>> What does a team need to enter Formula 1? See p18

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FIA reveals its accident investigation strategy

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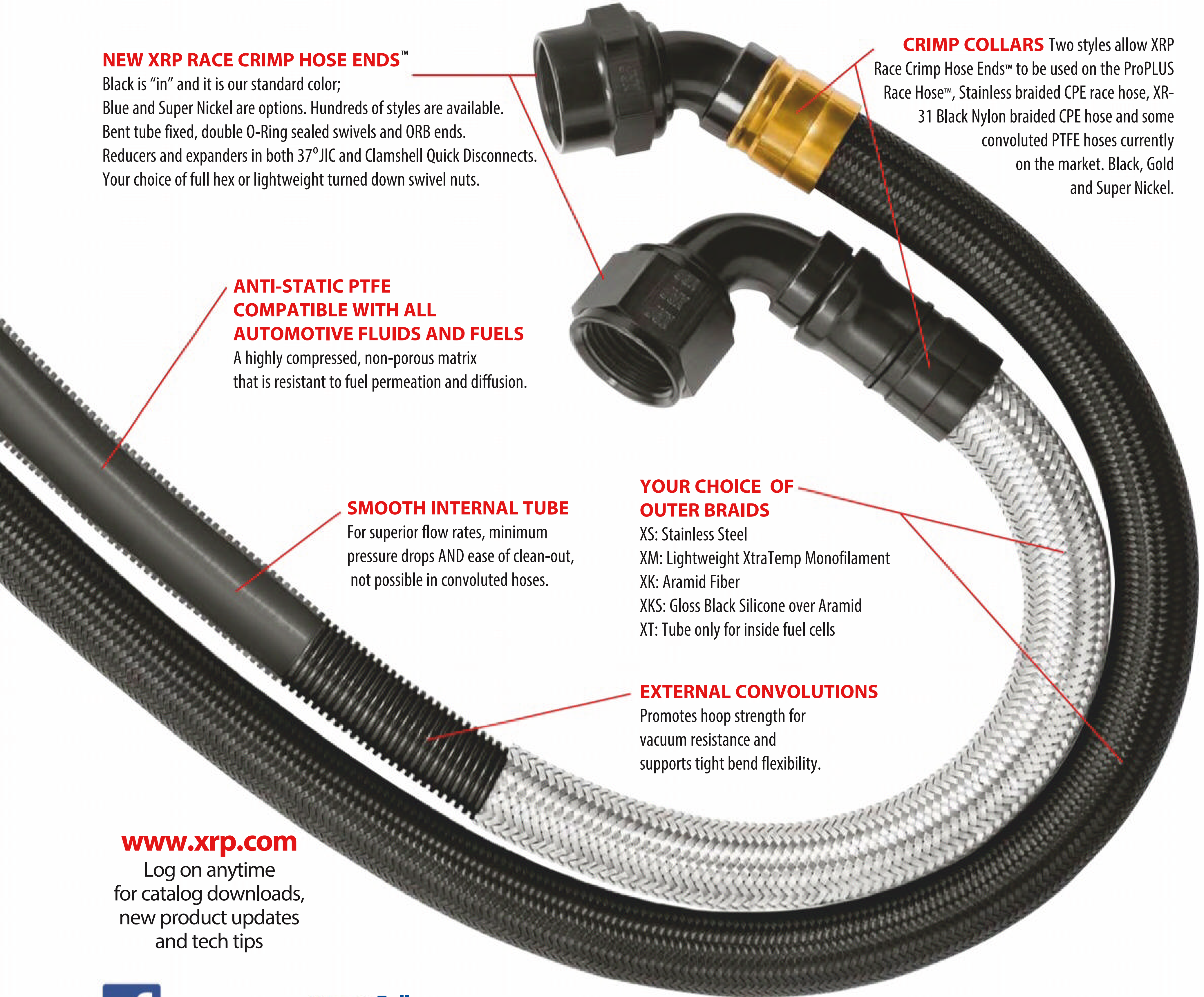

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A pause for thought

The hiatus Covid-19 has brought upon us all offers a unique possibility for fundamental change for the better

As the lockdown slowly starts to lift in the UK, and around the world, many of us are reflecting on the strangeness of the last few weeks, and wondering what the 'new normal' will actually look like.

Covid-19 stopped motorsport in its tracks. Re-starting isn't as straightforward as just carrying on as we were as there is a new world out there. A world of travel restrictions and social distancing. As we prepare to re-start the IMSA WeatherTech SportsCar Championship with Mazda, we have had to make a lot of difficult decisions, especially for the team members who will now stay in the United States for many weeks to avoid going back and forth from the UK with its quarantine and border restrictions.

Every race series wants to get going as soon as possible, to maximise the time available before 2020 ends. This has resulted in cramped calendars, which presents more problems for motorsport contractors and the media, who work across multiple series.

Some teams have had to decide whether or not they can complete the season, whilst amateur drivers who race in multiple series have had to choose where to commit, which has a knock-on effect on the teams that run them. This is before you consider the world of sponsorship contracts and television deals that need to be honoured before they agree to pay out.

Long-term future

Despite all this, the appetite to race is as strong as ever. But as we all come out, blinking into the sunlight, ready to fire up our racecars and do battle once again, we need to think about what the long-term future of motorsport looks like.

There are so many possibilities at the moment, and maybe that's the key to it. So many different forms of racing. Or maybe not?

