer at Extreme E, said: "This initiative pushes the boundaries of how we can re-purpose resources in a way that will benefit so many people.

"Over the past two Extreme E season campaigns, it has become clear that both creative thinking and a great deal of ingenuity is required to deliver the solutions necessary to combat the climate crisis. This fantastic initiative certainly achieves that."

Continental's partnership with Extreme E has already seen the launch of three generations of its pioneering CrossContact racing tyre, its most sustainable tyre ever.

The application of old PET bottles, making up 100% of the tyre carcass, and a new silica material created from rice husks, a waste product from agriculture, pushes the boundaries in tyre technology ahead of plans to integrate the new technology into volume production of various Continental premium tyres later this year.

This high-level basketball court has taken this innovation one step further, turning old tyres into the foundation of the sporting and social space, in line with the aim of "turning racing tyres into living space". This, in sum, strives to give people a lively place to play, burn off energy, and train.

Christian Kötz, Member of the Executive Board Tires at Continental, said: "These tyres raced in Saudi Arabia, Greenland, and Senegal. Now, in the form of a basketball court, they are helping to bring young people together and get them excited about sport.

"We're delighted that the Extreme E tyres are getting a second life after the end of their racing career. Circularity – in this case the reuse and continued use of tyres – is an important area, and one in which Continental is working hard."

Photos: Extreme E

ABOVE & BELOW Tyres raced in Senegal have been given a second life in a German basketball court

The court was created as part of a collaboration between the city of Hanover, property construction company Hanova, the BasKIDball project, the VIA Linden, and Serve the City Hannover associations and the SV Linden 07 club, on whose premises the half-court has been built. Elastomer processing company REGUPOL handled the transformation of the tyres into rubber paving blocks, and the court was assembled by Hanover-based company Kretschmer.

Belit Onay, Hanover's Mayor, added: "We would like to thank Continental and all those involved for this new basketball court, which creates a new space for kids and young people and brings sport and sustainability together in the same conversation.

"Initiatives like this show what is possible when so many people help to turn a community project into reality in our city. I'm grateful for all their contributions." RT

Extreme E delivers successful showcase of Hydrogen Fuel Cell system

AS Extreme E produced a spectacular opening X Prix of Season 3 on track, off track it delivered a successful first test of a new and innovative mobile fuel cell system provided by ENOWA, the championship's Green Hydrogen Power Partner.

As a more portable energy source, with a strong capability to store power, the Hydrogen Fuel Cell system will be a green power provider in the region of NEOM. During the Desert X Prix, the fuel cell was in operation for its first time, where it charged the championship's fleet of electric racing vehicles.

ENOWA is the engine room for renewable energy, water and hydrogen at NEOM and, since 2022, has been a part of a pioneering and multi-year relationship with Extreme E. The core aim of the partnership has been to showcase the use of green hydrogen power as part of the race site, and also be a platform for the promotion of hydrogen as a more widespread sustainable solution.

Green hydrogen is widely seen as the most promising energy carrier in the push for positive climate action. This technology supports the transportation of renewable energy over long distances and the decarbonisation of major industries and infrastructure.

Alejandro Agag, CEO and Founder of Extreme E, said: "I am tremendously proud that Extreme E's Desert X Prix could host this successful first test of this innovative new Hydrogen Fuel Cell system. As a championship driven by sustainability, it has been a fundamental aim to operate in the least impactful way and using hydrogen in this way is so crucial for our series, not to mention its overall aspirations for NEOM."

Roland Kaeppner, Executive Director Green Hydrogen and Green Fuels at ENOWA, said: "ENOWA plans to lead the development of world-class sustainable energy, water and hydrogen systems which I am sure will become a reference point in the future, and the Extreme E series will also benefit from this greater focus on technology and innovation."

The fuel cell system, provided by ENOWA in collaboration with Energys, is an off-grid energy technology, delivering a reliable hydrogen-based power solution for remote sites.

Based on technical specifications developed by ENOWA, the unique system is one of the world's largest commercial operating fuel cells, with 'first of its kind' combined functions. RT

LEFT The series has undertaken a mission to push the boundaries of sustainability and entertainment

Ricardo supports development of hydrogen engine

RICARDO, a global strategic, environmental, and engineering consulting company, has delivered a hydrogen-fuelled research engine to global engine specialist Cummins and automotive supplier BorgWarner, as part of Project BRUNEL, part funded by the Advanced Propulsion Centre (APC).

Cummins is a global specialist in diesel and alternative fuel engines and generators, and related components and technology. BorgWarner is an automotive tier 1 supplier and specialist in the design and manufacture of systems for electrified and conventional propulsion types, that includes injection equipment for conventional and renewable fuels. BorgWarner recently announced the intention to spin off its Fuel Systems segment, PHINIA Inc., which is expected to be a product leader in fuel systems, starters, alternators and aftermarket distribution.

The project aims to support internal combustion engine (ICE) sub-system suppliers to increase their use of hydrogen as an alternative zero-emissions fuel solution, across the light commercial vehicle market.

The engine is specifically designed to burn only hydrogen – with no supporting fuels that could give rise to any carbonaceous, or excessive air quality emissions.

Experts in hydrogen technology and integration, Ricardo has provided an engine based upon its world-renowned series of single-cylinder research units, which can help the research teams evaluate a wide variety of fuels. The engine is designed to help engineers evaluate a variety of injector types. RT

TWO YEARS ON THE BOUNCE?

From Aston Martin's attack, to Merc's misery, and from faltering Ferrari to Red Bull's sudden supremacy, **Craig Scarborough** examines the F1 teams' response to life after porpoising

TEAMS' fortunes in Formula 1 tend to be cyclical. Momentous rules upheaval for last season shook everyone up and this year subtle changes are continuing to have a big impact.

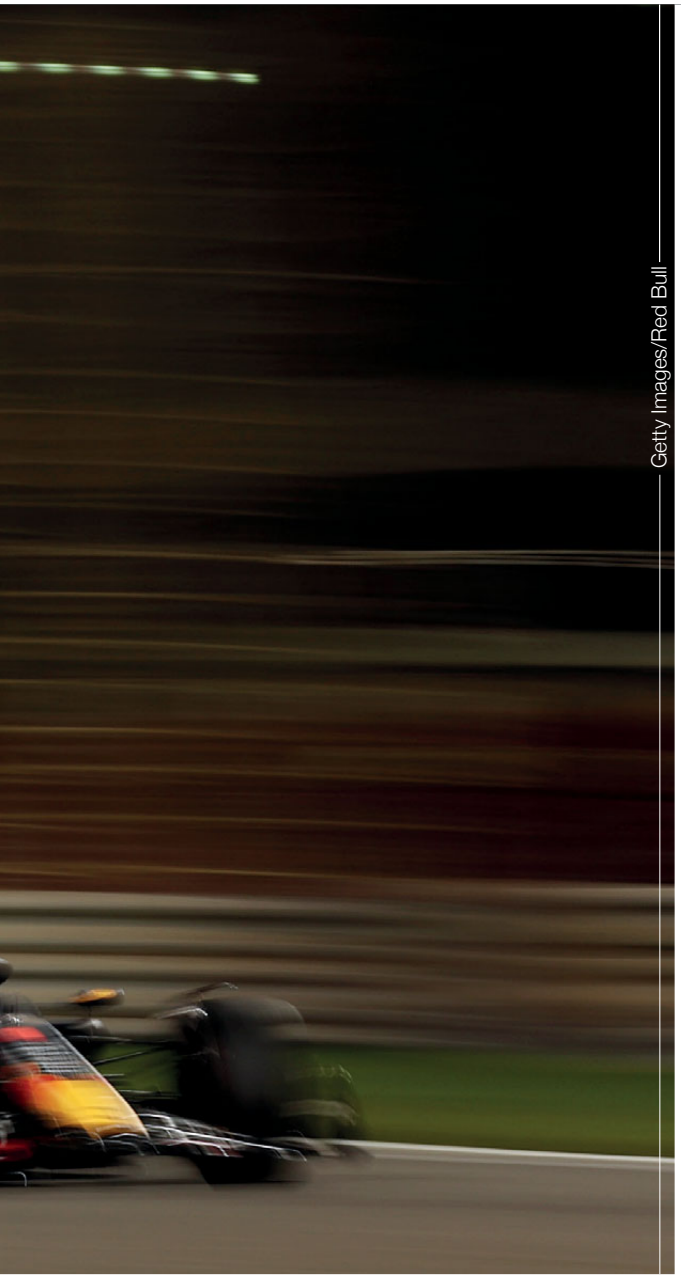
After teams had spent their limited cash and aero testing budgets, it was expected that normal service would be resumed this year, but that's not been the case. Red Bull continues to set the pace, but will be hampered by an overspend from 2021. Ferrari and Mercedes have both dropped the ball for the second season in a row, leaving Aston Martin to pick it up and run with it. But this is a long season of 23 races, so who will take the prize at the end of the year?

Counting the cost

Last year's rules reset was a landmark for the sport, dovetailing well-researched regulations that both managed costs and introduced cars that could race closer to each other. While the accounting for last season is still ongoing, we can guess most of the teams were under the budget cap of $145m, so that intention was met. The aerodynamic changes also appeared to meet the brief, as we certainly witnessed cars being able to race wheel-to-wheel, with far less of the stalemate situations where a following car could not get close enough to consider a pass on the driver ahead.

This closer racing was facilitated by a concept change from a flat bottom/diffuser floor, to something more like a full underfloor tunnel, working in ground effect. F1 had long since departed from the full length tunnels, which were banned in 1982. Indeed, the subsequent flat-bottom cars raced with minimal ground clearance all the way up to 1994, when a 5cm step was mandated below the car, along with the 'plank', in the wake of Ayrton Senna's fatal accident.

The return of the shaped underfloor offered the tantalising benefits of greater downforce, reduced wake and reduced drag. But, for the modern F1 aero departments, these


Getty Images/Red Bull

LEFT The trail of sparks wherever it goes betrays the fact that Red Bull's RB19 appears to be running at the ride height Mercedes so desperately sought to achieve last season

gains would soon be offset by a phenomenon not seen in the stepped-bottom cars: porpoising.

Prior to 1994, the cars' large floor surface, working in such close proximity to the ground, often led to the car bouncing down the straight as the downforce increased, stalled and recovered. By contrast, the aero story of the past decade has been of the exploitation of ever-higher rear ride heights to create a raked setup, giving more diffuser expansion. As a result, during the build-up to the 2022 campaign, the teams' simulations and methodologies were perhaps focused more on this greater ride height than the ramifications of the ultra-close proximity to the ground that was now such a factor.

As the cars took to the track in pre-season testing for 2022, the new ground-hugging floors did not exhibit the same performance and stability as aero testing had suggested, resulting instead in the return of porpoising. But this was a new form of porpoising, or 'bouncing' as the teams called it. It was not created by an underfloor stall, but simply a shift in the centre of pressure.

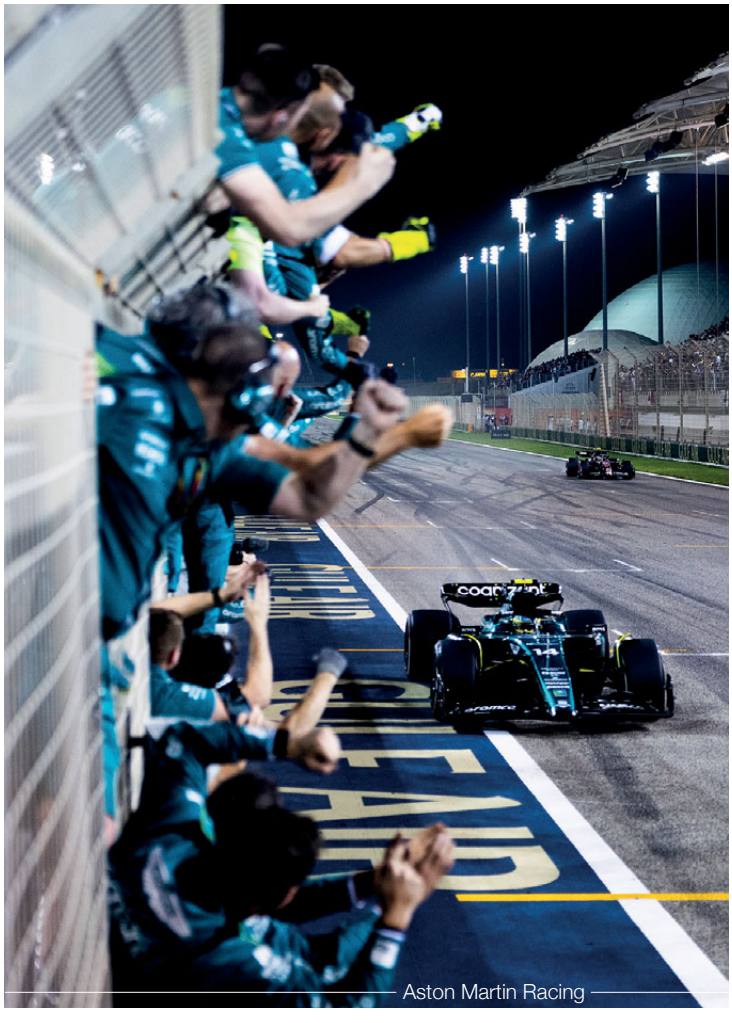
This could be instigated by ride height change caused by increasing downforce on the straights, or sometimes a bump in the track setting off the oscillation. The new rules package's simplification of not just the aero, but also suspension systems, meant that the teams were ill-equipped to deal with this bouncing and bigger trade-offs were necessary.

Two little ducks

In British bingo parlance, 22 is read as 'two little ducks': for most teams, their two cars bobbing up and down along the straights was a true representation of the year they were racing in. Porpoising certainly caught every team out; there were no exceptions. ▶

> *"This was a new form of porpoising: not created by an underfloor stall, but simply a shift in the centre of pressure"*

BELOW The Aston Martin AMR23 has been the standout performer in the early races


Aston Martin Racing

> *"The conspiracy theory was that the Technical Directive scuppered Ferrari's season"*

Every team discovered and cured it in their own way. Red Bull, the squad in the ascendancy, was perhaps least affected, or more likely quickest to respond. It was pointed out that its technical director, Adrian Newey, was the only engineer in the sport with the experience of the old aero concept.

It was clear from early races that Red Bull ran the car with a little rake in its setup. We are talking a difference of millimetres from front to rear, compared to over 100 mm from the season before. At the time, this was perceived as an aero approach to the new rules, being flat to the track to help the floor seal against the ground. In retrospect, this may have been more a response to porpoising than a predetermined setup.

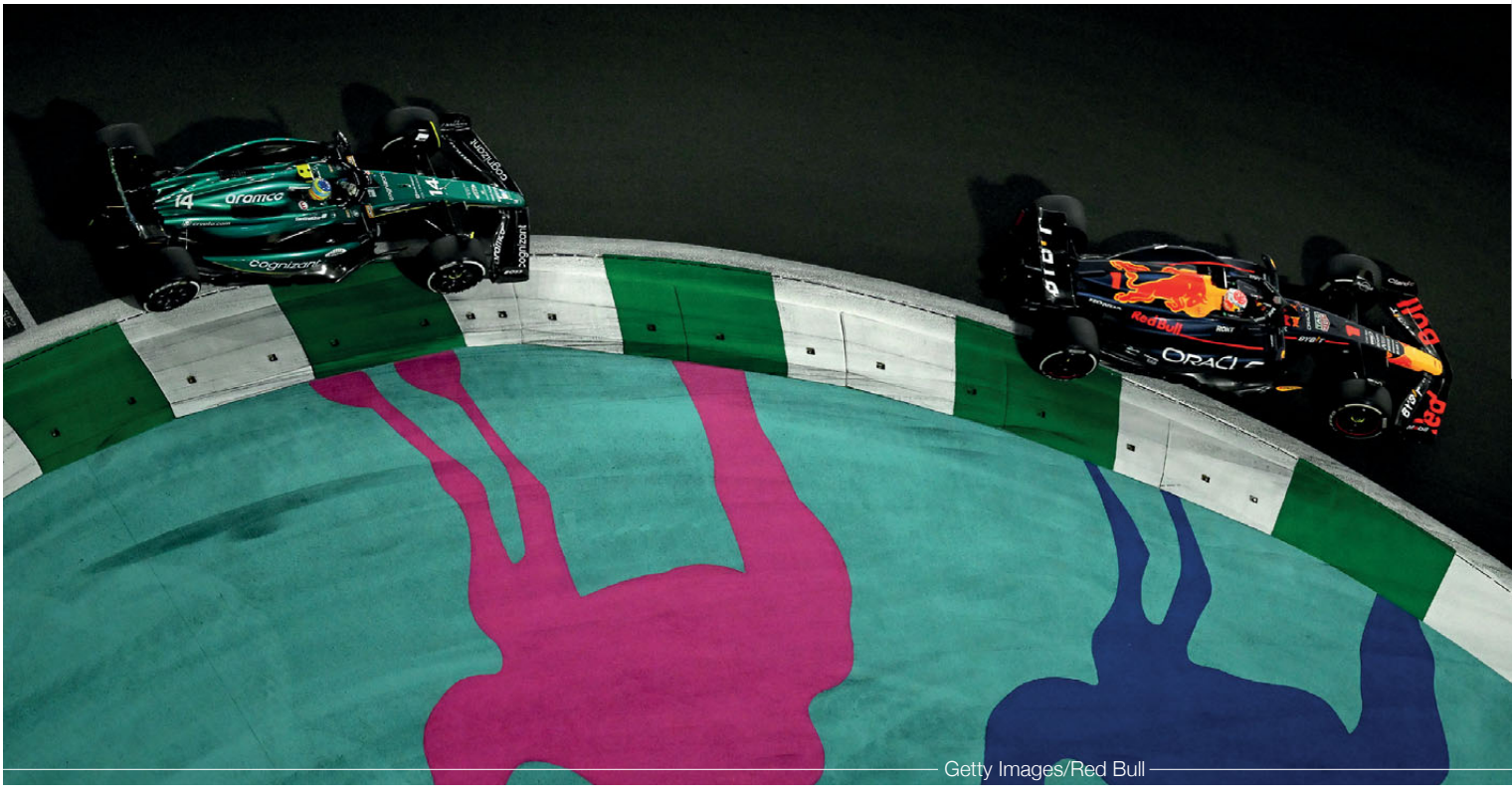
The RB18, which eventually went on to win both championships, also featured some subtle complexity in its suspension. The front inboard suspension was completely hidden from view as the pull rod operation mounts the hardware deep in the footwell, away from inquisitive eyes. But the rear spring/damper setup was visible a few times through the season as gearbox/engine changes were hastily actioned during the course of a GP weekend.

Ferrari

Compliance was provided in pitch and roll through separate and decoupled springs and dampers. Red Bull has used carbon disc springs for many seasons to tune the spring rate curve to its needs and also Multimatic-supplied dampers. But the RB18 also showed a separate compliance element for both pitch and roll in the links between the rocker and the primary spring/dampers. These appear to have offered another setup option to tailor the suspension response, possibly in order to accommodate a softer initial setup, until suspension compression needed to be stiffer to cope with the onset of porpoising.

ABOVE Does Ferrari's poor performance and reliability in the early weeks of the new season suggest its '23 campaign already looks doomed?

BELOW Aston Martin's AMR23 has illuminated the start of the 2023 season. Could it even emerge as Red Bull's closest competition?