How can teams, manufacturers and governing bodies embrace the ideas around different racing concepts? Will the new model be designed to encourage more private teams to enter race series, or will it be aimed squarely at the car manufacturers?

When I'm not running Multimatic's Vehicle Dynamics Centre, or race engineering the no.77 Mazda, I'm president of the FIA's GT Commission. These are just the sort of questions we ask all the time.

Often, until a new idea hits motorsport, the industry is guilty of believing things can't change, but customer racing, diesel-powered prototypes and electric racing have shown that change *is* possible. Regulations are a joint effort between competitors and governing bodies, and future evolutions have an opportunity to be radically different to how things have always traditionally been done.

BoP ideas and handcuffed technical regulations may be fun sponges for technical folk, but they allow differing solutions to race in the same category. And many a BoP race has been known to be quite entertaining.

My personal view is that it would be great to see series embracing new engineering philosophies, including virtual racing in their portfolios, exploring alternative fuel options and employing remote working to improve carbon footprints and help reduce costs.

Motor racing needs to find a new relevance and with balance of performance can lead the search for new fuels and powertrains in competition, with the aim of reducing its carbon footprint

We already have so much around us that can be improved and made sympathetic to today's and tomorrow's challenges.

Sense of urgency

Adaption is not a new concept for motorsport, the industry has always had to evolve. But there is now a sense of urgency for racing to adapt quickly and radically. These challenges should be seen as opportunities rather than problems. In fact, in this digital era there are even more opportunities to be had from increased fan engagement with current and new audiences, to technically refining e-racing platforms. The advanced engineering capabilities that exist in motorsport are a prime field to grab hold of these industries and accelerate their progress.

Motorsport is used to working to condensed time frames, sometimes with limited resources but resourceful thinking, and has plenty of personnel within its ranks who would thrive on this challenge.

There will undoubtedly still be huge economic challenges ahead but as everyone, from competitors to manufacturers, has a heightened awareness now, there can be a conscious effort to control excessive budgets that spiral costs out of control. Plus, we already have in place efforts to equalise the playing field for everyone – the BoP fun sponge can still be a chance to think laterally.

To continue to thrive, the whole industry of motorsport must adapt and explore these new and exciting possibilities, even if they weren't the bedrock of motorsport in the past. Right now, we have a unique opportunity to fundamentally change how things *were* done and ensure a new and sustainable future for this magnificent industry.

Leena Gade is the vehicle dynamics centre manager and race engineer at Multimatic Engineering, UK

There is now a sense of urgency for racing to adapt quickly and radically


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Snapshot

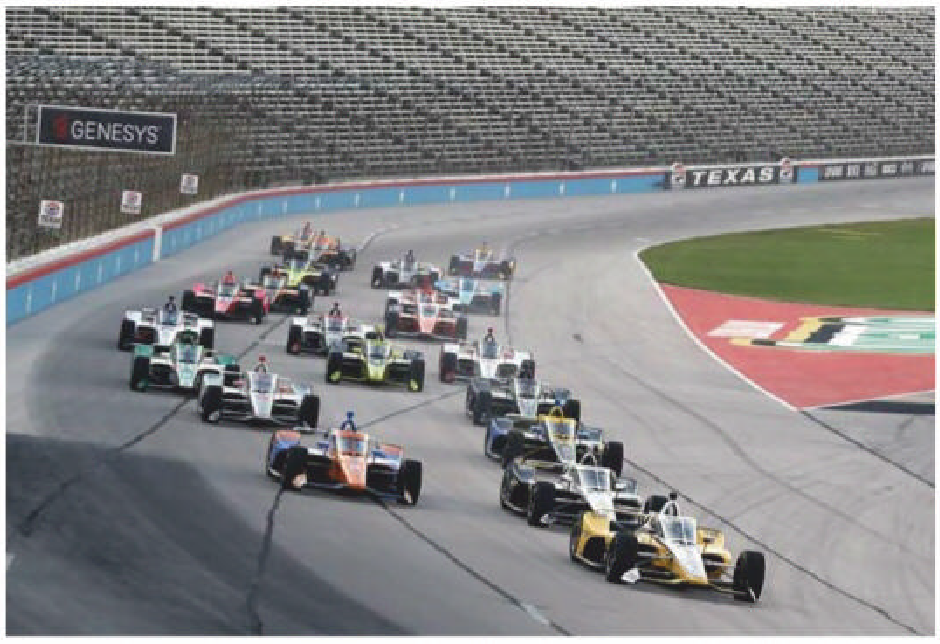
From cats to goldfish to managers to naming protocols

He comes sliding round the slippery corner, head thrust forward determinedly, totally committed in pursuit, in a glorious four-paw drift. Yes, you guessed. Bertie, our black cat, chasing his twin, Humphrey, who has nicked his favourite toy. Given a more suitable physiology, what a marvellous racing driver a cat could make. Fantastic reflexes, incredible agility, superb eye-to-paw coordination, wonderful eyesight and ruthless concentration on the task in hand, to the exclusion of everything else.

Funny what lockdown has one thinking about!

But, thanks to IndyCar, I was recently able to watch my first live motor racing event for many months – the Texas 300. Not being turned on by virtual racing, it was a sense of relief to me to be experiencing at least a partial return to normality, plus the buzz of watching high-speed action with all its attendant strategies, pit stops etc. Speedways can present lengthy periods of not much happening, until suddenly there's a car in the wall, often then taking out other competitors and instantly changing the whole race picture. Or a particularly dramatic four-abreast-into-a-corner moment, or a daring outside line overtake. All these were part of last week's race. Just missing, of course, were the cheering fans, the empty grandstands a reminder that normality remains some way off yet.