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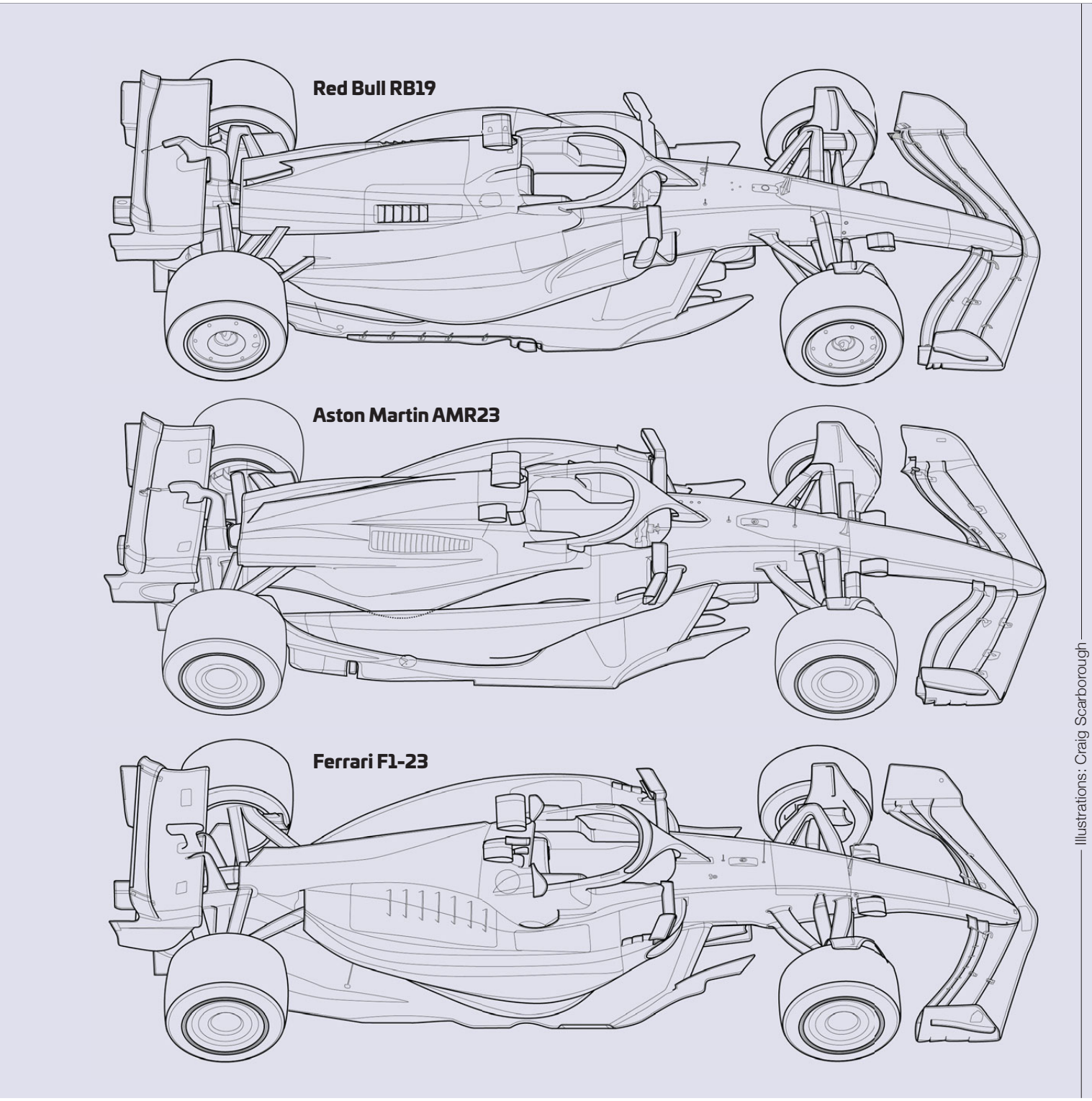


Illustrations: Craig Scarborough

TOP TO BOTTOM
In the second year of the ruleset, the teams have still yet to converge on the same solutions. The treatment of the floor, plus evolution of the sidepods, differentiates the Red Bull (top), Aston Martin (middle) and Ferrari (bottom)

Red alert

Ferrari made a stride forward in 2022, suddenly leaping to the front row and top step of the podium at the start of the year. While the cars exhibited porpoising, sometimes shockingly so, they were able to maintain the pace while still bouncing. Like its rivals, Ferrari ran more rear ride height, with a low front ride height. It was also seen to run similar compliant drop links in the rear suspension.

As the season progressed and the Red Bull found its feet, shedding its initially heavy weight, Ferrari didn't seem to make ground. This led to speculation about the impact of the mid-season technical directive, TD039. Ironically, this technical directive was almost directly the result of Mercedes' plight and lobbying…

The British-based team had developed a very different car to its rivals for 2022. It adopted the 'downforce is everything' approach, with tiny sidepods and a car designed to run super-close to the ground in pursuit of the enticing downforce figures promised by its pre-season simulation. But those promises never translated into reality and by Baku – where Lewis Hamilton complained loudly over the radio and struggled to climb from his cockpit – its ▶

porpoising misery had brought matters to a head. It was the catalyst for the FIA's introduction of an Aero Oscillation Metric (AOM), a value calculated to be the safest level of bouncing acceptable. Should a team exceed this metric, it would be asked to take measures to reduce it, or suffer an FIA-mandated change to ride height.

After much debate with the teams, TD039 was actioned from the Belgian GP. No team was officially sanctioned under the AOM, but often a driver would be warned by their race engineer that a certain speed through particular sections of track would reach the AOM limit, leading the driver to ease off through that sector.

The conspiracy theory was that TD039 scuppered Ferrari's season. The TD also detailed flex tests to the floor; in particular to prevent the rear underfloor flexing upwards. It's believed several teams had some flexibility in the boat-tail section of floor, to prevent an initial bounce leading to full blown porpoising. The FIA always maintained it was happy with the team's design in this area. It's my belief Ferrari was already on the decline by mid-season, so the drop in performance that accompanied the implementation of TD039 was coincidental.

Even with the increased ground clearance enforced by its struggles, the Mercedes W13 was still bouncing. Worse still, the loss of performance from the floor had to be recovered from a larger rear wing – adding drag to an already draggy car.

> *"The RB19 sits super-low to the track. Any trace of rake has gone"*

The team did recover its season, the car racing with high downforce/high drag rear wings. Excellent racecraft/strategy contributed to a win in both the sprint and race at the penultimate GP, where the nature of the track matched the car's sweet spot.

2023: Red Bull strikes low blow

Revised rules for 2023 were a by-product of TD039, mandating a revision of the floor geometry to relieve some of the factors causing the bouncing. These were two-fold: the outer floor edge was raised 10 mm; the diffuser throat raised 15 mm. The plan was to make the floor less peaky in pitch and roll.

With these supposed benefits and a year of experience with these floors under the teams' belts, the 20023 campaign was expected to shake out quite differently to the Red Bull dominance of 2022. Given the knowledge that the teams' simulation and wind tunnel testing did not reflect the actuality of the car on track, work had continued through the year to ensure predictions for the 2023 cars would be more accurate.

Meanwhile, Red Bull's 2022 season was affected even before it began with an aero testing fine imposed for exceeding the budget cap in 2021. Already down on its rivals due to the championship victory, ▶

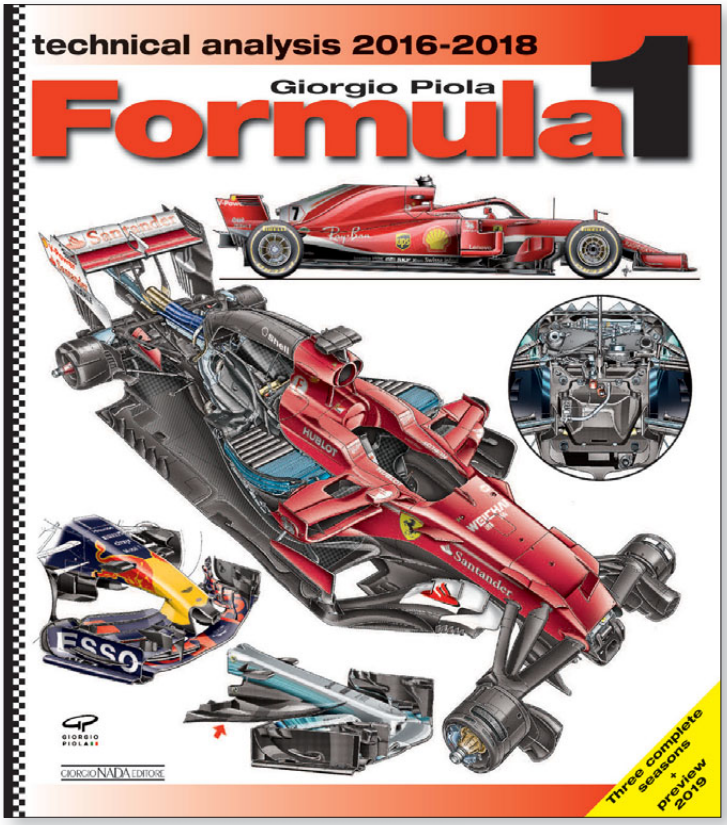
Getty Images/Red Bull

BELOW The RB19s have the jump on the rest of the field, but less aero resources available for the development race

Giorgio Piola

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

NEW



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there was a further restriction on wind tunnel and CFD. Already having just 70% of the median team's aero testing, a further 10% was deducted, giving Red Bull just 63% of the seventh-placed team in 2022. There is inescapable irony that this team was Aston Martin. Williams, which placed last in 2022, has 115% of Aston Martin's aero testing.

Given the need to be fast out of the blocks and yet save development time for both in-season development and the 2024 car, Red Bull's new car was perhaps predictably an evolution of the old one: more an RB18+ than a RB19. However, that's not to say the reigning champions had gone soft over the winter. It's still an aggressive update, but relies on reworking the known good concepts on the outgoing car.

> *"Aerodynamically, the AMR23 has been described as a Red Bull copy by fans, but that's far from accurate"*

In summary, the nose has been raised and the front wing adapted, while the sidepods have evolved to feature a deep undercut along their flanks. But, when sat on track, the key difference in the RB19 is evident: it sits super-low to the track. Any trace of rake has gone.

Once running, sparks abound from the titanium skid blocks in the plank and floor edge. The car appears to be running the design ride height Mercedes had always wanted for the 2022 car. From this, we can perhaps assess last year's rake to have been a response to bouncing, as the new car's ability to run so low, without any ill effects, suggests this is realising the latent performance of these new floors, which can be extracted if you can get the suspension and aero to work in unison.

So far, there's been no sight of the inner springs and dampers. It will take a few races to understand if this is the dual rate setup of the RB18 or something new.

Ferrari, meanwhile, also appeared with an evolved car, retaining the nose/front wing arrangement, the bathtub sidepods and even the slight rake. The team collapsed last season, resulting in team principal Matteo Binotto being replaced with the razor-sharp Fred Vasseur during the winter. So, it's not clear if it was a surprise that the car evolved rather than took a decisive step forwards.

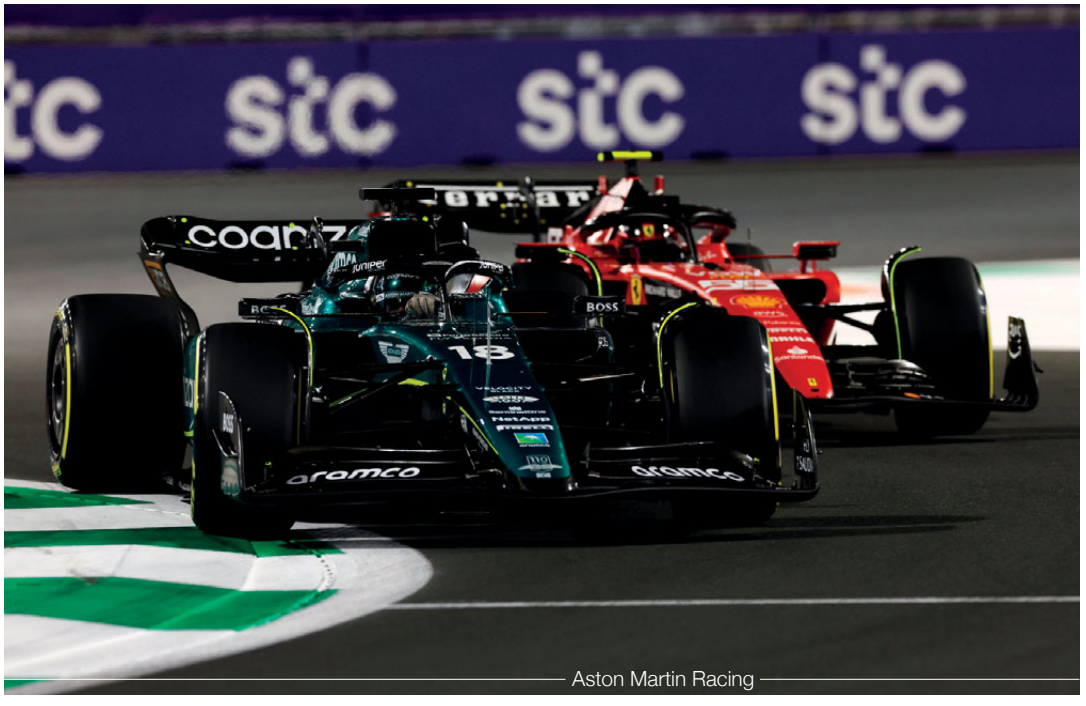
From testing through to the opening races, Ferrari appears to be in more trouble. The minimum expected was to be second fastest, but the F1-23 hasn't achieved that level yet. Its strong traction and good straightline speed is seemingly marred by tyre degradation and the car looks difficult to drive.

This shortfall in performance has already contributed to another departure from the operation: David Sanchez, head of vehicle concept. It's clear something is amiss at the Ferrari technical department.

Comments from the team after the first races suggest, worryingly, that the car isn't working on track at the design ride heights proven in aero testing.

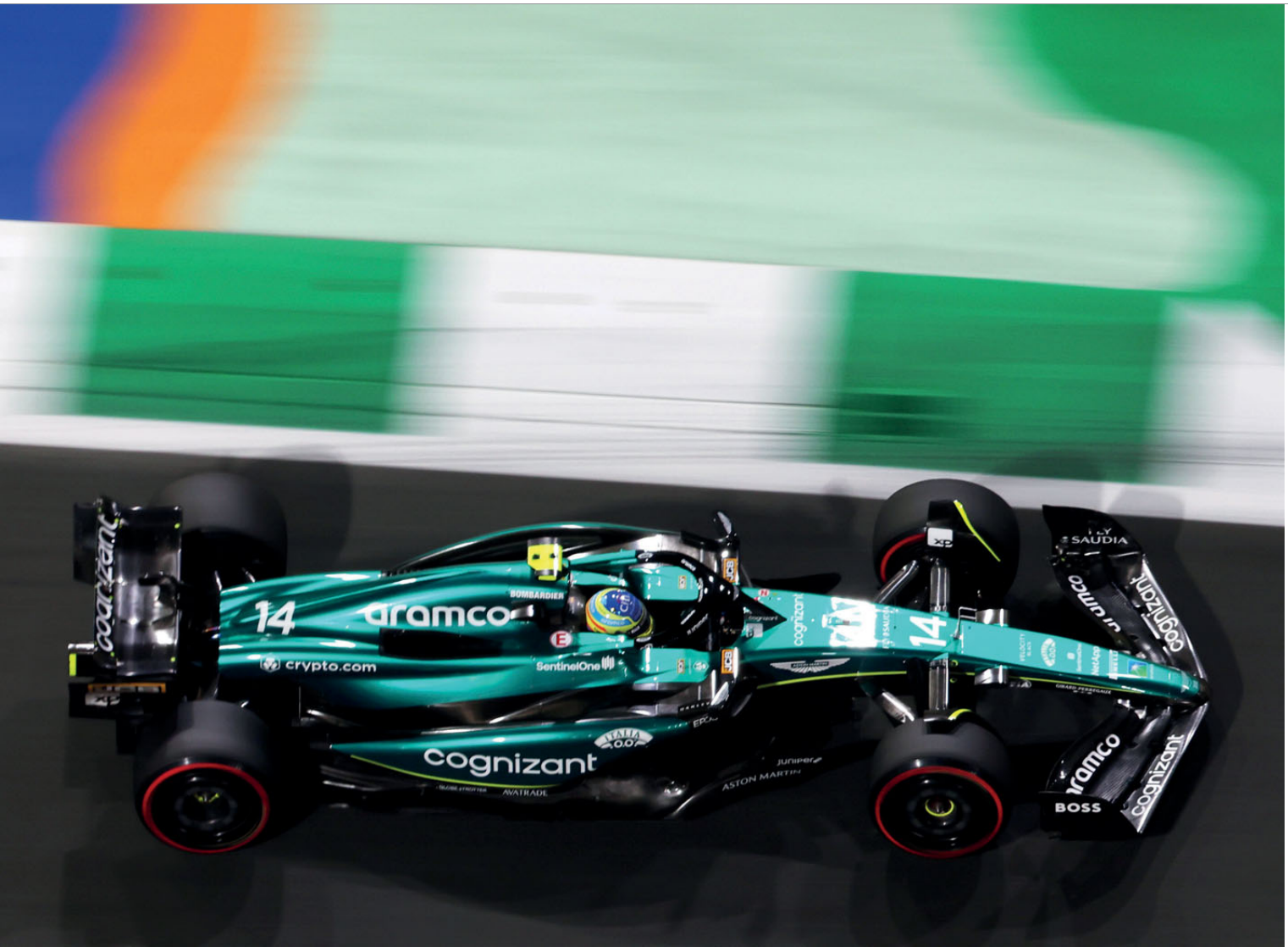
If Ferrari has a correlation problem, it's not an easy fix for several reasons. Firstly, it has only 75% of the aero testing limit, reducing the runs available to recalibrate its simulations. Secondly, this all costs money in a budget-capped formula. Then thirdly, it involves eating time when rivals are already ahead or


Aston Martin Racing



Aston Martin Racing

ABOVE & LEFT
The Aston Martin's sidepods, dubbed 'water slides' by some, have been a talking point – so has its ability to shake up the podium positions



potentially catching it up.

Moreover, its race performance showed tyre degradation was poor. Further bad news is the car lacks reliability. At the season's start, each car has limited power unit components: three of most parts, but just two batteries and two hybrid control electronics. One of the latter failed in Bahrain's practice session on Charles Leclerc's car, another in the race – requiring a third to be fitted for Race 2 in Saudi Arabia, with an associated 10-place grid penalty. After a season of turbo failures in 2022, more race retirements are not what Ferrari needs to mount a championship campaign.

Where did Aston come from?

Ferrari's lack of pace is where Aston Martin enters the chat! This was a team languishing at the back at the start of 2022, with a failed car concept and another interim package already in the pipeline. Aston Martin's season did recover through 2022, which demonstrated the depth of new investment at the team.

It's worth considering the team's heritage for a moment. Based out of Silverstone as the Jordan squad in 1991, the same group has gone through several owners (Midland, Spyker, Force India, Racing Point) to become Aston Martin Racing (AMR). This evolution created a team with limited resources, but the ability to target them to often be best of the rest behind the leading squads.

Andy Green, formerly of Jordan and for a long time the CTO at Aston Martin, once said all that was needed to bridge the gap to the leaders was more money. Well, with Lawrence Stroll's investment in the team, there is now that money: enough to reach the budget cap and investment besides.

There's now a huge new team campus being built opposite the old factory. What's more, the money has brought new staff, chiefly Dan Fallows from Red Bull. A lot has been made of the new car's design being pinned on Fallows, as he was Adrian Newey's Head of Aero at the title winners. But Fallows has joined with a number of staff from Red Bull and other teams. The bolstering of the resources, coupled with the team's inherited ability to maximise them, has borne fruits in 2023.

After a 2022 season to forget, the new year brought the full effect of the team's overhaul, its AMR23 being a distinctive change from the rest of the grid. This is an all-new car, taking only what it had to from its predecessor, largely the Mercedes powertrain, including the rear gearbox carrier and suspension. Aerodynamically, it's been described as a Red Bull copy by fans, but that's far from accurate because it's a totally separate design concept. As yet details of the underfloor are not evident, but the visible floor edge, diffuser outlet and inlet fences are unique, while the sidepods are still generating debate as to their effect and importance.

Sidepods have been a major topic in F1 ▶

Daimler

since last year. There are many variations, with perhaps now four philosophies shown to work: Ferrari with its wide-flanked, ridged-back bathtub design; Mercedes with its narrow zero-sidepods; and Red Bull having a deep undercut with a sloped top. Most teams now adopt the Red Bull format, but Aston Martin has its own concept.

It has to be said that despite the majority of the design debate being around sidepods, they are not the primary performance factor in current F1 cars. But they do influence the way the underfloor works, by loading the floor edge and directing airflow back under the floor in different ways, plus they are a factor in the car's overall downforce/drag figures as they shape the airflow around the car.

As for AMR's sidepods, the fronts are quite conventional, while there is a high inlet with a deep undercut below. But the top surface, rather than sloping down gently as on Red Bull or Alpine's car, is sloped aggressively down over the radiators within.

This slope is partially obscured by the ridged side, forming what people are calling the 'water slides' as the sloped surface drops down between the ridges and the centre of the car. This appears to amalgamate several teams' designs in a new concept, both directing airflow to the diffuser down the water slide and shielding the rear tyres to reduce drag.

> *"The Mercedes is high off the ground compared to the Red Bull, which the team says is running 10 mm lower than them"*

On track, the car runs flat and low, with performance to match the Red Bull in almost all areas. But of course there's always a catch: the AMR23 struggles on straightline speed. It has been able to follow the Red Bull early on in races, but once it's over a second behind, it loses its DRS straightline speed gain and soon drops away at a greater rate per lap.

If the car is closer to Red Bull in performance, then it's also ahead of the struggling Ferrari and Mercedes. Quick out of the blocks, it's also clear that the AMR23 is a car early in its development cycle. If Aston Martin can use its aero testing resource advantage, it should be able to develop throughout the year, at a faster rate than its rivals.

It makes for quite an interesting situation: while Aston Martin is taking

podiums with the same Power Unit and drivetrain as Mercedes, the factory team appears to have recreated last year's issues. When launched, the W14 was full of whispers of a huge leap in performance. Indeed, the changes to the car concept and the level of detail solutions around the car suggested Mercedes had learnt from its terrible year and had bounced back, ready to fight for the lead.

There was a change in nose shape and height, the floor was completely reworked and the contentious zero sidepods have had a logical reworking, with a wider flank to manage tyre wake, albeit retaining the inlet cutting vertically up the side of the transition between chassis and sidepod. Furthermore, the zero format sidepod relies on the fuel tank area of the monocoque being so sculpted to accommodate the radiators, that the main fuel volume sits very high above the hybrid battery, with very little being low down in the car.

Its shakedown runs once again foretold of a year of issues. Day 1 running was curtailed with a fuel problem. Accelerometer sensors on the steering wheel suggested something was amiss with the power steering, and at low ride heights the car was clearly bottoming, if not fully porpoising.

LEFT The W14 might run high but at times still has the pace to make life hard for rivals, as well as its own drivers

Daimler

ABOVE Time for a change of concept? The data does not make good reading on the Mercedes screens

Testing and into the first races showed the car was clearly struggling for performance, this being relative as it was still ahead of the rest of the grid, but behind Aston Martin and fighting with Ferrari. Again, it transpires that the dreaded correlation between aero testing and reality has gone askew. This time, there are rumoured to be issues with the wind tunnel model itself, but at this early stage there are details to confirm.

Looking at the W14 on track, it's high off the ground compared to the Red Bull, which the team say is running 10 mm lower than them. This added clearance damages performance, but keeps some of the problems associated with grinding along the track at bay; it also leaves the car a handful to drive and it's clear the car is in far from its ideal window in this configuration.

Looking ahead, Mercedes had already planned a step forwards in aero setup for the race at Imola. But worryingly, there have been increasing demands for a concept change from the team principal, Toto Wolff, and the drivers. Although at this stage the exact nature of the correlation problems aren't public, saying that a major change is needed when the issues might be far more subtle and easy to change, is akin to the proverbial 'throwing the baby away with the bathwater'.

Chasing the Bull

Given these varying fortunes at the start of the year, how might the 2023 season shakeout? For Red Bull the message is clear: make points early in the title race, as rivals may well catch up from both their own development and the lack of aero testing available to the champions. A cautionary note also needs to be sounded concerning reliability, for the drivetrain has shown early weakness in the gearshift smoothness and driveshaft stress.

For Aston Martin, the stakes have been raised. There's a real chance it could establish itself as the second best team and wins could be possible if the cards fall the right way. Since Jordan in 1991, there's never been an opportunity for this outfit as big as this. But it is up against wise and experienced opposition; it will need to push hard to maintain its position, by developing the car and overcoming the straightline speed deficit.

Ferrari, as ever, has no excuse for struggling, but this year I think the reorientation under Fred Vasseur might be more important than the race for second. The correlation problems could be a quick fix or could highlight a fundamental car concept issue. The Prancing Horse is already struggling with reliability and PU components – in a season of 23 races!

Looking at its recovery last year, Mercedes might be expected to gain the most throughout the season. That is based on its correlation problems being easily resolvable and the new car demands not being required and/or listened to. A revised car wouldn't be expected to appear until mid-season.

The stakes are high and while the championship is seemingly a slam-dunk for Red Bull, it's looking likely at the moment that two of its rivals have missed getting the ball in the hoop entirely. The pace of the fightback is what's going to make the season so interesting. At some point, Red Bull's performance will plateau just as its rivals are getting started. Exactly when that crossover point arrives will really decide the championships.

MEET THE BEAST

Featuring 2024 Honda IndyCar hybrid power unit technology, the CR-V Hybrid Racer has been developed as a rolling laboratory for Honda Performance Development's experiments with electrification, hybrid technology and renewable fuels. **Chris Pickering** talks to HPD President David Salters

OFFICIALLY, it's the Honda CR-V Hybrid Racer. But we far prefer the informal term that its creators have for the car you see here. The Beast.

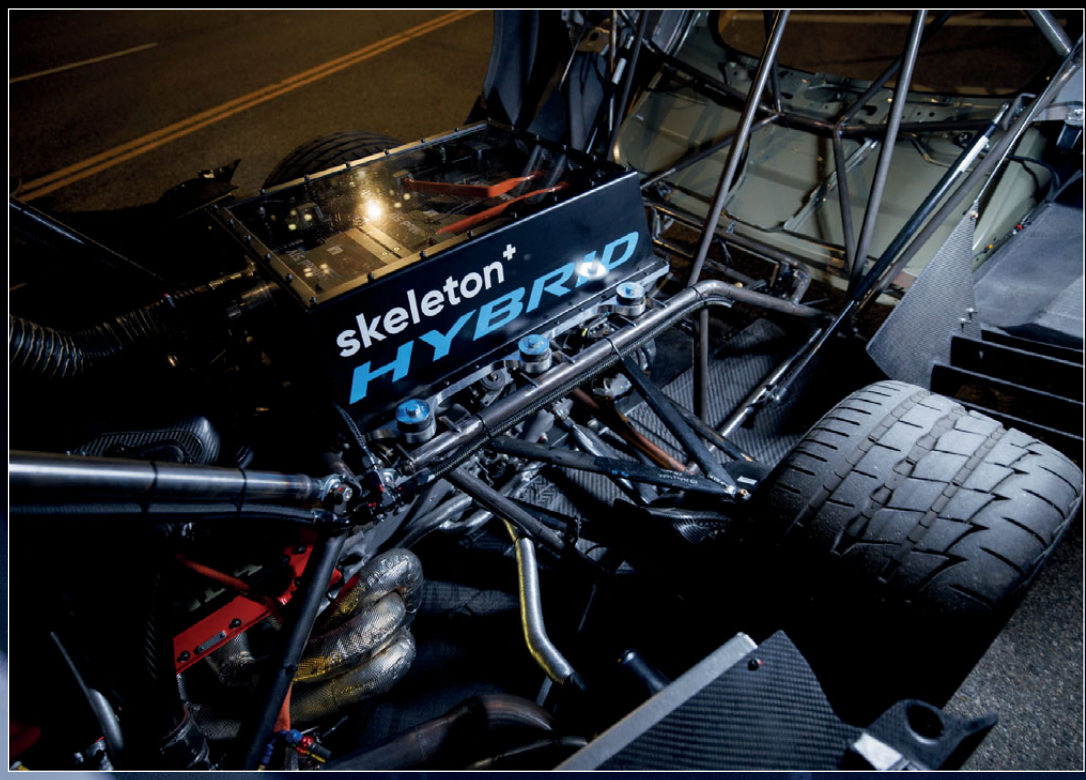
Part IndyCar and part NSX GT3, perhaps the most surprising thing about The Beast is that it does also have some genuine CR-V production parts in it. Not a lot, admittedly, but the windscreen, the roof and the rest of the bodywork from the beltline up are taken straight from the production line. It even has the factory sunroof.

The purpose of this car is twofold. Firstly, it's a promotional tool to stimulate interest in Honda's hybrid technology using one of the company's most popular road-going models as its inspiration. Secondly, it's designed to serve as a testbed, giving the engineers a sandbox to experiment with different ideas.

"It just started off with some brainstorming," recalls David Salters, president and technical director of Honda Performance Development (HPD). "We wanted to do something fun with electrification that would showcase some of our skills. And we also wanted to create a laboratory for different powertrain technology that will evolve over time. At some point in the future, [the powertrain in] this car will begin to morph into something else."

In theory, it seems like a straightforward exercise. The HPD engineers already had the basis of the powertrain in the 2.2-litre twin turbocharged IndyCar V6. Although substantially different in its specification, the work done on the powertrain for the 2024 car provided a framework for The Beast's hybrid system.

The rear end structure could be taken from the Dallara IR-18 IndyCar, including a modified version of its pushrod-operated double wishbone suspension. At the other end, the Acura NSX GT3 Evo22 – also developed by HPD – would supply the front suspension and its Brembo brakes. The BorgWarner



RIGHT Skeleton Technologies supplies the supercapacitor bank. The technology's rapid charging ability will see it favoured over the more common battery-based ERS in the 2024 IndyCar hybrid powertrain

Photos: Larry Chen

ABOVE The car is billed as a "an IndyCar Wolf in CR-V Clothing"

EFR7163 turbochargers and McLaren Applied Technologies TAG 400i engine control unit would come from the IR-18, as would the Xtrac six-speed transmission and the Mega-Line paddleshift system. Even the radiators could be adapted from those found on the current IndyCar.

So, a simple question of connecting the dots? "That's exactly what we thought… turns out, it's quite complicated," jokes Salters. "We had a lot of knowledge around the front and back of the car, and we thought pure enthusiasm would glue it together. In reality, it's been a great learning experience."

That enthusiasm may have powered the project, but it also relied on a good deal of hard work. What started off as a Saturday morning club grew into a progressively bigger commitment. In total, the project took 11 months, which is a pretty swift turnaround for what effectively constitutes a whole new racecar. That's all the more impressive when you consider that it was all secondary to HPD's day job. The Beast began to take shape just as the firm was gearing up for what would prove to be its third consecutive Indy 500 victory.

"It was such a passion project that everyone just wanted to get involved, because it literally is a beast. It's awesome," Salters enthuses. "But there was a lot of detail work involved. We actually ended up doing quite a lot of vehicle dynamics simulations to make the two ends of the car play nicely together. A fair amount of work went into the kinematics and the ride heights to ensure we could set the car up as we wanted and it ▶

wouldn't have any nasty vices."

Even seemingly straightforward tasks like balancing the brakes became quite involved. As with the next generation IndyCar, the CR-V would run a hybrid system on the rear end with no energy recovery from the front axle. However, the brake systems on the current IndyCar and the NSX bore little resemblance to each other, and they would be going onto a vehicle bigger and heavier than either of them.

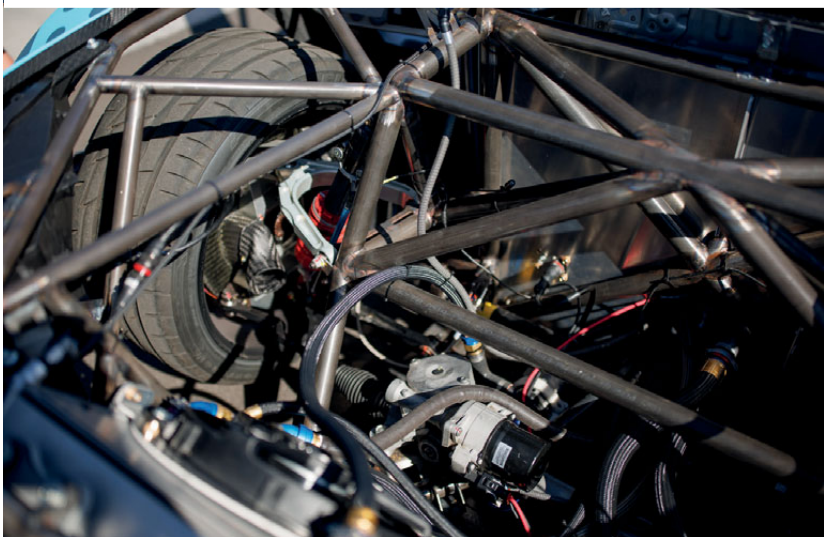
On the front, the 380 mm steel discs of the NSX GT3 Evo22 were retained. The IndyCar-derived setup at the back was adapted to take custom-made 355 mm steel discs from Brembo. As with the kinematics development, HPD started off with a simulation model to ensure that the brakes would behave as intended in their new application.

All this work has paid off, HPD's commercial manager John Whiteman points out: "We had James Hinchcliffe driving the car for some demonstration laps at St Petersburg for the first event of the season. He hopped into the car for the first time on Friday, having never seen it before, and went back Saturday and Sunday. And it was quite surprising, based on his feedback, just how well-sorted it was for a brand new car on a relatively narrow course like that."

Photos: Larry Chen

Blood, sweat and tears

The main part of the chassis is a chromoly steel spaceframe, using the engine and transaxle as stressed members. An additional tubular steel frame helps to support the bodywork, which is hinged at the back, allowing the entire rear section to be tilted up as a clamshell. The lower half is of carbon-composite construction, incorporating a massive front splitter and extravagantly louvered, flared wheel arches. There's an equally impressive rear wing, along with butterfly half-cut doors on either side for the driver and passenger.



TOP The Beast has sufficient space available at the front to accommodate a motor (or motors) in the future

ABOVE The main part of the chassis is a traditional spaceframe construction, using the engine and transaxle as stressed members

LEFT The CR-V Hybrid Racer was demonstrated on the streets of IndyCar's opening race at St Petersburg

Yes, you can take a friend along in The Beast.

"This was very much a collaborative effort," notes Whiteman. "Along with the mechanical design from HPD, American Honda's design group in Torrance, California, handled the styling. The Automotive Development Centre in Ohio did a lot of the assembly work and there's a lot of blood, sweat and tears from them in the car. It wouldn't exist without their long, long hours of putting the car together."

Styling inspiration came from the silhouette racers of the 1980s and 1990s, from series like Group B rallying, Japanese Super GT racing and the DTM. Even the unique livery designed by American Honda's senior exterior designer Lili Melikian is a love letter to motorsport, with ghosted images of the IndyCar powertrain and the series' circuits hidden within its patterns.

Hybrid heart

The Beast's direct-injected V6 – taken from the current IndyCar – is the same unit that will form the basis of HPD's hybrid powertrain next year (plans for the series ▶

to move to a 2.4-litre format having been postponed indefinitely due to supply chain issues). However, that's not to say that Salters and his colleagues have simply lifted the powertrain out of the racecar.

> *"We wanted to create a laboratory for different powertrain technology that will evolve over time"*

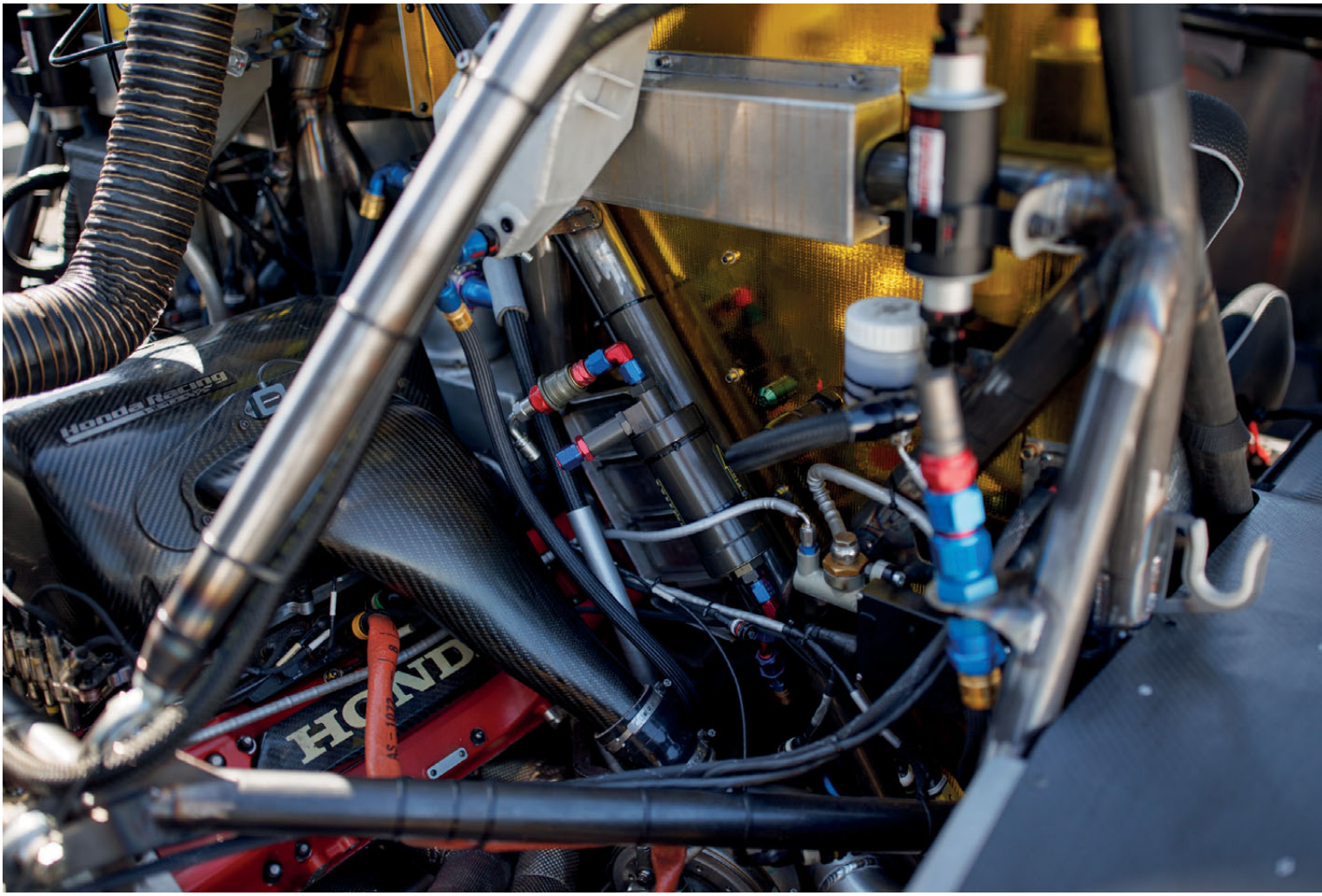
"There are similarities and we've used some of the same suppliers because we have good relationships in place, but the actual components are different," comments Salters. "We use them in different ways too. The CR-V Hybrid Racer weighs almost 3,000 lb (1,360 kg) and we've put a lot more energy in it so we can do some more EV-orientated things with it and learn about those."