Sad to remark, but in my opinion Dallara's previously quite svelte (compared to current F1 cars, anyway) IndyCar has had its proportions destroyed by the newly mandated Aeroscreen. From initial prototypes, which to my eye were just about passable, the 'screen has morphed into a bizarre piece of kit. Although unquestionably hi-tech, it looks as if, rivets 'n' all, it belongs to a dirt track car.



Aeroscreen: safety first, but at the expense of the design aesthetic of IndyCar

Goldfish bowl

From ahead, the view resembles a driver's head in a weird, bucket-shaped goldfish bowl. My cats would be fascinated by it. It's as bad as the Halo as there's even less sight of the occupant. It's safer, I imagine, because there are no apertures through which debris can enter, but hell, both systems really emasculate the aesthetics of the world's top single-seater racecars.

Away from US racing, the potential for Sebastian Vettel not to be on the F1 grid in 2021 to some extent mirrors the absence of Alonso. Two very fast and experienced drivers that, despite being multiple World Champions, have failed to achieve their dreams of winning further championships with Ferrari. Although both have their character faults, the finger has to be pointed at Ferrari management, which only seems to succeed when it isn't all Italian!

At the other end of the scale, but also suffering from a failure of management, is Williams. All started to crumble for this great team when it began taking drivers based on their budget rather than their talent. If Williams needed the money that badly, it would have done better to have sold off assets then, rather than being forced to do so now.

Formula 1 results bring money, which, as others have also observed, probably would have exceeded the income derived from signing moderately capable pay-drivers instead of potential winners. ROKiT as F1 sponsor never felt right (nor did Rich Energy, which apparently almost went to Williams before ending up – literally – at Haas). I've seen such deals that appear out of nowhere before and, unfortunately, they almost always fail to deliver on the announcement hype. Few doubt Claire Williams' depth of feeling for the team, but more truth and less 'spin' from a constantly contradictory narrative would help offset the lack of credibility from which the famous outfit now suffers.

McLaren's far-from-camera-shy Zak Brown quickly learnt that lesson, concentrating on changing the self-absorbed 'we are the best' culture and employing such members as Andreas Seidel to drag the team out of the mire. New signing Daniel Ricciardo hasn't recently displayed the best judgement and this surely has to be a final roll of the dice for him. It seems to me from the casual way he described talks with Ferrari that came to nothing, he didn't want it badly enough.

A shame, certainly, Renault also didn't deliver on its performance promises, but this has been a feature of Cyril Abiteboul's management for some time now.

There's no doubt being team principal in modern F1 is a fiendishly difficult job, and it is easy to sit and poke holes in individuals and structures, but it is what these people are paid handsomely to do. Toto Wolff and Red Bull (mainly) are the benchmark. For an example of having a grounded handle on matters, look no further than Racing Point's Otmar Szafnauer. His big test will be if the Aston Martin name and the finance it should bring, combined with the budget cap, allows the team to fight near the front, with the greater pressure.

Badge engineering

Meanwhile, Ross Brawn announced that no new engine manufacturers will be permitted to enter F1 before 2026. While understanding the logic, I don't see why this has to be a rule. More likely could be a prospective F1 participant reaching a badge-engineering deal with one of the four current PU suppliers to get into the game, while itself having a 2026 PU designed and developed once regulations are announced.

An enormous amount of learning about F1, technical, sporting and political, would mean the manufacturer being much better prepared for the introduction of its own product, and with greater credibility. There have been a number of historic examples in F1 of re-naming engines. Most recently, in 2016, Red Bull continued its association with Renault but re-badged the engines TAG Heuer, in deference to its sponsor.

In post-Covid times, a name transfer may be essential if any of the big four pull out.

Being team principal in modern F1 is a fiendishly difficult job

Safety first

Racecar looks at the advances made in safety across all motorsport disciplines, and its wider application to society as a whole

By DIETER RENCKEN

Motorsport, by its very nature, will never be entirely free of accidents, but the days of glorifying the daredevil antics of drivers are behind us, now focus is firmly on the preservation of life

During Formula 1's formative years, the sport's protagonists generally adopted cavalier approaches to safety. Contemporary photographs of Ferrari's first world championship grand prix winner, Froilan Gonzales, show him racing to victory in the 1951 British Grand Prix in short sleeves, head topped by a yellow helmet bearing two rows of holes – the Argentine punched these into his 'half lid' to provide a modicum of cooling.

Fast forward a decade and standards were little better. The 1961-'65 Formula 1 regulations include the following paragraphs: 'Protection against fire: The car shall be equipped with a general circuit-breaker either operating automatically or under the control of the driver.' Continuing; 'A fastening system for a safety belt shall be provided, the belt itself being optional.'

It all sounds extremely courageous, if exceedingly naïve, but the fact is such behaviour simply could not continue, as Sir Jackie Stewart regularly relates. At the height of his career, he and wife, Helen, tried to recall the number of friends they had lost to motor racing over the years. 'We stopped counting when we got to 50,' he said, adding, 'People call that era 'the good old days', but they were the bad old days…'

Nevertheless, the triple world champion continued racing, vowing to make racing safer. Not particularly difficult given that 'safety barriers' at some venues comprised straw bales, trees lined the circuits, crowd control was zero and seldom were ambulances even on standby. Medical facilities? The closest hospital, even if it was an hour away by unmade road. Incredible as it

‘People call that era ‘the good old days’, but they were the bad old days…’

Sir Jackie Stewart

seems 50 years on, the Scot received nothing but scorn for his efforts at the time.