IndyCar has yet to confirm the suppliers or the capacity of the energy storage system that will be used in the series next year. What we do know is that it will be a supercapacitor-based system, and The Beast uses something similar, albeit larger. German-Estonian cleantech company Skeleton Technologies supplies the supercapacitor bank, while the MGU comes from British start up Empel Systems. Again, it's too early for HPD to comment on the IndyCar configuration, but it is known that the hybrid system on the CR-V is packaged differently, with the MGU placed behind the gearbox.

All this makes The Beast a significantly different machine to its forthcoming single-seater counterpart. It's also electronically speed-limited with very different aero characteristics to the IR-18, and a set of road-legal Firestone Firehawk Indy 500 tyres shod on 2Elle Engineering rims in place of the purpose-built slicks on the racecar. As such there's no danger of infringing IndyCar's track test restrictions – a rig test based on the 2024 car's specifications would be far more informative – but there are still lessons that can be applied back to motorsport.

Unusual

"We're working with IndyCar, GM and Ilmor to support the introduction of the hybrid system in 2024. This is a very different application, but there'll be some learnings around the general behaviour of the components for sure, which we'll share with ▶



BELOW The Beast's direct-injected V6 is the same unit that will form the basis of HPD's hybrid powertrain next year

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LEFT Its looks are reminiscent of the Group B rally and silhouette GT racing cars of the 1980s and '90s, but the technology under the skin is strictly 21st century

everyone," comments Salters. "It's also been really useful for team building, getting to know Skeleton and Empel better."

In particular, it's helping to build the HPD engineers' experience with supercapacitors. This isn't the first time that the technology has been used in motorsport – notably, Toyota used supercapacitors on its TS030 and TS040 LMP1 machines – but it is comparatively unusual, with most manufacturers choosing to go down the battery route.

Supercapacitors

Although the specifications have yet to be confirmed, the push-to-pass system in IndyCar will almost certainly have a far lower energy capacity than the heavily-hybridised powertrains found in sportscar racing. As such, it's likely to be power density (rather than energy) that dominates the requirements, and that's where supercapacitors excel.

"Supercapacitors are very well suited to short bursts of high power. They can be charged and discharged very quickly," comments Salters. "They're also inherently safe. You can't put them into thermal runaway or anything like that."

That's not to say that the installation is trivial, he points out. The supercapacitors still need to be cooled, and there's very limited packaging space when you're dealing with a chassis that was designed ▶

Honda CR-V Hybrid Racer Specifications

Powertrain
Honda HI23TT 2.2-litre, twin-turbocharged V6 engine
BorgWarner EFR7163 turbochargers
McLaren Applied Technologies TAG 400i Engine Control Unit
Drive-by-wire controlled port throttle
Shell 100% renewable race fuel
Driver-activated Empel electric motor generator unit
Skeleton supercapacitor energy storage system
Xtrac six-speed transmission; Mega-Line assisted paddle-shift

Chassis and Bodywork
Chromoly tube frame chassis
New, 6th generation Honda CR-V Hybrid bodywork from beltline up
Standard Honda CR-V Hybrid windshield and greenhouse
Custom carbon fibre lower bodywork incorporating flared fenders
Butterfly half-cut doors provide access for driver and passenger
Radiator adapted by HPD from the Dallara IR-18 IndyCar
Clamshell rear bodywork to display power unit and drivetrain
Custom downforce-producing front splitter and rear wing

Suspension
Front suspension from HPD-developed Acura NSX GT3 Evo22
Rear suspension adapted from Dallara IR-18 IndyCar
Brembo 380 mm front brakes from Acura NSX GT3 Evo22
Brembo 355 mm custom rear brakes adapted to Dallara IR-18 suspension
Firestone Firehawk Indy 500 Ultra-High Performance Summer Tyres
Front tyres 285/35-20; Rear tyres a massive 305/35-20
2Elle Engineering 20x10.5 Front and 20x11 Rear two-piece alloy wheels

Whacky racers

THE Honda CR-V Hybrid Racer is perhaps the strangest vehicle ever to come from the fertile minds of IndyCar engineers, but it's certainly not alone.

In 1995, to celebrate 10 years of the Espace going on sale, Renault created the bonkers Espace F1. This took the 3.5-litre V10 engine and rear chassis structure from the Formula 1 World Championship-winning Williams FW15C and combined it with a four-seat carbon fibre body based on the iconic French people carrier.

The Espace F1 produced 800 bhp and 520 lb/ft of torque. The naturally aspirated 3.5-litre, 40-valve V10 engine was mounted in the middle of the car. It sent drive to the rear wheels through a six-speed, semi-automatic sequential gearbox.

The MPV could go from 0-62 mph in 2.8 sec and 0-120 mph in 6.9 sec, with a top speed of 194 mph, and could still seat four people.

Ford's UK arm also has a long history of similarly outrageous projects, stretching right back to the GT40-based Transit Supervan of 1971. This matched up an actual Ford GT40 chassis and running gear – including a 435 bhp 5.0-litre V8 – to the body of a classic 1965 Transit van.

Its latest iteration, the Supervan 4, features a 2,000 hp electric drivetrain with four separate motors. RT

BELOW & BOTTOM
Renault's Espace F1 (below) and Ford's 1971 Supervan (bottom)

more than a decade ago for a non-hybrid powertrain.

"Packaging is always a challenge in any racecar, in terms of space, vibration and heat management," notes Salters. "I think as IndyCar reveals more details, you'll see it's a pretty novel system with some very cool ideas on the racecar. We don't have the same constraints with the CR-V, so we've chosen a different set of components that work well for that application."

Quite how IndyCar will eventually utilise hybrid technology on its ovals remains to be seen. There has been speculation that regeneration will occur under conventional braking at road and street courses, but that some form of steering wheel-mounted regen paddle – similar to those used in Formula E – could be employed on ovals.

"The jury's out with the ovals really on what we do with electrification," suggests Salters. "We'll see what we can do to challenge ourselves there. Obviously, you do get drafts, tows, lifts in ovals and it'd be intriguing to see how we can use electrification to improve the show. The racing in IndyCar, as we know, is already standout. But can we make it even better or help differentiate more or show the skill of the driver and help with the entertainment or showing the technology? We're thinking about this stuff at the moment with IndyCar. So there's some good discussions happening, honestly speaking."

Sustainable fuel

Another interesting feature of The Beast was the decision to use the fully-sustainable second generation biofuel from Shell that debuted in the IndyCar series this year. Said to cut greenhouse gas emissions by an impressive 60 per cent compared to conventional fossil-derived gasoline, it's a 'drop-in' substitute for the previous E85 fuel that doesn't require any significant engine modifications.

"IndyCar was already one of the leading series for sustainable fuels with the previous E85 blend. This moves things on even further," comments Salters. "The numbers involved are huge. It's a single, straightforward change that reduces the CO2 emissions by 60 per cent. And it's here already – we're racing with the fuel this season in IndyCar, so the opportunity was there to use this technology in The Beast as well."

And this is just the start. The Beast's


Chris Owens/IndyCar

capacious spaceframe has been designed to accommodate different powertrain technologies, with further electrification a distinct possibility.

"Many glasses of wine were being consumed in the brainstorming process, which is always a bit dangerous," jokes Salters. "We had an evening at St Pete's where we started to mull over what we might do with it. We haven't quite figured that out yet – we've only run it for two days so far – but I'm sure at some point, it will become full EV and there'll be motors everywhere or something like that."

It's an intriguing prospect, but first The Beast has a packed schedule of demonstrations at IndyCar events throughout this season. For the fans, this will be an opportunity to see (and hear) IndyCar technology as they've never experienced it before. It's also hoped that the CR-V will attract interest from outside of the series, showcasing HPD's capabilities to a wider audience.

"This was a project that stretched right across Honda in North America, and it's been very motivational," comments Salters. "We want people to get interested in IndyCar racing, and see what we're doing. And we're also trying to celebrate our heritage in the series. Honda has a great car culture following among people who aren't necessarily into the racing. This project brings those two sides together, and it will hopefully generate more interest around what we do, and also around IndyCar itself."

After all, if you want to get noticed, an 800 hp Honda CR-V seems like a pretty good place to start. Throw in low-carbon sustainable fuel and a hefty dollop of electrical assistance, and you have a thoroughly modern Beast. RT

> *"We ended up doing a lot of vehicle dynamics simulations to make the two ends of the car play nicely together"*

ABOVE The challenges of IndyCar's imminent switch to hybrids haven't caused HPD to neglect its 'day job': winning races. Marcus Ericsson dodged multiple incidents in a chaotic season-opening race, winning the Firestone Grand Prix of St. Petersburg

RIGHT The bodywork is hinged at the back, allowing the entire rear section to be tilted up as a clamshell

THE MAGIC OF MERC'S MAGNIFICENT FORMULA E POWERTRAIN

The Mercedes-EQ powertrain redefined Formula E, dominating the end of the World Championship's Gen2 era. **Chris Pickering** discovers what made it so special

THEY never do things by halves at Mercedes-Benz. With the team struggling for form currently, it's easy to forget that the Northamptonshire-based outfit has still won all-bar-one of the Formula 1 World Constructers' championships since the current regulations were introduced in 2014. It was a similar pattern with the brand's involvement in the glory years of the DTM championship in the nineties, Group C in the eighties and Fangio's domination of F1 in the fifties.

The Silver Arrows' comparatively brief venture into Formula E was no less emphatic, with two double world championships from three seasons as a full works team.

Much of that success came down to the strength of the Mercedes-EQ powertrain, which also stood customer team Venturi in good stead – the Monegasque outfit finishing as the runner up to Mercedes in the drivers' championship in Season 7 and in the constructors' championship in Season 8.

To find out just what made that package so special, we spoke to Pierre Godof – chief engineer for F1 powertrains at Mercedes AMG High Performance Powertrains (HPP) and formerly chief engineer for powertrains on the Formula E programme.

Godof transferred over to the Formula E squad from F1 in 2018. By that point there was already a small group of HPP engineers supporting the HWA Racelab team that was quietly paving the way for Mercedes' full works effort the following season.

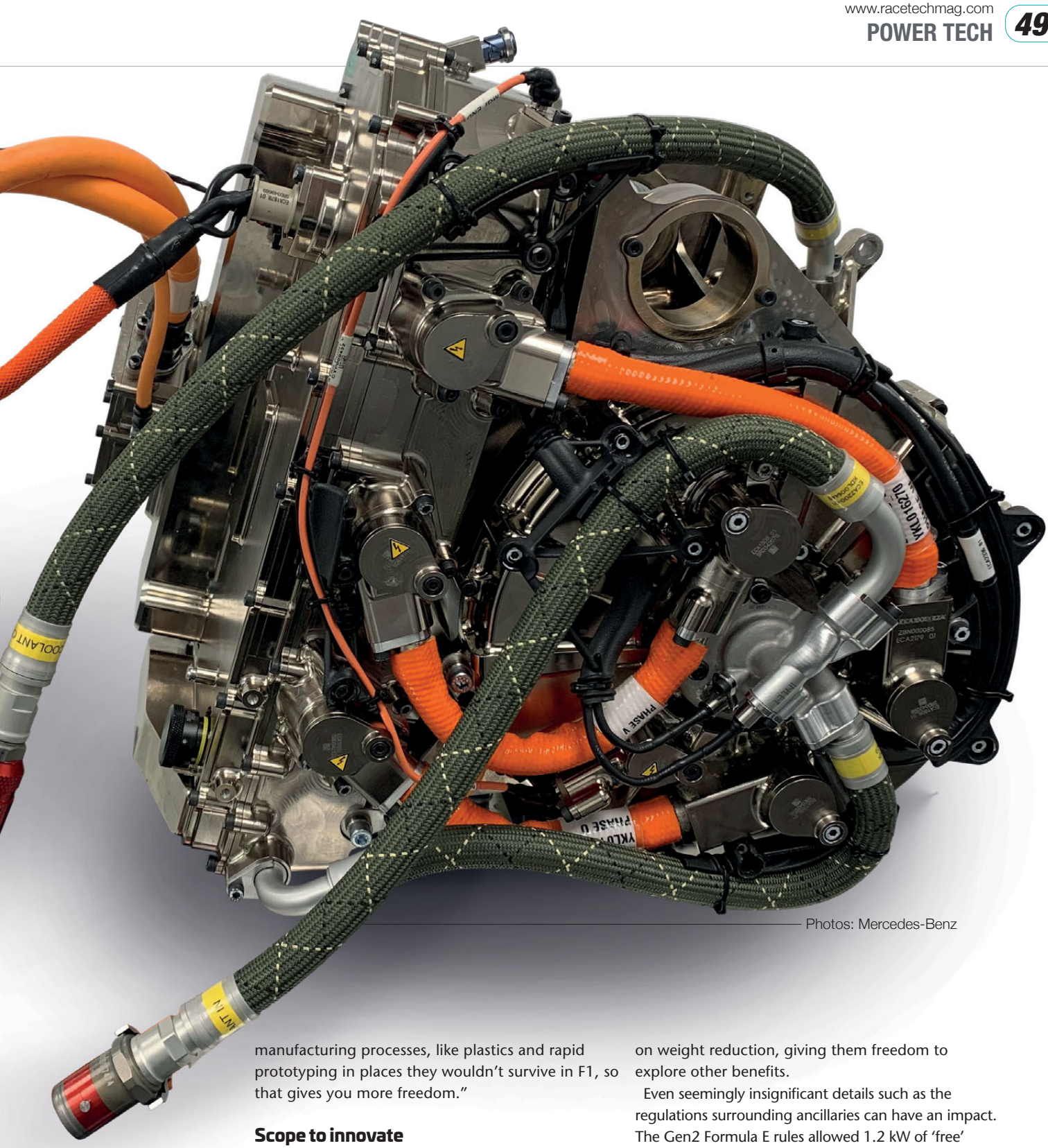
"Andy Cowell [HPP's managing director] was the person who made that happen," recalls Godof. "His vision was to base the FE powertrain on Formula 1 technology, and then use that as another path to promote our electric powertrain learning. It's something we had seen in 2008 with the KERS system. We found that when HPP picks up another technology, it just promotes learning throughout the operation."

Working with the HWA team helped to fast-track Mercedes' entry into Formula E, Godof recalls.

"Access to those people really helped us to accelerate our learning when it came to Formula E-specific topics," he comments. "The environment is totally different to Formula 1. In some respects it's actually a much easier set of conditions to work with – the levels of temperature and vibration, for instance, are a lot lower than Formula 1 – but FE brings its own unique challenges."

The average speed in Formula E is a little over half that of Formula 1, and the comparatively short sessions mean that the cars cover far less distance.

"In Formula 1, we'd made engines with a mileage target of nearly 10,000 km, but in Formula E it's less than 3,000 km," notes Godof. "That makes the development a lot quicker – we could do a full durability test on the dyno in three days. Every new idea you come up with, you put it in there and a few days later you've got your answer. Plus, the lower temperatures open the door to different



Photos: Mercedes-Benz

ABOVE Development of the motor and inverter challenged Merc's engineering group to push their own boundaries

manufacturing processes, like plastics and rapid prototyping in places they wouldn't survive in F1, so that gives you more freedom."

Scope to innovate

This sense of freedom becomes a recurring theme while talking about Formula E. While key elements of the car are made up of spec components, such as the chassis, the aero kit and the battery, this actually gives the engineers working on the powertrain more control over the vehicle as a whole. For instance, the standardised bodywork means the powertrain engineers aren't under pressure to trade packaging volume or cooling requirements for aerodynamic gains. Likewise, the comparatively generous minimum weight allowance means that the engineers don't have to focus quite so aggressively on weight reduction, giving them freedom to explore other benefits.

Even seemingly insignificant details such as the regulations surrounding ancillaries can have an impact. The Gen2 Formula E rules allowed 1.2 kW of 'free' power that could be used to drive pumps and suchlike outside of the 250 kW allowance for propulsion.

"In FE you can use a fan to cool the gearbox, which in F1 would be called an aerodynamic device," comments Godof. "That opens up more control options. For instance, you can turn off the gearbox pump initially to raise the oil temperature, which brings the viscosity down and reduces the losses. It's much more interesting than dealing with mechanically-driven ancillaries. Overall, FE is a nice playground for a powertrain engineer."

The high degree of standardisation elsewhere on ▶

LEFT Pierre Godof was chief engineer for powertrains on the Formula E project

the car also means that the powertrain engineers can focus their work on the motor, power electronics and drivetrain, knowing that the rest was in safe hands. "When you do the FMEA analysis for an electric or hybrid car, a lot of it rests on the battery being safe," notes Godof. "That's something the Formula E organisation has handled very well indeed. I remember going to the Season Five track tests. We saw powertrains blowing up with big high-voltage shorts elsewhere in the system, but the battery still survived. That made us realise that people who were still getting to grips with the technology could turn up, knowing that their battery was safe."

ABC

There were to be three main iterations of the powertrain in the end, running alphabetically from EA to EC. As Cowell had intended, the first of these stuck very closely to the contemporary Formula 1 ERS template.

"We started off with exactly the same methodology that we used to design the MGU-K, the inverter and so on in F1 – to the point where the MGU-K in Formula 1 produced 120 kW so we knew we'd just double the size of the power module to cope with 250 kW in Formula E," comments Godof. "You learn a lot about your simulation models from scaling things up like that, as it's not an opportunity you normally get in Formula 1."

From a practical perspective, the F1 technology also gave the team a well-proven starting point. The EA powertrain was a development platform that was never intended to be raced, but it set things in motion for what was to come.

Although it originated as an engine manufacturer, HPP's Formula 1 KERS experience meant that there was already plenty of in-house expertise on the electrical side. Perhaps ironically, it was the resolutely mechanical world of drivetrain design that took the Brixworth engineers out of their comfort zone.

"We were used to making geartrains for the engine itself, but a complete gearbox and differential was not really in the HPP portfolio at that time, so that was a bit of a departure," Godof admits.

One of the key things that had emerged through the early discussions with HWA was that efficiency was the dominant factor in Formula E. Mercedes' simulations confirmed that a one per cent vehicle efficiency improvement equated to around a tenth of a second in lap time. This guided the development of the gearbox and the packaging of the motor.