Despite great progress at the insistence of the Grand Prix Drivers' Association and others who followed in the Scot's racing boots – including, it must be said, F1 tsar Bernie Ecclestone, who appointed Dr Sid Watkins as permanent medical delegate with powers to cancel a race – motorsport's mortality rate remained unacceptably high.

Public tragedies

It took the Roland Ratzenberger and Ayrton Senna tragedies at Imola in 1994 – 24 hours apart, and arguably the most public tragedies in history due to F1's global reach – to galvanise the authorities into action. Even then, overall progress was slow, primarily due to the costs of safety.

In the wake of those deaths, along with a host of others in high-profile series such as IndyCar and endurance racing, sponsors threatened to exit, manufacturers no longer wished to be associated with the risks and teams and suppliers feared litigation of the type that blighted Williams for 11 years before team members were eventually acquitted in the wake of the Senna tragedy.

Something needed to be done urgently at all levels, and in all motorsport disciplines, to ensure the survival of competitors, officials and spectators / fans. And of the sport itself. Focus turned to safety, initially via research and study group, then through a dedicated Safety Department created by the FIA to apply science and data analysis to safety.

Advances in motorsport helmet design and manufacture have far wider reaching applications to society as a whole

The first visible adoption was HANS, followed by a number of initiatives such as wheel tethers, helmet visor panels and, more recently, Halo and Aeroscreen. But contemporary cars and circuits incorporate a number of low-key, or unseen, innovations that raised standards to levels undreamed of in Stewart's day, let alone the Gonzales era.

By its nature, motorsport will never be totally safe, but that still has to be the ultimate objective.

Overall progress was slow, primarily due to the costs of safety

Such studies are not cheap, and were initially funded by the FIA Foundation and FIA Institute – both originally funded by the sale of F1's commercial rights at the turn of the century – until the end of 2017. After that, the governing body launched the FIA Innovation Fund (FIF) using proceeds from the subsequent sale to Liberty Media of one per cent of the FIA's holding in Delta Topco, F1's most recent rights holder.

Starting with a grant of €45m (approx. £40.3m / $50.6m), FIF currently holds €63m (approx. £56.4m / $70.9m) in reserve and, since its inception, has funded 25 initiatives worth over €20m (approx. £17.9m / $22.5m) with motorsport safety and allied activities accounting for a quarter (by value) of approved projects to date. Such contributions complement ongoing funding from the Foundation and the governing body itself.

Safety Department

The FIA's Safety Department is led by Australian engineer Adam Baker, formerly head of track and test at BMW Motorsport. He reports directly to Peter Bayer, FIA Secretary General – Sport, with a recent appointment being that of Tim Malyon. The ex-Sauber and Red Bull engineer has also worked in Formula E and DTM, and heads safety research.

Their combined CV highlights the FIA's commitment to safety. In addition to this in-house expertise, the Safety Department accesses various industry working groups,

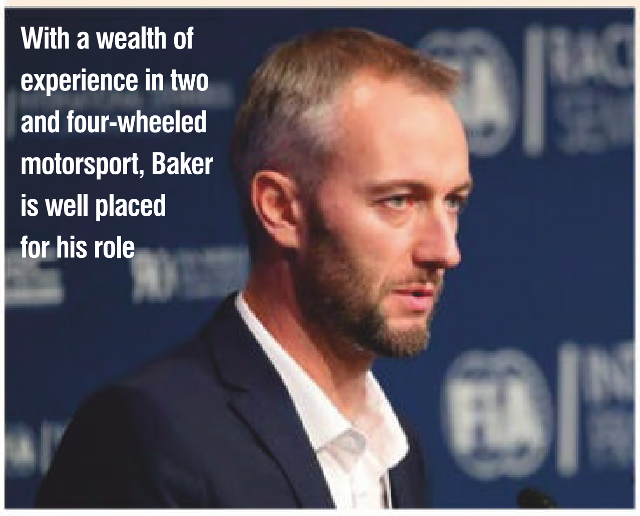
Adam Baker, FIA safety director

Adam Baker studied engineering in Melbourne, Australia, where he also completed post-graduate studies in law. His career began at Holden in 1998, working on high-performance road car projects for Holden Special Vehicles (HSV). His work there introduced him to the parent company, Tom Walkinshaw Racing (TWR), who offered him the chance to work in motorsport full time.

He started at TWR in 2001, working in the IndyCar series in the United States. In 2002, he switched to Cosworth, moving to Formula 1 and spending one season each with Arrows, Jordan and Jaguar.

In 2005, he joined BMW in Munich and worked in a number of roles within BMW-Williams, and later BMW-Sauber, finishing as head of the Race & Test department for F1 powertrain. After eight seasons working trackside in F1, he moved to the BMW World Superbike team. A year later he became head of powertrain development at BMW Motorsport, before returning trackside again to lead the Race & Test department for five years. His responsibilities there were for racing activities across all BMW Motorsport projects, including WEC, Formula E and DTM.

In 2018, he joined the FIA as safety director, responsible for the prevention of fatal and serious injury in all forms of motorsport.


With a wealth of experience in two and four-wheeled motorsport, Baker is well placed for his role

accident specialists and drivers worldwide in order to monitor and analyse all fatal and serious accidents in global motorsport via the FIA's World Accident Database (WADB).

The FIA's Industry Working Group (IWG) comprises over 50 members, with the group including helmet and racing apparel brands, circuit safety specialists, fuel system and electronics suppliers, applied technology companies, motor and allied manufacturers and Cranfield Impact Centre, an offshoot of the university of the same name.

The IWG is managed by the FIA Safety Department and reports to the Safety Commission. Meetings at which projects initiated by the FIA are presented and discussed with all stakeholders are called on a regular basis to enable members to participate in their relevant fields of interest. IWG members have access to reporting on key improvements, research results and information on regulatory implementation.

Protocol demands that National Sporting Authorities (ASNs) report all fatal accidents in their respective regions, whether these occurred in FIA-governed world championship events or at national or grass roots levels, in turn providing the Safety Department with a broad database.

Findings are reviewed by the FIA Serious Accident Study Group (SASG), chaired by FIA president Jean Todt, and comprising the heads of all FIA sporting commissions and FIA sporting / technical departments.

Protocol demands that National Sporting Authorities report all fatal accidents in their respective regions

Prof Saillant, deputy president of the FIA's SASG

Once approved, the appropriate president(s) commit to implementation of findings and corrective measures in their respective championships, usually made via amendments to regulatory clauses.

'The aim of this group is eventually to reduce the risk of accidents,' says FIA Medical Commission president and SASG deputy president Gerard Saillant, 'and when an accident does occur, to reduce the physical consequences for the people concerned.'

The SASG then works in conjunction with the FIA Research Working Group, which evaluates safety measures to complement the work undertaken by the Safety Commission, led by former Williams technical director Sir Patrick Head, which tables recommendations to the World Motor Sport Council, the FIA's apex regulatory body.

Regulatory role

'The role of the Safety Commission is a regulatory one,' continues Saillant, 'the last step before the [WMSC]. The SASG is more 'on the ground', plus works in liaison with various research groups within the FIA.'

The SASG recently published the findings of 28 serious and fatal accidents that occurred in circuit racing during 2019, as reported by ASNs in each country. Although the FIA would not release individual details due to sensitivities, it is clear from recommendations that followed in May this year that research and analysis into each set of circumstances had been diligent.

The report categorises the 28 accidents into four main groups, and includes the following recommendations, which have been communicated to ASNs and technical / sporting working groups for incorporation in future regulations and / or procedures:

Single-seater cars

Debris containment

Mitigate and / or prevent debris coming loose from cars during accidents via tethering and design solutions.

Passive safety structure and survival cell

Review of front and side impact structures with respect to energy absorption, directional performance and compatibility with car-to-car impact. (This process is underway for Formulae 1 / 4 / E, with solutions for Formula 2 / 3 incorporated into the next car updates).

Front wing design and attachment

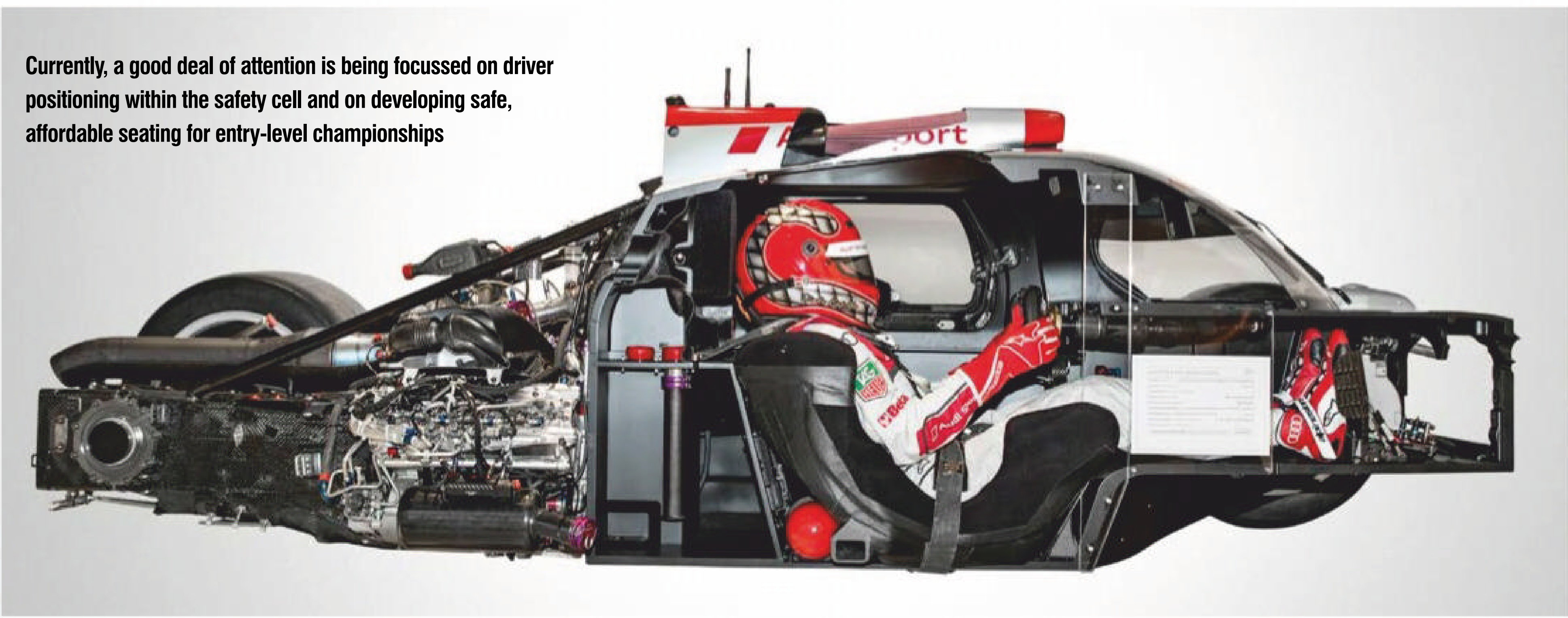
Review of design and wing-to-nose attachment systems to mitigate loss of assemblies. Establish whether future cars could incorporate wing designs with 'controlled failure' points.