"We'd heard that some of the teams were using longitudinal motors. Instinctively that just seemed wrong, because you need a bevel drive; that inherently involves sliding between the gears, and hence friction. So straight away we went for a transverse motor configuration with straight cut gears," notes Godof.

This basic template remained throughout the Formula E programme, but a question mark lay over how many gear meshes to use. A single mesh was fundamentally the most efficient option, but it required the use of a very big ring gear and a small pinion, resulting in low motor speeds. Adding a compound gear in between the two would mean a much smaller ring gear, which would reduce the size and mass of the transmission casing. It would also increase the speed of the motor, which is beneficial for electrical efficiency. However, the downside is that two gear meshes generate twice the frictional losses of one.

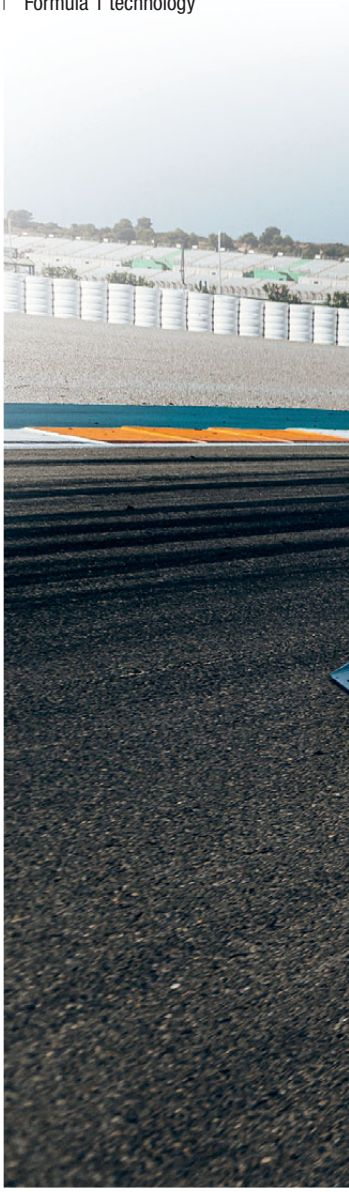
> *"The F1 mindset was one of Mercedes' biggest differentiators in Formula E"*

"It was all about working out the best compromise in terms of losses. After the FEA work on the gearbox, we always tested on the rig to quantify the losses. We also spent a lot of time on the rig and the test bench with the motor and the inverter," comments Godof. "That's not just a question of testing the components that you've made; it's also about validating your simulation model so you know what to optimise in the future. If you work with non-validated models, you can convince yourself you're doing the right thing when actually you're not."

Taking a risk

The concept for the EA powertrain was approved in March 2018, nine months before the start of Season Five. It completed a single track test in March the following year at the Varano circuit in Italy, just down the road from Dallara. By this point, work had already begun on the EB specification that was to follow, but the primary role of EA was to confirm whether this was

BELOW From the start, the vision was to base the FE powertrain on Formula 1 technology



heading in the right direction.

"We knew we were taking a bit of a risk by starting EB so early, but a lot of the items inside an electric motor have quite long lead times attached to them, so we wanted to get the ball rolling on those," notes Godof.

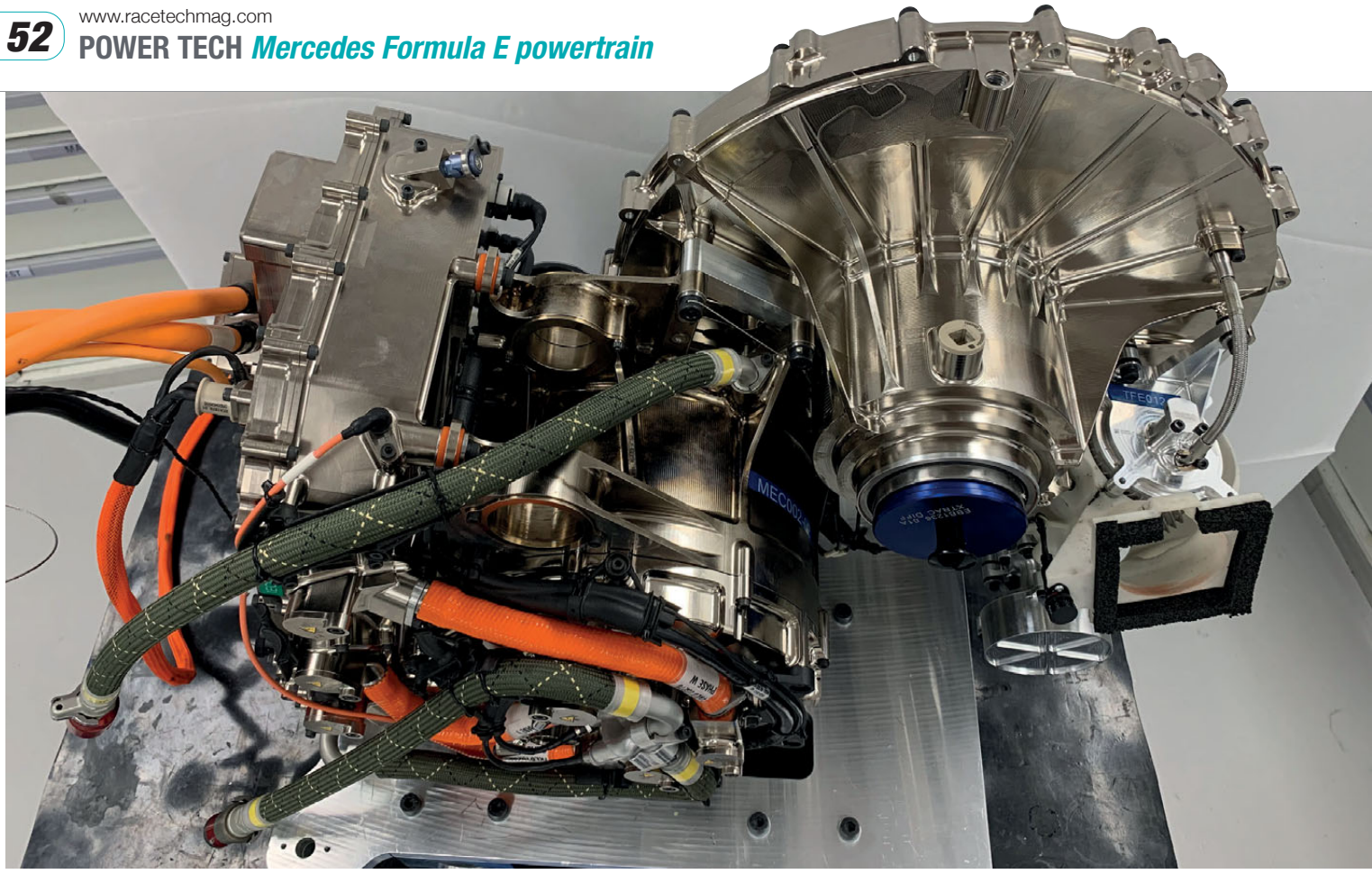
EB began track testing in June 2019. It knocked 0.2 seconds off the EA lap time and improved energy efficiency by two per cent. HPP's foray into driveline production also proved to be a success, with the gearbox carried over straight from the EA design, albeit with an updated differential. The new powertrain brought a raft of evolutionary changes, but the basic concept had proved sound. One of the optimisation areas that the team looked at was the weight of the motor, but the approach was quite specific to Formula E, Godof explains.

"In Formula 1 it's all about mass reduction, but the sensitivities are different in FE," he comments. "There wasn't a strong drive for a super-lightweight motor, because the ballast would have gone in a similar place to the motor, so you're swapping useful copper mass for inert ballast. In motor design terms, mass is generally tied to efficiency, so we chose to go for a comparatively heavy motor that we believed was better for car performance. That was the philosophy that the EB powertrain was based on. And that was the point that the FE hardware really started to diverge from F1."

The EB generation also saw the HPP engineers developing new tools to optimise their powertrain.

"I'd been in Formula 1 for 16 years at that point, and one of the things that struck me about Formula E was how thorough the optimisation needed to be. You couldn't just focus on the motor or the inverter or the gearbox – all of that needed to be optimised together, and with the chassis," comments Godof.

This holistic approach taps into the F1 mindset that he believes was one of Mercedes' biggest differentiators in Formula E: "At HPP, we've traditionally done everything in-house – if you understand the limits and boundaries of every part it gives you a better package. But in Formula E there were still teams that were buying their motor from one supplier, an inverter from someone else, a gearbox from someone else, the software from another supplier… And each one of those suppliers adds their own safety factor, because they don't want to risk the exposure if their component fails. You lose so much that way once you add up all of those safety factors." ▶



Baptism of fire

Mercedes officially joined the Formula E ranks in December 2019 – both as a works team and as a powertrain supplier to Venturi.

"The first time we saw all four cars [two from Mercedes and two from Venturi] on track together at the Valencia test was a really good feeling – especially as we'd worked through the night beforehand to make it possible. And then the first win at Berlin was really special too," comments Godof.

The team had set itself the target of picking up at least one race win in its first season. While this came true (along with third place in the constructors' championship that year), it certainly wasn't easy.

"Season Six was quite a painful journey," he recalls. "It was a steep learning curve and we got stung with quite a few Formula E-specific penalties. Your motor control needs to be absolutely spot on if you're going to hit the maximum power allowed in the rules without exceeding it when the wheels spin. That's something that's still catching people out now. Another one we had was over-cooling the car on the grid. It was tough, but that's what prepared us for seasons Seven and Eight."

ABOVE The need to optimise the whole package led HPP to develop not only the motor and inverter, but also the gearbox and differential

BELOW The standardised bodywork meant powertrain engineers weren't under pressure to trade packaging volume or cooling requirements for aerodynamic gains

For cost reasons, the teams had to homologate a single powertrain for seasons Seven and Eight. Mercedes' offering was dubbed EC, following the nomenclature established at the beginning of the project. Further optimisation on stator design, cooling and the copper content of the motor saw efficiency improve by another percent. Meanwhile, significant strides were made in the motor control and the efficiency of the power electronics.

"By that point we felt that we were getting towards a good understanding of the hardware definition in the motor, inverter and gearbox, and we'd validated our simulation models. So then the journey really took off for software," recalls Godof. "That was almost the last piece of the jigsaw, and it was key to performance at the track, ensuring that we could react to bumps and changes in grip level but still deliver the maximum power."

Once the EC hardware was homologated, software development and calibration became even more important. Numerous software iterations were developed with tangible benefits to the motor control and the efficiency.

In terms of scope, the software challenge in Formula E remained significantly simpler than F1, with no electro-hydraulic differential to control and no

gearshift strategy. On the other hand, the devil lies in the detail with Formula E powertrain control, and this saw another shift in priorities compared to the Formula 1 approach.

"In F1, there are far more things to control on the car, so the chassis engineers tend to take control of the vehicle control unit (VCU) that's making all the high-level decisions, and we piggyback the engine control onto that," comments Godof. "In Formula E, we took ownership of all that, including the energy management and the driver interface. We worked very closely with MBFE (Mercedes-Benz Formula E) and Venturi on that."

Glory years

The team's first double world championship came in Season Seven (2020-2021). In the drivers' contest, it was a close-fought battle between Nyck de Vries in the Mercedes and Edoardo Mortara in the Venturi, but the Dutchman came out on top. Similarly, while Mercedes had triumphed in the constructors' championship, Jaguar finished just three points behind.

Season Eight (held in 2022) saw the software battle continue. Again, it was the mindset and the sheer resources of a front-running grand prix constructor that helped to keep Mercedes ahead.

"I think one of the things that really helped us was the ability to turn software around very quickly without any mistakes," comments Godof. "Our sign-off process meant that we could release a new software version on the Wednesday, put it through the rig for software-in-the-loop testing and then onto the driver simulator ready for practice on the Friday."

Some likened the Formula E software battle to the race for aerodynamic supremacy in Formula 1. This hadn't gone unnoticed among the rulemakers, who promptly took steps to curb the potential expenditure. In Season Seven the teams had been allowed one software update per event, but for Season Eight this was reduced to six per season.

ABOVE Nyck de Vries and the Mercedes-EQ Formula E Team became the first ever all-electric motorsport world champions, winning the ABB FIA Formula E World Championship Drivers' and Teams' titles in 2021

Back at Brixworth, the software development continued. Each new iteration had to be checked on the rig for efficiency and FIA legality before going into the driving simulator to evaluate its energy usage. Those that showed a significant improvement could then be put through as an official update for the racecar.

The updates were clearly working. There was still stiff competition – notably from Mitch Evans in the Jaguar and Mortara in the Venturi – but Season Eight was to be another clean sweep for the Brixworth-based outfit.

BELOW A first win, for Stoffel Vandoorne in the final round of Season 6, was the launchpad for Merc's dominance

Legacy

In August 2021, Mercedes had announced that the following season would be its last in Formula E. But that's not quite the end of the story. Before the decision was taken, the HPP engineers had begun development of a Gen3 powertrain for Season Nine, known as the ED.

The comprehensive regulation changes for that season saw Godof and his colleagues return to the drawing board for the new 'ED' powertrain. This process was much the same as the one they'd carried ▶

FIA/Formula E

out at the beginning of the EA programme: the gear ratio was re-evaluated, as was the number of gear meshes to suit the new 350 kW motor's performance characteristics. Cooling was a major topic for both the rotor and stator design, due to the increased power output. Likewise, the inverter development began with beefed up power module stages.

"Our aim for ED was to keep the same losses as EC, which is not as straightforward as it sounds when you remember that we were going from 250 kW up to 350 kW," comments Godof.

The change in terminology here is deliberate, he points out: "During EC we started to talk about losses rather than efficiency. As an engineer, it's more useful to look at how many Watts you're losing in your power module, how much you're losing to windage and so on. Then you can focus on reducing those."

Often, throughout the Formula E programme, compromises had to be made between these requirements. This is another area where Godof believes working with an in-house team was an advantage.

"The engineering group was quite consistent throughout the journey, and it was amazing the way that we grew together in that time," he comments. "If you think about optimising the motor, the inverter, the gearbox, the chassis and the cooling…

ABOVE The EB iteration of the Formula E powertrain went on to set no fewer than 11 new world speed records powering a Voxan Wattman electric motorbike. It was ridden by former MotoGP rider and two-time Superbike World Champion Max Biaggi

LEFT Mercedes bowed out of Formula E as double World Champions at Seoul

Daimler

> *"The lower temperatures open the door to different manufacturing processes, like plastics and rapid prototyping, in places they wouldn't survive in F1"*

you've got to get all of those specialists to work together as one. I don't know how you'd do it if it was four separate companies. The interactions between those different parts of the design are massive in Formula E. By the time we did ED, I could see the team working so well as a group of engineers – really willing to push their own boundaries and to challenge each other."

Although it never ran on the track, ED did progress as far as durability testing on the rig before the metaphorical shutters rolled down on the team's Formula E programme. After that, the engineers were re-distributed back to F1 or road car projects. They took with them the knowledge that they'd acquired along the way.

"There was absolutely no way we could carry over the FE parts directly back into F1. The temperature range, the mass sensitivity and the optimisation criteria are all totally different, especially for Gen3. But the general learning was relevant for some of the new F1 challenges," comments Godof. "The learning around motor control, for instance, was very useful. And I think also that interaction of different teams, helping people to understand what each other's priorities were on their particular part of the design."

Some of the knowledge transfer came from concepts that had already been in the development queue for some time in Formula 1. In that environment, those ideas hadn't been a priority, but the different set of requirements found in Formula E pushed them into the limelight.

Other projects that have benefited from the Formula E experience include the Mercedes-Benz VISION EQXX concept car that has set a series of records for electric vehicle range, and the Voxan Wattman motorcycle, which used an EB powertrain to set a new electric speed record of 283 mph.

There is also another part of the Mercedes Formula E legacy out there. While the R&D operation and the intellectual property returned to Mercedes, the team's entry to the championship and many of its assets were sold to McLaren. Like Mercedes, the Woking squad is currently facing something of a baptism of fire in its first year of Formula E. But it's another organisation that has a reputation for coming up trumps in the end. Tenuous as that link may be, it would certainly make a fitting epilogue to the story.

AND NOW FOR SOMETHING COMPLETELY DIFFERENT...

The regulations governing the Hypercar class are focused on controlling performance outcome instead of setting design or geometrical restrictions. **Gary Watkins** explains the major shift in philosophy that underpins a new golden era of sportscar racing

START talking about Balance of Performance, and sandbagging will almost inevitably come into the conversation. In sportscar racing over recent years they've gone together like Tom Kristensen and the Le Mans 24 Hours, Jacky Ickx and Derek Bell and, for the fans who make the pilgrimage to the French enduro each summer, frites and mayonnaise.

That association may well be on the way to becoming a thing of the past. There has been a concerted push by the rule makers and the manufacturers competing in the Hypercar class of the World Endurance Championship to finally break the link.

A new BoP system has been introduced for 2023, and the organisational partnership of the FIA and the Automobile Club de l'Ouest that runs the WEC appears confident that sandbagging will disappear from the landscape in Hypercar. The reason for that confidence, which appears to be shared by the manufacturers, is not just the processes put in place for the new season, but the rule book – or correctly rule books – on top of which the BoP sits.

ABOVE The Hypercar and LMDh platforms clashed for the first time at Sebring

There has been a sea change in the way the BoP is calculated and then applied in the first season that the new LMDh prototypes join the Le Mans Hypercar machinery that came on stream in the WEC in 2021. Simulation is now the key. The seven designs from Toyota, Ferrari, Porsche, Peugeot, Cadillac, Glickenhaus and Vanwall participating in Hypercar over the full WEC have been balanced based on their potential rather than the performance they show on the racetrack. Lap times will be ignored when it comes to calculating the BoP, according to ACO competition director Thierry Bouvet.

> *"The seven designs have been balanced based on their potential rather than the performance they show on the race track"*

Manipulation

The 2023 Hypercar BoP was fixed ahead of the Sebring 1000 Miles series opener on March 17 for the first half of the season right up to – and crucially including – Le Mans on the second weekend of June. There is scope for change, but only minimal change. The idea is that this new approach will remove scope for manipulation of the system, a manufacturer understating its performance in the opening races of the season to get a favourable BoP, perhaps in the 'Big One' in June.

That has happened before, of course. You don't have to look too far back in the history of the late GTE Pro class to find examples, before and after the automatic BoP system was introduced for 2017. The draconian BoP hit Ferrari took under the so-called black ball rules – a change outside of the remit of the auto system – ahead of the two races at Bahrain that brought the COVID-hit 2021 WEC to a climax were interpreted as a slap on the wrist for the massive upturn of form it showed on the ▶

way to class victory at Le Mans that August.

The document by which the new BoP is governed isn't in the public domain, just like its predecessor after the official introduction of performance balancing into the top class in the WEC at the outset of the Hypercar era. But the FIA and the ACO offered a short explanation of the latest system and what they are trying to achieve during the week of the SuperSebring double-header when the WEC again joined the bill of the Sebring 12 Hours IMSA SportsCar Championship round.

The foundations on which the new BoP has been built are regulations that have created a grid of cars that should be very close together in terms of performance from the get-go. So much so, reckons Toyota Gazoo Racing Europe technical director Pascal Vasselon, that any "small differences in performance should only need fine tuning" with the BoP.

The original LMH rules, published as long ago as December 2018, weren't created with that in mind, however. The idea of a BoP wasn't introduced until the following summer: it was a condition of Aston Martin's still-born entry into the Hypercar class with a race version of its Adrian Newey-inspired Valkyrie super-sportscar for the road. But closing up of the field and lowering the financial bar to entry were among the aims when the FIA, the ACO and a handful of manufacturers first sat around the table to come up with a successor to LMP1.

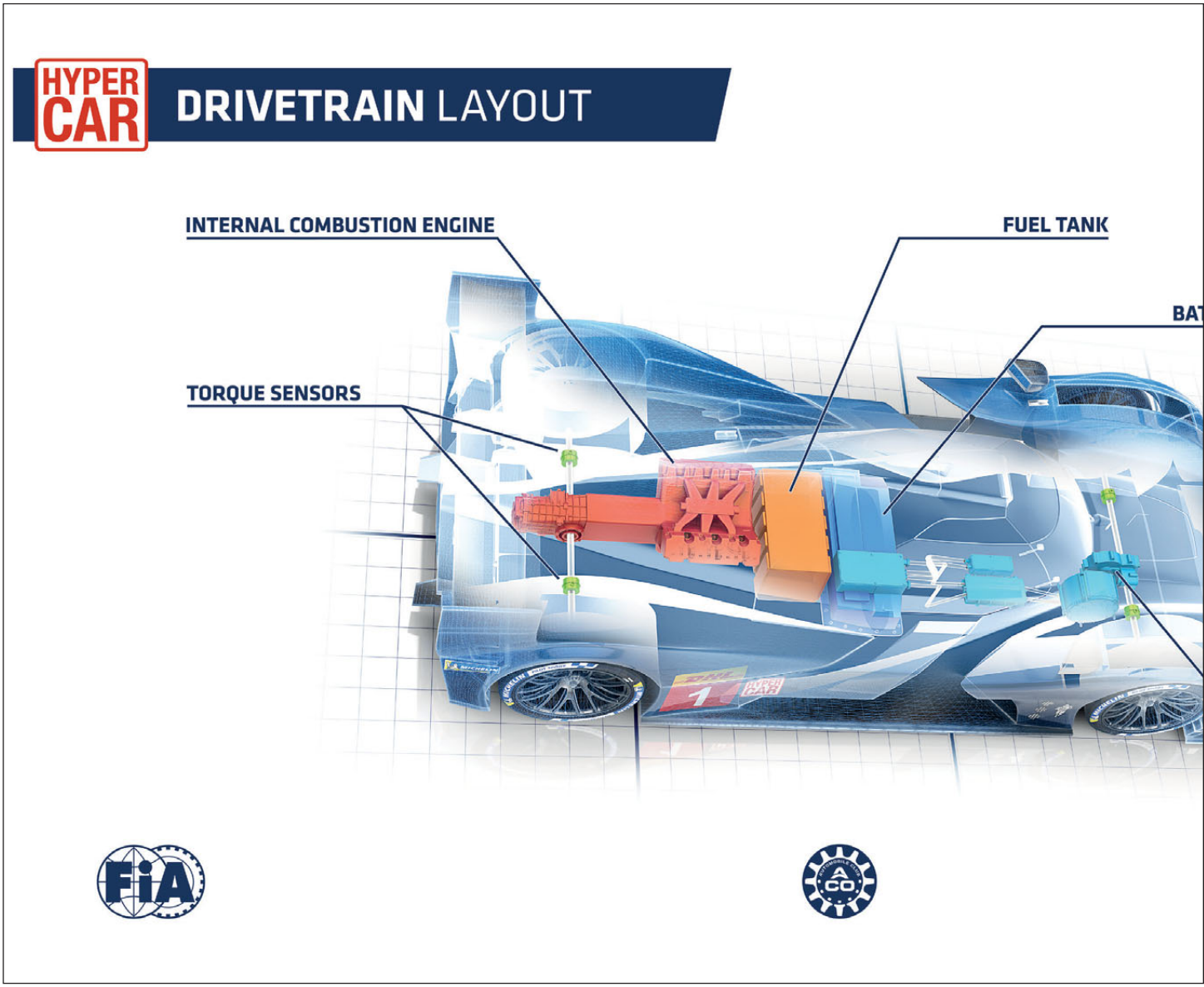
Rocketships

A massive reduction in costs was clearly required from the high-tech rocketships of the LMP1 hybrid era and the solution was to fundamentally alter the way the regs were written. Rather than setting out prescriptions saying what could not be done, the rules specify the results of the design process.

"The main technical principle is to regulate the

RIGHT Torque sensors, resistant to electromagnetic field and heat, are installed onto the driveshafts of the cars

BELOW The shift in approach allows for far greater variety of technical solutions



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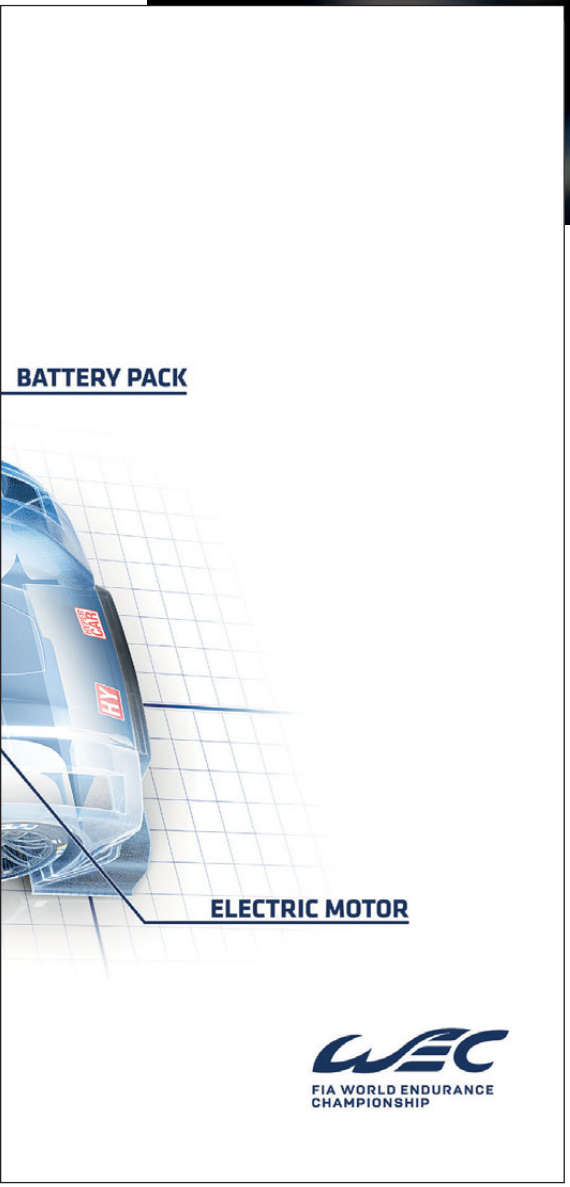


performance outcome of the design and not the technical architecture in terms of geometric restrictions," says Marek Nawarecki, the FIA's director of sports and touring cars. "The concept is completely different to that which went before, but also completely different to those previously seen at this level of motorsport."

Targets are laid down for downforce and drag, so-called performance windows into which each car must fit. They are the same for both LMH and LMDh. And the targets are deliberately modest, to reduce costs and to allow manufacturers to implant their styling cues onto their machinery. The idea is that the shape of the car shouldn't be solely determined in the wind tunnel or in the virtual realm in CFD. The single aerodynamic configuration allowed on each car is then validated in the full-size wind tunnels at Sauber in Hinwil, Switzerland for the WEC and the Windshear tunnel in Concord, North Carolina for IMSA.

The same principle has been applied to the powertrains. Again, it is the outcome that is laid down rather than any prescriptions on the architecture or capacity. The maximum output is set at 520 kW (697 bhp) for the combined powertrain – the internal combustion engine and the hybrid system if there is one – and a torque curve prescribed for each car in the BoP. This is measured in real time by driveshaft torque meters on each driven wheel. "It's like a live dyno session!" says Bouvet.

> *"Simulation is now the key"*

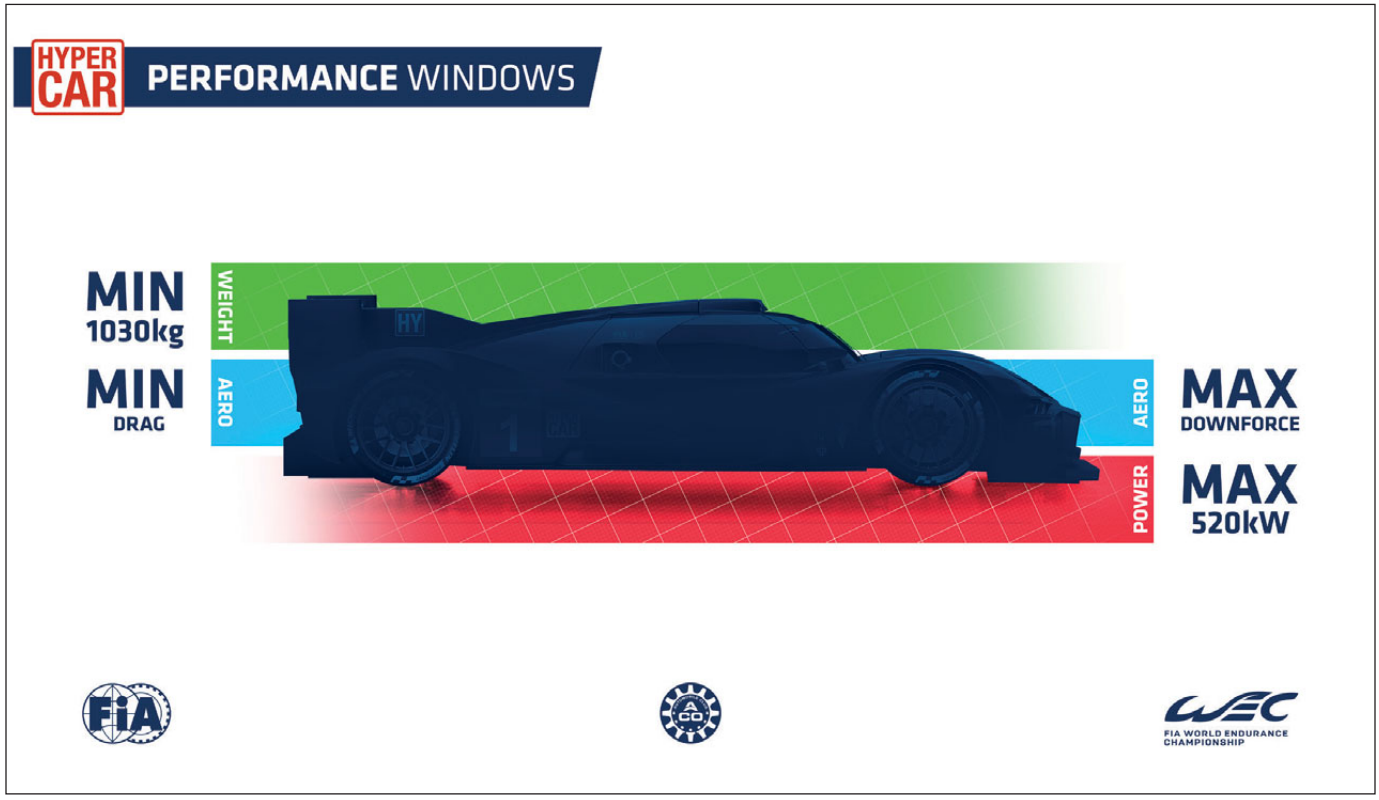
Data is king

The upshot is that the FIA, the ACO and IMSA in North America now have a substantial amount of data. Between them they have run 500,000 simulations, which have resulted in the BoP in place for the first half of the season.

"The BoP is [designed] to balance the potential of the performance of each ▶

LAT Images/IMSA

LEFT Advances with data acquisition and analysis processes underpin the new regulatory approach. Here IMSA tech director Dave Kurdock crunches the numbers



ABOVE The ability to measure the main performance parameters has enabled the creation of the performance windows central to the new regulatory approach

LEFT Toyota's dominance at Sebring suggests it is closest of the manufacturers to realizing the full potential of a car that is now in its third season

car, which is defined by the key characteristics," says Nawarecki. "All the parameters – all the primary performance cards – that are essential to the performance potential are captured." What he calls "secondary parameters", things like set-up and what the drivers do behind the steering wheel, are not taken into account.

> *"I remember following the Toyotas last year and they didn't look good"*

The simulation resulted in a slightly different BoP for Sebring to the next three rounds of the WEC at the Algarve circuit and Spa in April, and then Le Mans. That explains the publication of two tables by the WEC ahead of the season.

"We looked at each track individually, and there was one outlier," says Bouvet in reference to the bumpy Sebring International Raceway, which for much of its 3.74-mile course has a concrete surface that dates back to the venue's roots as a World War 2 bomber base. The FIA and the ACO don't regard the two tables as different BoPs, rather a push for accuracy in light of the specific demands of one of the circuits.

Robust evaluation

The rule makers haven't gone into detail about why, say, the Cadillac V-Series.R LMDh has a similar BoP across the four races – only a three-kilogram ▶

Stellantis

difference in minimum weight and the same power output – whereas the Toyota GR010 HYBRID LMH will run 19 kg lighter from Algarve on, though with five kilowatts (6.7 bhp) less power. Nawarecki says only that "we made one robust evaluation of all the cars".

The process of simulation will continue through the season and BoP changes could be made. There is now a distinction between what is called the 'manufacturer BoP' and the 'platform BoP'. Any change before Le Mans will only be made to the latter, in that it would be an adjustment to the balance between the cars competing under two different rulebooks. Any changes required would be effected across all cars built to one set of regulations. "It is fundamental to us to have the two platforms having the same potential," says Bouvet.

Platform change

A platform change may be made every two races, meaning the first movement in the BoP can only come ahead of the Spa 6 Hours on April 29. A manufacturer change – meaning individual revisions to the BoP of perhaps multiple cars – can be only made post-Le Mans and then will be set in stone for the rest of the season. Another platform change could come after a further two races, which would mean in time for November's eight-hour seasonal-finale in Bahrain.

> *"We looked at each track individually, and there was one outlier: Sebring"*

That contrasts with the previous system where two races' worth of data were required for a change. That explains why Peugeot's avant-garde 9X8 got a performance break for Bahrain, the final appearance of its three post-Le Mans starts in 2022.

The FIA and the ACO are insistent that the changes will not be made on the basis of lap time. "It's not about qually or [race] lap time, it's about absolute and relative [between LMH and LMDh] potential," says Nawarecki.

The conclusion from the Sebring 1000 Miles and Toyota's dominant one-two victory would have to be that the Japanese manufacturer came close – or at least closest – to achieving its potential with a car that is now in its third season and having undergone a second upgrade within the strict homologation rules in place across LMH and LMDh. Its rivals were happy to admit that they didn't.

"There's a lot of low-hanging fruit for us," said Earl Bamber, who lost out on a podium to the best of the Ferrari 499P LMHs by just 10s in the solo Cadillac Racing entry. He was at pains to point out that the Chip Ganassi Racing team running the V-Series.R was effectively

LEFT The performance targets are deliberately modest, reducing costs and enabling avant-garde solutions such as those adopted by the wingless Peugeot 9X8 (left)

BELOW One of the most innovative solutions is the use of torque sensors, allowing calculation and monitoring of BoP-allocated energy per stint in real-time

a start-up group working together for the team. When the car raced in the Daytona IMSA series-opener in January it was largely run by personnel from Ganassi's IndyCar Series squad.

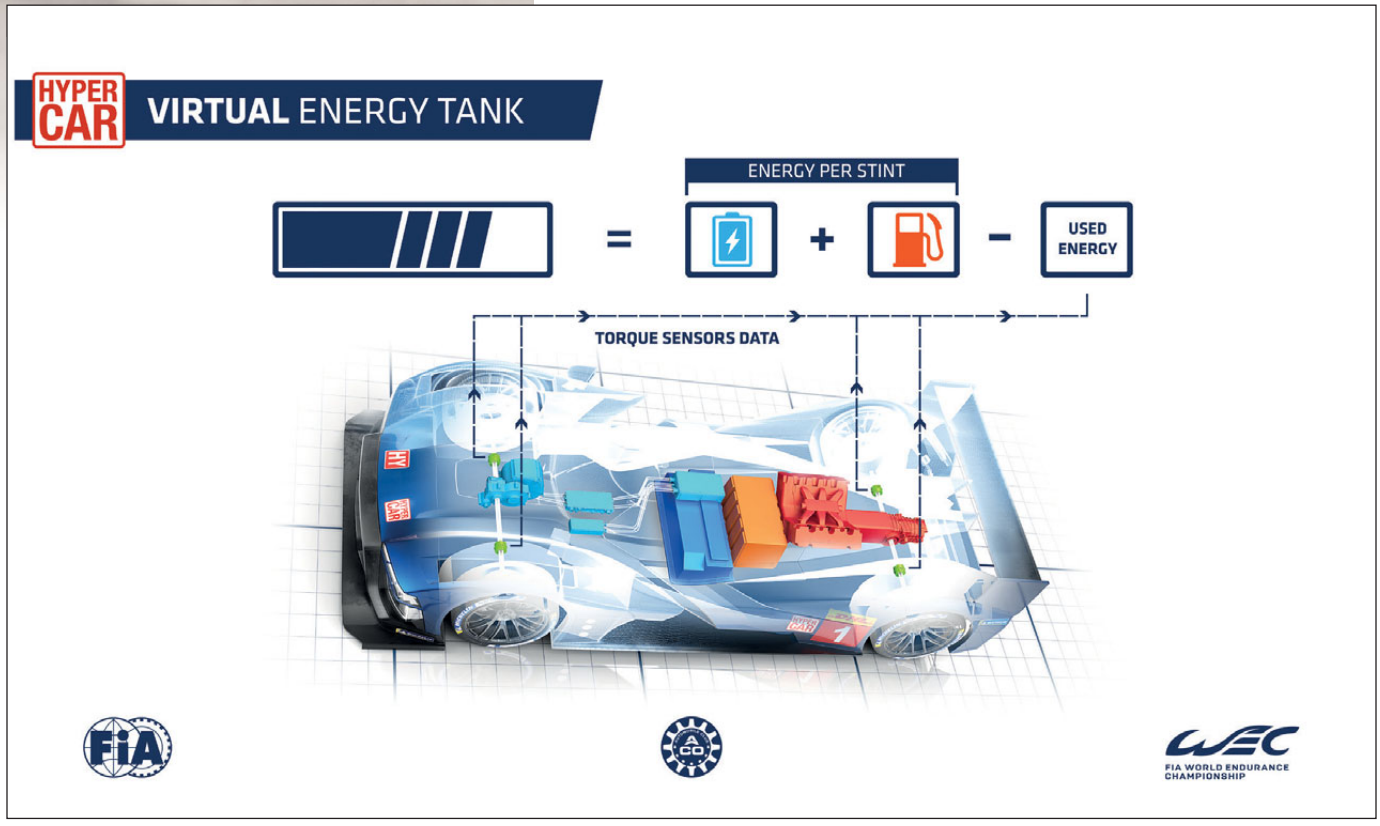
Porsche driver Kevin Estre conceded that there was much to learn for the German manufacturer after its two 963 LMDhs finished fifth and sixth on its return to the top class of the WEC. But he pointed out that just 12 months ago Toyota was having its own struggles on the debut of the GR010 at Sebring.