Headrest design

Iterate design and specifications to increase robustness of retention and increase probability that headrest remains in situ during impact.

Front anti-intrusion panel

After success with retro-fit upgrades to current cars, latest specification of panels to be incorporated into next generation cars.



Currently, a good deal of attention is being focussed on driver positioning within the safety cell and on developing safe, affordable seating for entry-level championships


Huge advances have been made in electronic safety systems at circuits, but there are more to come, including advanced marshalling systems and direct-to-car notifications

Closed-cockpit cars

Seat

Update FIA standard for mass market competition seats, and training material to educate on correct positioning of driver.

All categories

Electronic safety systems

Review notification of drivers approaching the scene of an incident, with two steps proposed: initial step to improve driver notification and deployment of advanced marshalling systems, incorporating automated yellow flag generation. Second step: direct car-to-car notification and coordinated power reduction.

Tyre pressure monitoring systems

Already in use in senior series, to be deployed in additional categories.

Circuits and operational

Race neutralisation

Development of in-car marshalling systems able to be installed / removed from cars during events.

Low angle barrier impact

FIA safety barrier standard to provide for impact angles of between zero and 20 degrees.

Note: only aspects that incorporate technical solutions have been detailed above, and individual solutions will be tailored according to the specifics of each category / championship.

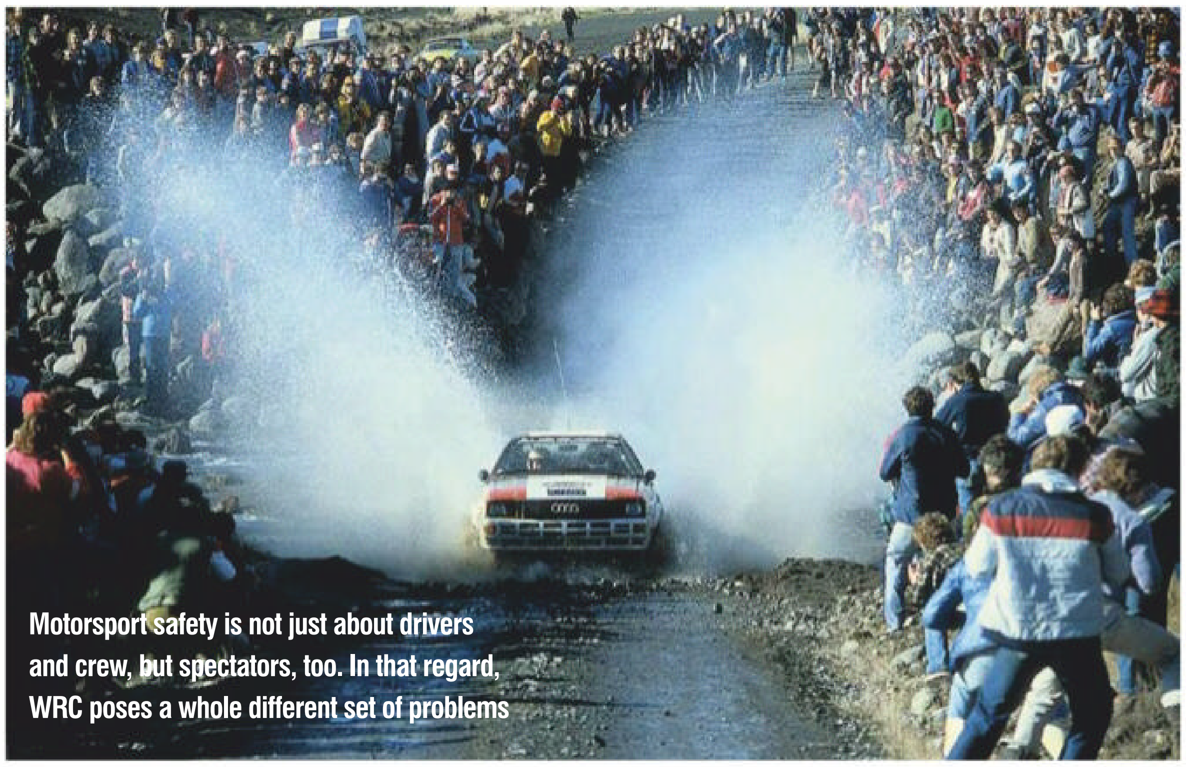
'As with all accident investigation work, our findings related to circuit racing form the basis of a range of technical and operational initiatives, both to prevent serious accidents occurring and to mitigate the consequences if they do,' Baker said.

However, Baker emphasises that 98 per cent of fatal accidents in contemporary motorsport occur at amateur level, with the most commonly identified contributory factors pointing to a need for improved marshal training and race neutralisation (circuit racing), enhanced spectator management and better stage selection and preparation in the case of rallies and other closed-road events. But these latter factors are primarily human elements.

Saliently, the World Accident Database indicates that between 2015 and 2019, closed road-related disciplines accounted for over 50 per cent of the total number of fatalities in motorsport globally, with non-occupant (spectator) safety receiving highest priority. However, the findings also point to an urgent need for improved occupant protection in closed cockpit environments, whether in rally, hillclimb or cross-country competitions.

Safety manifesto

For the purposes of this feature, the FIA provided *Racecar Engineering* with an advance copy of the Closed Road Competition [Safety] Manifesto, compiled by the Safety Department. This document contains a


Motorsport safety is not just about drivers and crew, but spectators, too. In that regard, WRC poses a whole different set of problems

Closed road-related disciplines accounted for over 50 per cent of the total number of fatalities in motorsport globally

number of recommendations ranging from cockpit safety measures through to electronic systems and operational safety guidelines to rally control aids, and illustrates how findings are converted to real world recommendations.

With the 2022 WRC regulations providing for spaceframe vehicles, the FIA Research and Technical departments will ensure the crashworthiness of this next gen World Rally Car by defining full-scale frontal, side, rear and roof impact anti-intrusion test standards, a reference spaceframe survival cell and updated Appendix J safety cage regulations.

In addition, the manifesto outlines updates to FIA Standard 8855-1999 mass market 'competition seats' to increase lateral safety, while ensuring appropriate cost for entry-level seats. Work also continues on seat brackets – to decouple seat / driver mass from car mass during accidents – and various door cavity foams to provide improved energy absorption during lateral impacts.

The use of polycarbonate windscreens is under investigation, as are low cost, 'fit-and-forget' accident data recorders and alternative communication technologies (satellite, 5G GSM, LAN) to ensure compatibility with onboard systems. The Manifesto also calls for drones with facial recognition systems to aid crowd safety, and systems to monitor spectators on rally stages from Rally HQ, using onboard video.

Human modelling

A vital simulation tool used by Baker and his team is Total Human Model for Safety (THUMS), developed jointly by Toyota Motor Corporation and Toyota Central R&D Labs. See *Racecar Engineering* V27N5 for a more detailed analysis.

It was first used in motorsport accident analysis by the FIA after Anthony Davidson's 2012 high-speed LMP1 crash in which the Briton broke vertebrae T11 and T12 when his Toyota TS030 was tagged by a slower GT car during overtaking.

Unlike dummy models, which are simplified representation of humans, THUMS represents actual humans in detail, including their outer shape and bones, muscles, ligaments, tendons and internal organs. It can therefore be used in crash simulations in motorsport arenas to analyse clinical impact.

'For the purpose of crash simulation, the most significant recent change has been our efforts to build true in-house capability within the FIA Safety Department using the THUMS human body model, both to investigate accidents and complement physical testing to conduct research,' confirms Baker.

'Building upon our work with several THUMS research partners, last year we brought the technology in house. Around 12 months ago we hired a research engineer experienced in finite element modelling of the human body for biomechanical research.

'His expertise has allowed us to initiate detailed studies in the virtual environment using THUMS, refining our understanding of how existing safety systems work, and our ability to perform rapid evaluations of proposed new solutions and devices.'

The next big thing

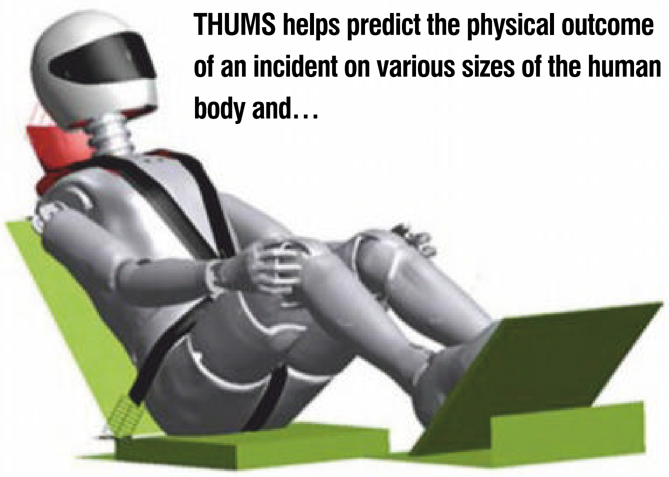
Although the bulk of the Safety Department's work has focussed on single-seater and closed-cockpit cars, karting, which falls within the FIA's scope via the International Karting Commission formed in 1962, has certainly not been overlooked from a safety perspective. The latest project is the development of a brace designed to reduce neck injuries.

Effectively a HANS device for use with low backrest seats and / or belt-less activities, the brace – said by Baker to be the 'next big thing' in human safety after HANS and Halo – is aimed at karting, motocross and mountain biking, and could eventually extend to hobby users, too. The FIA is currently collaborating with its motorcycle equivalent, FIM, to introduce the brace in two-wheeler competition.

Clearly, motorsport safety has progressed in leaps and bounds since Stewart's crusading days, with reporting, analysis and simulation providing the cornerstones of what will always be a work in progress, a never-ending task, that could not exist without a safety first culture at all levels and, crucially, generous funding from the sale of the FIA's commercial rights to various championships, F1 being by far the largest benefactor. There is also an increased recognition from competitors that safety needs to come first.