"I remember last year following them when I was driving the 911 RSR [in GTE Pro], and they didn't look good, probably not much better than we were today," he said after the race at Sebring. "We're going through the same learning process as they did."

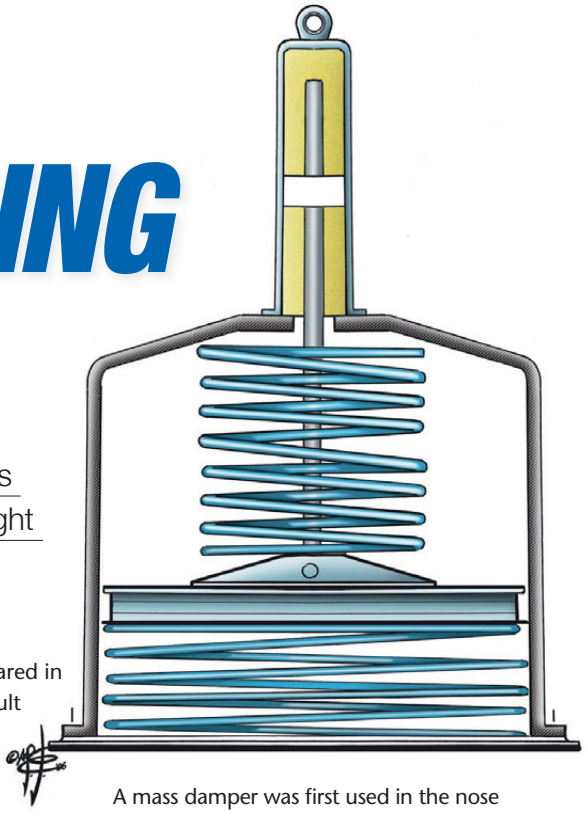
Gagging clause

There was no criticism of the BoP at Sebring. For the moment, all the manufacturers are singing from the same song sheet, and understandably so. The new balancing system is as much their work as the FIA and the ACO's, though there's also a clause in the sporting rules effectively banning its discussion in the open.

"There has been a ton of work to get us to this point," says Laura Wontrop Klauser, sportscar programme manager at Cadillac parent General Motors. "I would say that if we truly didn't believe we had something we could work with, we wouldn't be here."



FORMULA 1 TECHNOLOGY
THE ENGINEERING EXPLAINED

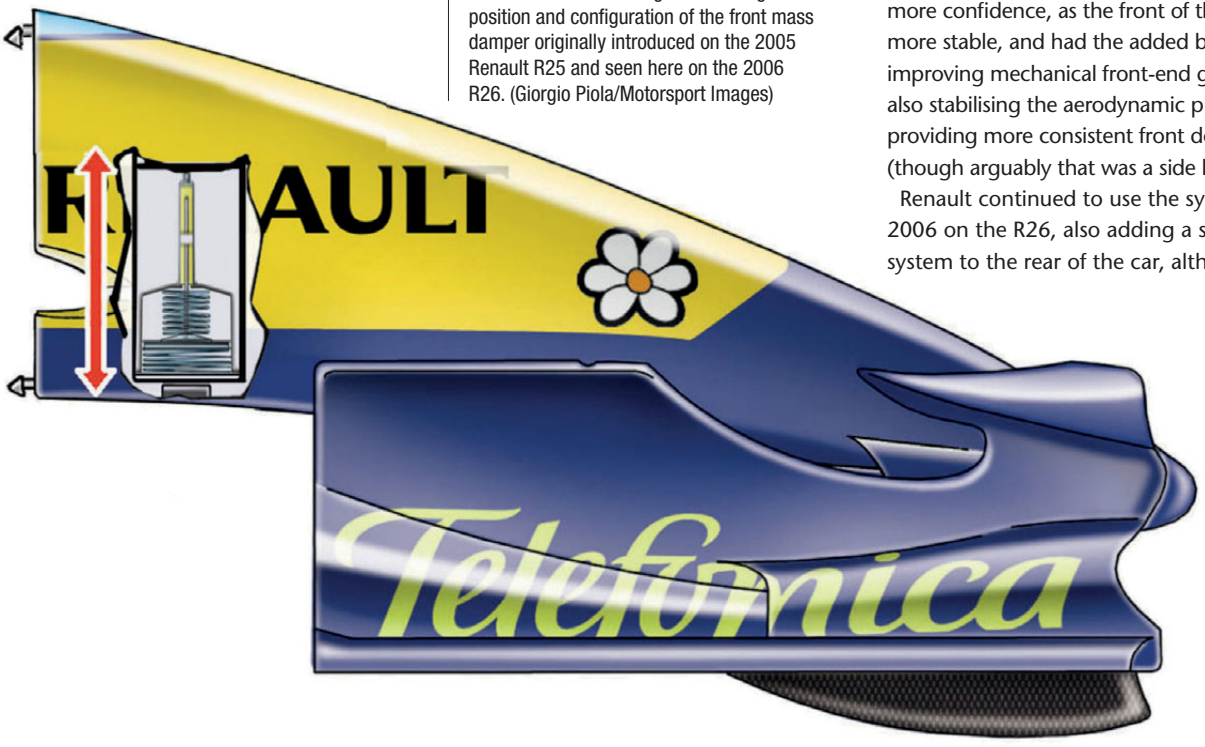


In this extract from his new book, **Steve Rendle** examines the innovations that made the difference as increasingly tight regulations marked F1's passage towards its hybrid era

BY the dawn of the 21st century, the F1 regulations were sufficiently restrictive that it became very difficult for designers to come up with any revolutionary 'game-changing' concepts, and the competition was sufficiently close that even a very small advantage in lap-time performance paid dividends. This resulted in a series of relatively short-lived developments, some of which unquestionably contributed to championship wins for their innovators.

Mass dampers

The first of these innovations appeared in 2005, and was developed by Renault in the form of the mass-damper system (not to be confused with the J-damper, or inerter, which has a similar role, and is explained in detail in Chapter 4). In simple terms, the tuned mass-damper system comprised a weight suspended between two springs in a vertically-mounted cylinder containing damping fluid.



ABOVE & BELOW A diagram showing the position and configuration of the front mass damper originally introduced on the 2005 Renault R25 and seen here on the 2006 R26. (Giorgio Piola/Motorsport Images)

A mass damper was first used in the nose of the Renault R25 that took Fernando Alonso to his first World Championship title in 2005. The role of the mass damper was to damp the oscillations at the front of the chassis as the car travelled over bumps in the track (improving stability over kerbs). This provided the driver with more confidence, as the front of the car was more stable, and had the added benefit of improving mechanical front-end grip, whilst also stabilising the aerodynamic platform, providing more consistent front downforce (though arguably that was a side benefit).

Renault continued to use the system in 2006 on the R26, also adding a similar system to the rear of the car, although that

proved less significant. Rival teams introduced their own similar systems later in the 2005 season, but the fact that the Renault was designed with the mass-damper system integrated as part of the package enabled the team to use it to optimum effect, while some rivals struggled.

For 2007, mass-damper systems were banned after a ruling from the FIA that they were being used to benefit aerodynamic performance, and therefore constituted a moveable aerodynamic device (which was specifically prohibited by the regulations).

J-dampers (inerters)

In parallel with the development of mass dampers around 2005, J-dampers, also known as inerters, were introduced. It is thought that McLaren was the first team to implement such a device.

Although the ultimate role of the inerter is similar to the mass damper, the inerter is a significantly different component, but was banned from the start of the 2022 season. Inerters are discussed in more detail in Chapter 4.

Kinetic Energy Recovery System (KERS)

The 2009 season was pivotal for new technology in F1, with the introduction of rule changes to slow the cars. The new regulations were primarily designed to limit aerodynamic development, but in a portent of the future, Kinetic Energy Recovery Systems (KERS) were also permitted for the first time. ▶

Extract from *Formula 1 Technology The engineering explained*, written by Steve Rendle, Evro Publishing, hardback, priced £55

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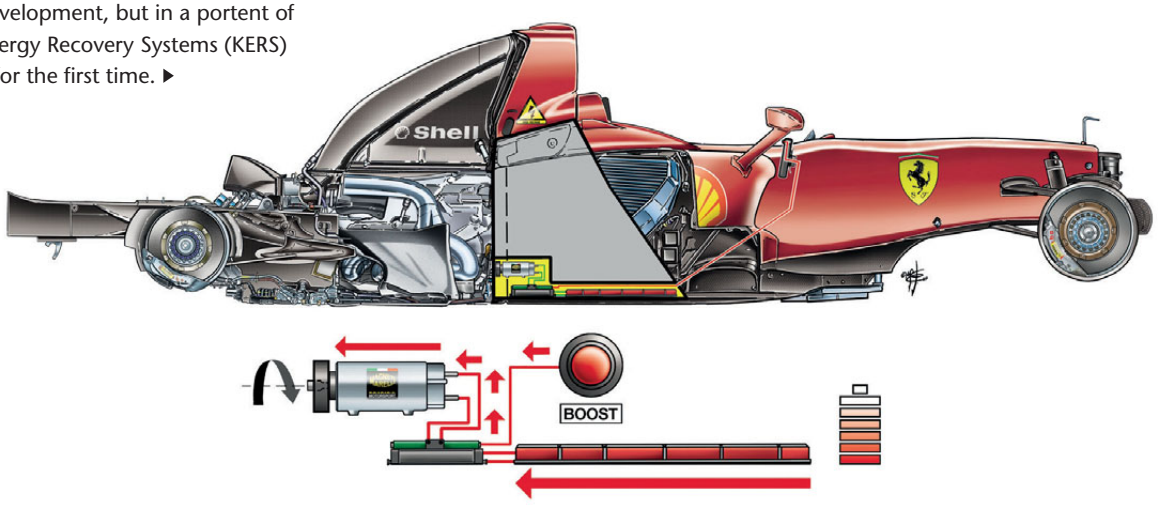
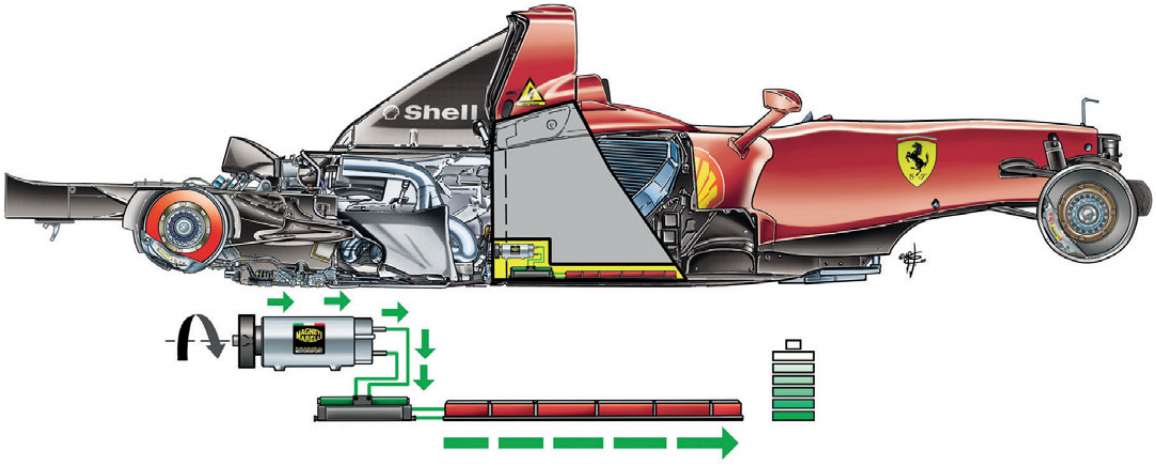


RIGHT KERS on the 2009 Ferrari F60, showing the location of the components and the system operation in 'boost' mode. (Giorgio Piola/ Motorsport Images)



RIGHT Operation of the Ferrari F60 KERS system in 'charging' mode. (Giorgio Piola/ Motorsport Images)

Additionally, slick tyres were reintroduced for the first time since 1997.

The initial take-up of KERS by teams was limited, partly due to the extra weight of the system in its early form negating its benefits. KERS allowed the harvesting under braking of up to 400 kJ of energy that could later be discharged, providing a boost of 60 kW (approximately 80 bhp) for around 6.6s per lap. The driver could decide whether to use all the energy in 'one hit' or in small 'chunks' around a lap.

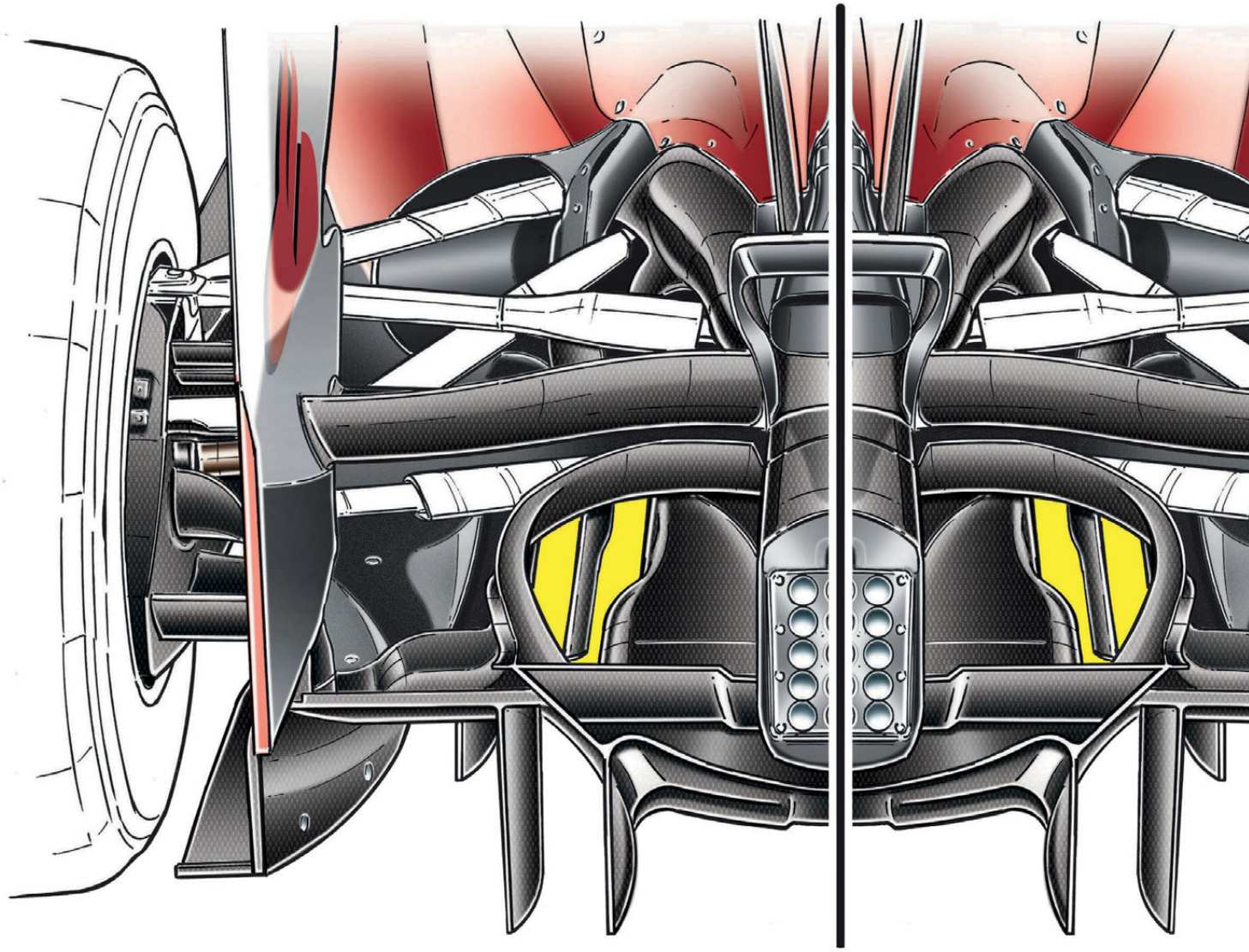
KERS was not used by all the teams in 2009, and its use was suspended for 2010, before being reintroduced for 2011. The use of KERS continued until the end of 2013, when it was superseded by the current hybrid powerplants incorporating energy recovering systems (ERS).

Double diffuser

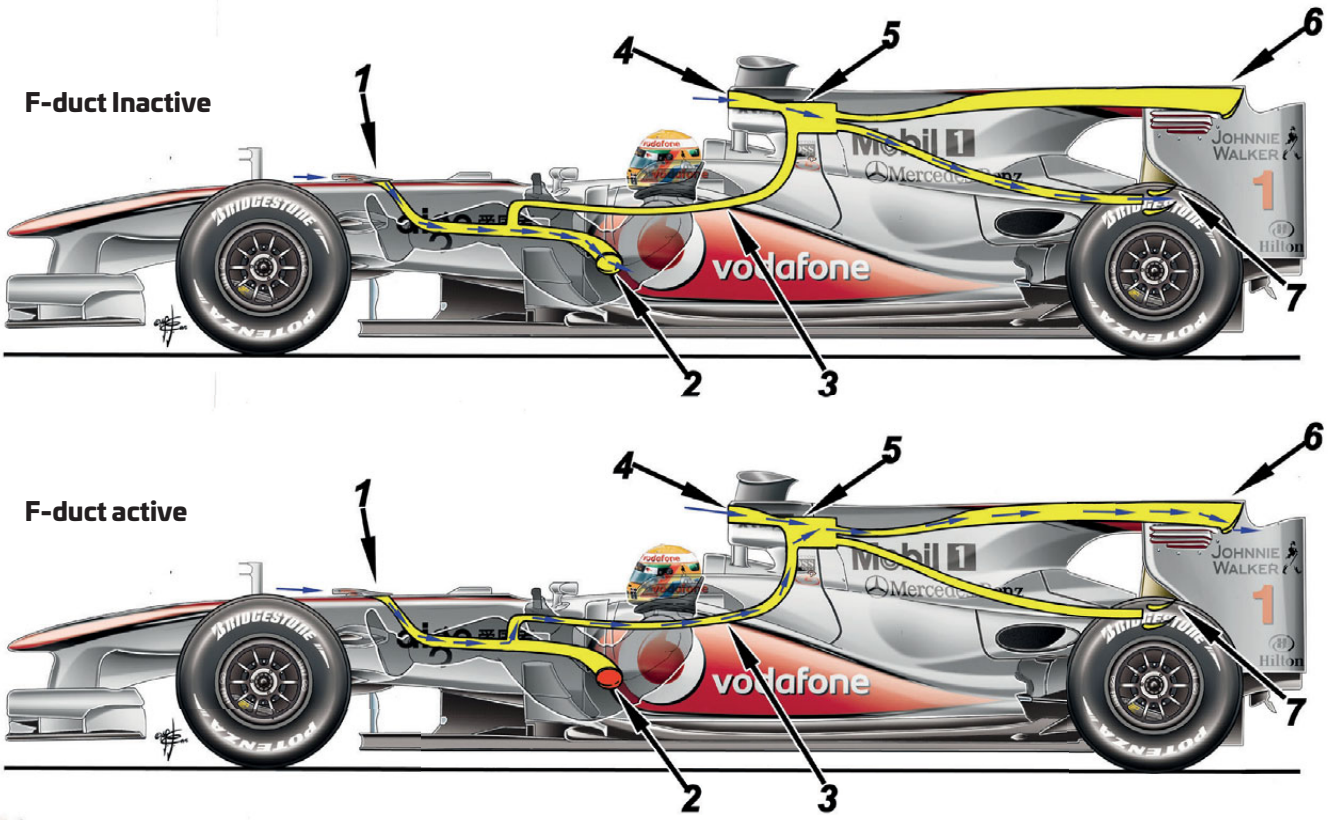
Another innovation that first appeared in 2009 was an extremely effective, and controversial, aerodynamic development in the form of the double diffuser. The revised rules, aimed at slowing the cars, involved significant changes to aerodynamic devices, including the front and rear wings and the diffuser, and the permitted dimensions of the diffuser were significantly reduced.

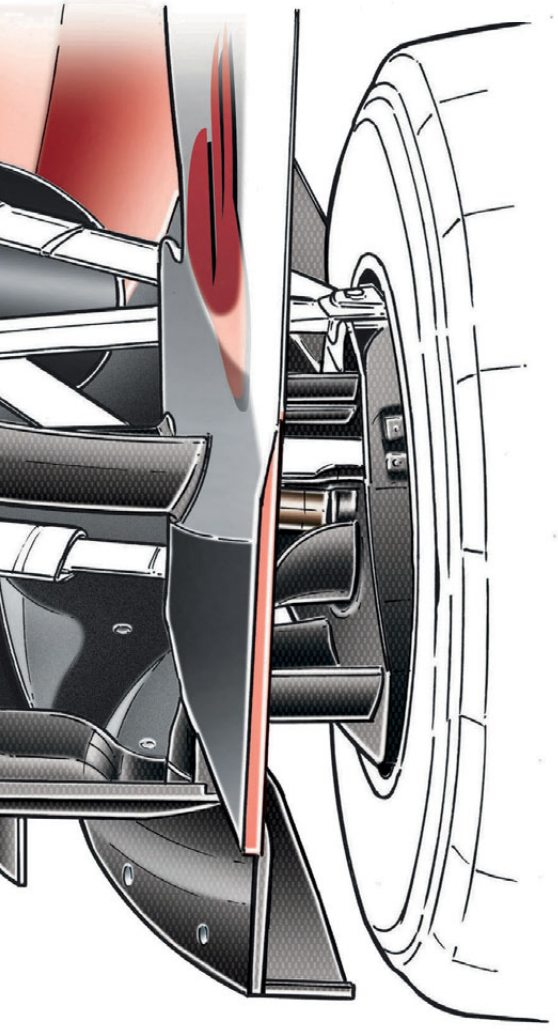
From the start of the 2009 season, Brawn GP, Williams and Toyota ran 'double diffusers', exploiting a loophole in the regulations. The role and operation of the diffuser is explained in Chapter 3, but essentially, the double diffuser made use of two additional tunnels alongside the gearbox, fed with air from holes in the floor. This increased the airflow through the diffuser as a whole, creating a much larger, deeper and more powerful aerodynamic device.

Brawn GP was one of the three teams that designed their 2009 cars from the outset to integrate and optimise the double-diffuser concept, and this was a major contributor to the team – born from the ashes of the Honda team, which had decided to quit F1 at the end of 2008 – dominating the World Championship.



BELOW The 2010 Ferrari F10 featured a double diffuser. Additional tunnels either side of the gearbox (highlighted yellow) were fed with air through holes in the floor. (Giorgio Piola/ Motorsport Images)





ABOVE An illustration of the operation of the F-duct on the 2010 McLaren MP4/25. 'Inactive' shows the 'normal' mode and 'active' shows how the airflow is diverted to stall the rear wing when the system is operated by the driver. (Giorgio Piola/Motorsport Images)

1 Air intake duct in nose ('switching' air)
2 Duct in cockpit covered by driver to activate system
3 Air duct to engine cover ('switching' air)
4 Intake duct in engine cover (main airflow)
5 Air 'switch' ducting
6 Air outlet at rear wing (main airflow)
7 Air vent duct ('switching' air)

F-duct

Over the next few seasons, into the following decade, aerodynamic developments would dominate the sport as the teams strived to claw back the downforce lost due to the regulation changes. The next innovation would be the F-duct, pioneered by McLaren in 2010 with the aim of reducing drag by stalling the airflow over one of the rear-wing elements.

This clever system was operated by the driver from the cockpit using a 'fluid switch', acting along similar principles to a relay in an electrical circuit, where a small current is used to switch a much larger current.

Air flowing from the exterior of the car through a duct opening into the cockpit (the 'small current') could be diverted by the driver placing his hand over the cockpit duct, and this 'control' air was used to divert the main airflow (the 'large current') flowing through a separate duct to direct air to the rear wing (normally this air would flow through a bypass vent, until ▶

RIGHT The F-duct activation duct on the side of the cockpit in the 2010 Renault R30. The driver covered the duct with his left hand to operate the system and stall the rear wing. (Motorsport Images)

diverted by the operation of the F-duct).

This extra air disrupted the airflow over one of the two rear wing elements (see Chapter 3 for details of the operating principles of the front and rear wings), causing the airflow to separate from the surface of the wing element, thereby stalling the wing and reducing its drag. This reduction in drag could be implemented on straights to provide an increase in top speed.

Rival teams were quick to adopt their own versions of the F-duct, with varying degrees of success, but the system was outlawed for the 2011 season, when the rules were amended to introduce a Drag Reduction System (DRS), which provided a similar effect by moving the rear wing upper element (see Chapter 3).

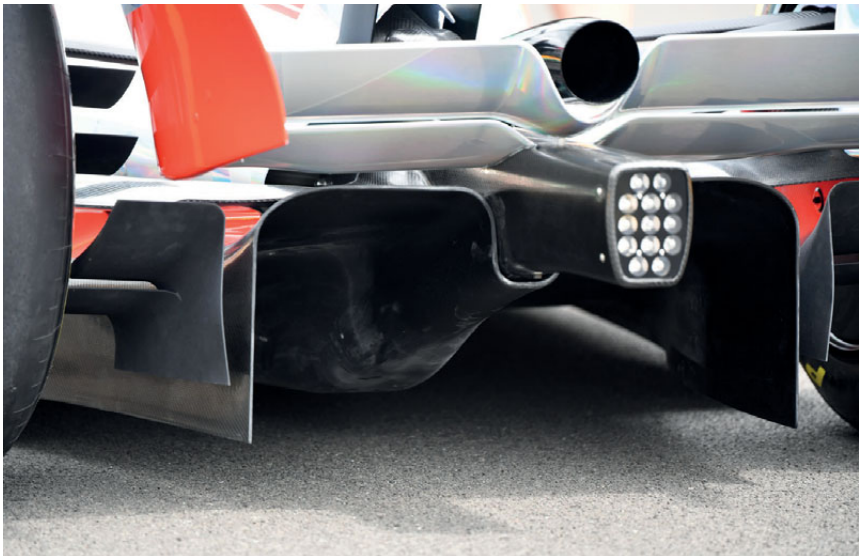
> *"F1 engineering is still pushing the boundaries of both technology and the rule book today"*

ABOVE A model of a typical car conforming to the new regulations originally intended for introduction in 2021 was unveiled to the press at the United States Grand Prix in October 2019. (Motorsport Images)

BELOW A rear view of the full-scale mock-up 2022 car showing the diffuser and the rear of the underfloor 'ground-effect' tunnels. (Motorsport Images)

Into the current era

Increasingly restrictive regulations – aimed at controlling speeds, improving safety, reducing the opportunity for any single team to gain a significant advantage and improving the racing from the point of view of the spectators – have reduced the scope for F1 designers and engineers to come up with ingenious game-changing innovations. This has not stopped teams from trying, with designers constantly striving to find loopholes in the regulations to provide an advantage. ▶



From flexible wings, whose aerodynamic characteristics change under load, to clever systems to pre-warm tyres and brakes on the way to the grid, F1 engineering is still pushing the boundaries of both technology and the rule book today. More recent innovations that have had a direct bearing on today's cars will be discussed in more detail in the following chapters.

New regulations introduced for 2022

For the start of the 2022 season, the FIA introduced the most significant changes to the F1 rules for many years, with the focus on improving overtaking opportunities and thus the overall quality of racing. The amended regulations were originally intended to be introduced for the start of the 2021 season, but the challenges presented by the global pandemic, and the resulting disruption to the world at large, resulted in the changes being postponed until 2022.

A full-size mock-up to illustrate how the revised cars might look was unveiled ahead of the 2021 British Grand Prix, and following the launch of the mock-up, a number of refinements were made to the regulations ahead of the start of the 2022 season.

One of the key aims of the new regulations was to reduce the loss of downforce suffered by a car when following closely in the aerodynamic wake of a car ahead. To achieve this, underbody tunnels have been reintroduced to F1 for the first time since the 1980s 'ground-effect' era, and the front and rear wings have been simplified, in order to ensure that the floor provides a greater contribution to the overall level of downforce produced.

> *"The downforce contributed by the floor is more stable relative to the downforce produced by the wings"*

The downforce contributed by the floor is more stable relative to the downforce produced by the wings, and is less affected by the wake of a car ahead. The aerodynamics of the new cars are also intended to create a greater 'upwash' of air from the floor at the rear of the car to reduce the effect of the wake on a following car.

Additional significant changes for 2022 included a change to larger (and heavier) 18in wheels (from the previous 13in wheels) with new low-profile tyres, a ban on suspension inerters (see Chapter 4) and

ABOVE A full-scale mock-up of a typical 2022 car was shown at a launch event at Silverstone in July 2021 ahead of the British Grand Prix. (Motorsport Images)

RIGHT The action during the early part of 2022 suggested that the revised FIA regulations were working to good effect. Here Charles Leclerc (Ferrari F1-75), Max Verstappen (Red Bull RB18) and Lewis Hamilton (Mercedes W13) engage in a memorable battle during the 2022 British Grand Prix. (Author)

more stringent crash-testing, resulting in a significant increase in the quantity of energy to be absorbed during front and rear impact tests.

As a result of the rule changes, the regulated minimum weight of the cars increased from 752 kg to 798 kg – a significant change.

Another important development for 2022 was the FIA's categorisation of the components fitted to the cars: Listed Team Components; Standard Supply; Transferable; and Open Source Components – see Chapter 17 for more details.

A further significant change is the way in which the regulations have been structured for the design teams. Previously, most dimensions specified in the regulations were expressed as linear dimensions measured from datum lines or points. For 2022, a system of cartesian co-ordinates was introduced to define boundaries for the shapes of certain components and the three-dimensional volumes in which they must be situated. As the Computer Aided Design (CAD) systems used by the teams have a similar cartesian co-ordinate system, this makes it easier for the designers to interpret and visualise the dimensions and shapes specified in the regulations.

By the end of the 2022 season, it seemed that the new rules had achieved their goal of facilitating closer racing and levelling the F1 playing field to some degree, resulting in some memorable on-track battles and the end of a prolonged period of Mercedes dominance.

Improved on-track action, coupled with a drive to engage with a wider, younger audience and a policy of taking the show to new venues around the world, will hopefully ensure that F1 continues to go from strength to strength at the pinnacle of motorsport.

MOLECULES OR ELECTRONS?

Sergio Rinland says F1's rising popularity offers motorsport a fabulous opportunity to reprise its role as an influencer – but this time the stakes are high

MOLECULES or Electrons? That is the question. Despite the best intentions of politicians to save humanity from itself, wiping ICE vehicles from the face of the Earth in order to reach the goal of net zero emissions by 2050, it looks like an almost impossible task. There will not be enough batteries nor lithium to power *all* the automotive fleet by 2050 and here we are still not including air and maritime mobility.

Are battery-powered EVs the *only* solution to achieve 2050's goal? Many people meeting last month at the annual EEMS event, hosted by the Motorsport Industry Association, believe there are other solutions. Even though the event is mostly related to motorsport, the discussions there will have wide implications in the automotive and mobility industries at large.

As was the case historically, motorsport is back as an 'influencer' of technologies. Many mobility solutions are being or will be tested in motorsport: ICE powered by sustainable fuels; EVs powered by Li-Ion batteries; and hydrogen, both as a fuel for ICEs and electricity generation fuel cells. All good news for our industry.

On top of that, the turnaround in the popularity of Formula 1 is testament to the 'entertainment' aspects of motorsport being as or more important than its technological contribution.

For the first time, we have evidence in 'black and white' of the fact that the carbon footprint of the racing cars themselves is negligible. So new regulations are being formulated to have an adequate 'sustainability metric' to measure the contribution of the whole industry, from manufacturing to logistics, and reward competitors accordingly. Similar ideas to the old Le Mans 'Index of Performance' have been ▶

Getty Images/Red Bull

BELOW The resurgence in F1's popularity offers the perfect platform from which to promote the use of e-fuels

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HISTORIC RACING TECHNOLOGY brings a unique perspective to the business of restoring, preparing and maintaining historic competition cars in the 21st century, with in-depth technical articles on the engineering and craftsmanship behind this fast growing industry.

Where **Historic Racing Technology** differs from existing titles is a clear focus on the challenges and opportunities of running these cars in the modern era. From laser scanning through to five-axis CNC machining, historic racing specialists are increasingly blending modern methods and traditional techniques. As a result, it's now possible to produce authentic parts with an unprecedented level of accuracy. In some cases this goes a step further, re-engineering aspects of the car to deliver improved safety or reliability... and sometimes performance.

Featuring technical articles from some of the industry's most experienced journalists and engineers, **Historic Racing Technology** is dedicated to the classic motorsport scene across the globe. It takes a fresh new approach, looking at the future of historic motorsport as well as the past.

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mentioned as a possible future metric not just for endurance racing, but for all, F1 included.

Going back to my first paragraph, because Li-Ion batteries are not the only solution to our energy-thirsty society, the discussion is directed towards the question: Molecules or Electrons? And the answer is, as we can predict, Molecules. Those will be around our energy recipes for the foreseeable future unless *all* electricity needed to feed our batteries or to separate hydrogen to be used as a fuel comes from sustainable resources (wind generators, solar panels, or nuclear). Even if the answer is 'Electrons', those electrons will need some molecules, for now, to be generated.

> ***"Show the world we lead the R&D on all the possible solutions to become 'net zero' by 2050"***

So, what does all this have to do with motorsport? Everything, I would say, because motorsport is the most technology-driven sport and hence energy-hungry, so we need to not only solve the energy issue and answer that question, but we need to show the world we lead the R&D on all the possible solutions to become 'net zero' by 2050.

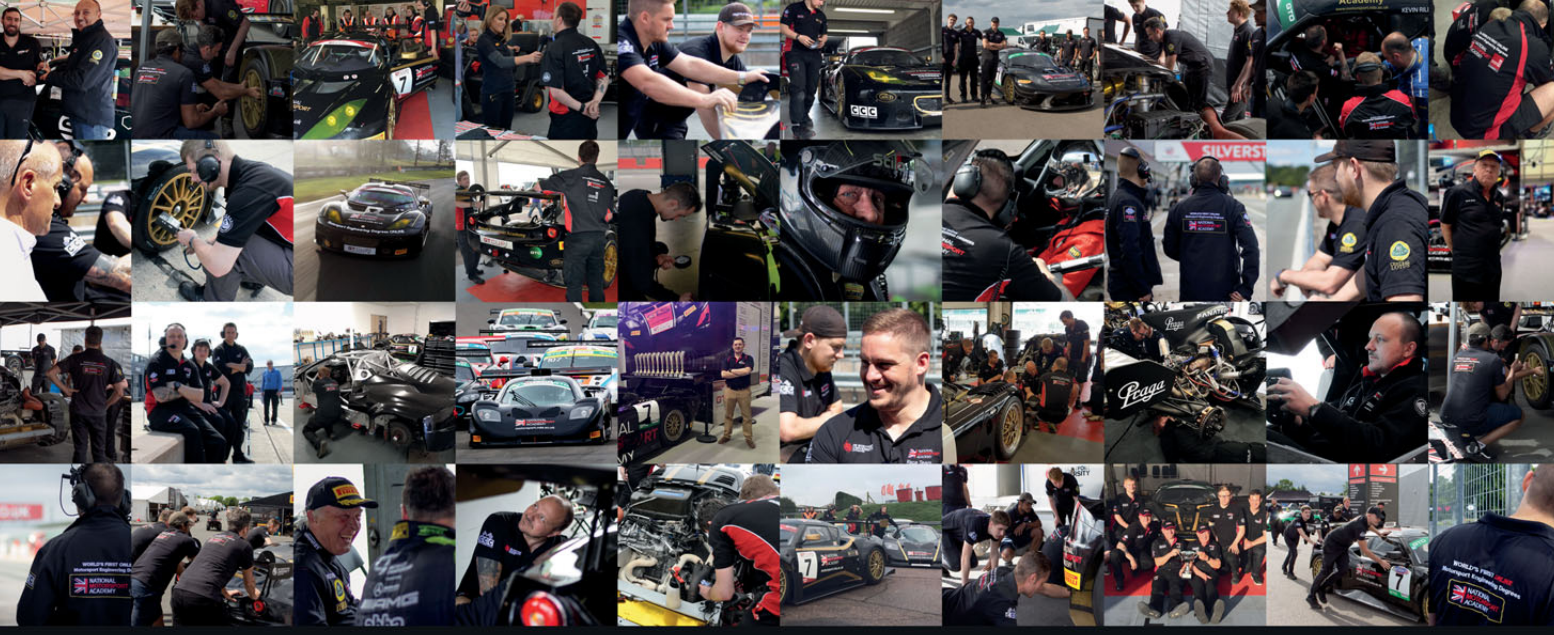
We have to make sure we convey the message that 'net zero' does not necessarily mean 'no emissions'; it means the net balance is zero. And here is where the e-fuels being adopted by F1 from 2026 – to continue using ICE as part of the hybrid system – are part of that message. Manufacturing and logistics have to follow closely, but make sure the wider public knows about what we are doing! Otherwise, it is not worth it.

The only places where we should insist on 'zero emissions' are inside populated areas, big cities, where for now the only viable solution is Li-Ion batteries, followed closely by hydrogen fuel cells. Again, 'zero emissions' inside the cities, but not necessarily 'net zero' because not all electricity to charge those batteries or separate those hydrogen molecules will come from renewable sources for the time being. So when politicians push for only EVs inside cities, they should also be looking to where that electricity is coming from and make sure the net balance is 'zero'.

For the rest of the energy spectrum, the role being played by motorsport now and in the future is of paramount importance, to the planet *and* for the sustainability of motorsport as an entertainment and an industry. RT

ABOVE & BELOW
Motorsport's R&D capabilities are underlined by the consortium of Japanese manufacturers currently exploring hydrogen and carbon neutral fuel alternatives to BEVs. Toyota's Corolla is testing liquified hydrogen, transported from Australia by the Suiso Frontier liquid hydrogen carrier built by Kawasaki Heavy Industries

Courtesy of HySTRA



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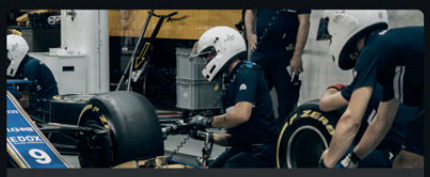

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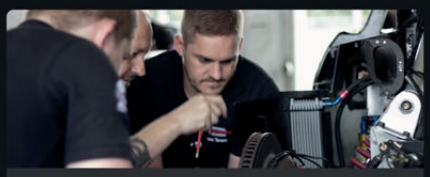

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