Although the focus will always be on motorsport's top categories, it is clear from the depth and breadth of research undertaken by the Safety Department that the FIA leaves no stone unturned in its quest for zero fatalities in all categories in what is, by definition, an extremely dangerous activity. Stewart once said drivers should be penalised for their mistakes, not die for them. It's an ideal the FIA has taken to heart.

THUMS represents actual humans in detail, including their outer shape and bones, muscles, ligaments, tendons and internal organs



THUMS helps predict the physical outcome of an incident on various sizes of the human body and…

…that has proved a hugely beneficial tool in both accident investigation and research for all forms of racing, including amateur sport

Safety transfer

It is all well and good expending millions in search of motorsport safety, but what about real world relevance? The FIA is, after all, charged with two pillars of responsibility – Sport and Mobility – and safety is an essential element of both activities.

The neck brace, when it comes to fruition, provides one example of the crossover between the two, while a low-cost, safe motorcycle helmet provides another.

There are approximately three million motorcycles on the world's roads, 80 per cent of which are in Asia – a region that has notoriously lax safety standards. Working with Spanish helmet manufacturer NZI, FIA safety engineers refined a helmet design that could be produced at an affordable price and pass UN safety tests. A prototype was completed at the end of last year, with the next step being field testing. Though that has been delayed by Covid-19, it is due to resume shortly.

'We know the helmet is safe, but we want to make sure it's also fit for purpose in hot and humid climates,' explains Baker. 'We are going to get riders' feedback to prove this is a suitable product.'

The FIA's Mobility department identified three countries in which to test the first batch of helmets – India, Jamaica and Tanzania – and will work with FIA member clubs, road safety agencies and local stakeholders in all three of these countries to promote higher quality helmets to a broad cross section of motorcycle riders around the globe.

Specialist in hydroforming technology

When it comes to Formula 1 and motorsport applications, space is at a premium, and high-precision components are an absolute requirement. Hydroformed exhaust systems are light, accurate and can be made of exotic alloys such as titanium and inconel

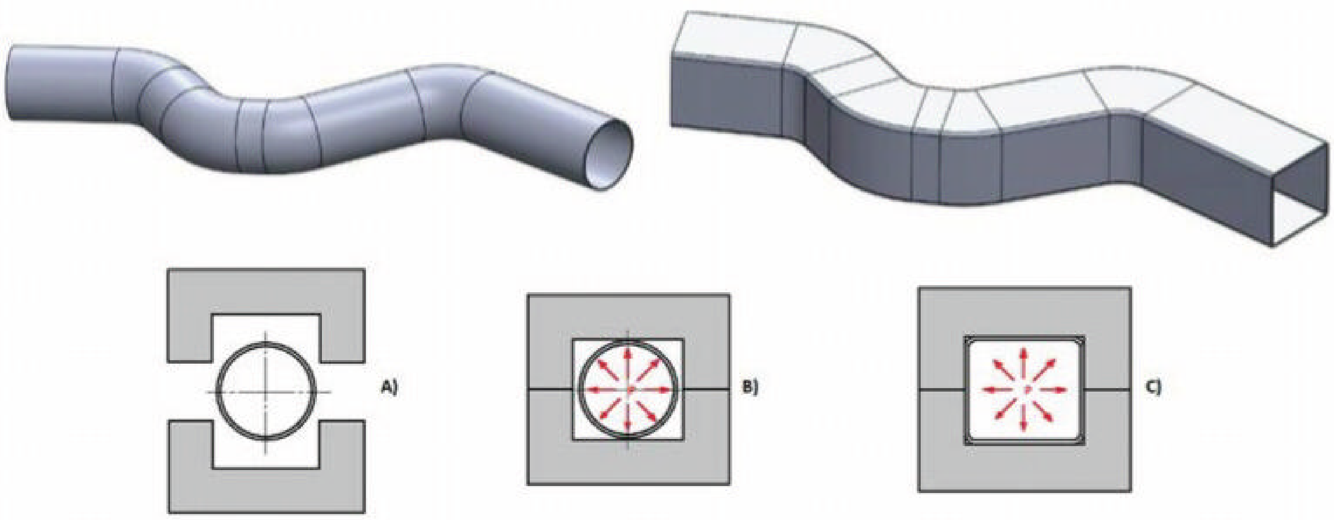
Hydroforming is a manufacturing process which uses a high-pressure fluid to achieve the plastic deformation of metal components, specifically tubes.

The technology expands pipes, or specific pre-formed shapes, from the inside out by means of a liquid working medium in a closed die. This method makes it possible to manufacture hollow components with a complex external shape, or with localised section variations, from a single piece.

The peculiarities of the deformation technique are very effective in the construction of exhaust systems, for example, where the need to build parts with complex routings and with the aim of optimising the fluid dynamic performance within is very relevant.

Design and optimisation of hydroforming processes require knowledge of the fundamentals to determine the necessary process loads, estimate feasibility and obtain an improved comprehension of influences on the reliability and quality of component manufacturing.

A hydroforming press equipped with a hydro tool. Examples of what can be achieved in the foreground



The basic principle of tube hydroforming – expanding a smaller shape enclosed within the hydroforming matrix into a different shape using a fluid under pressure

Hydroformed component after the forming process is complete, ready to be removed from the tool

In recent years, V System Srl has gained extensive experience in the creation of hydroformed exhaust systems for motorsport. For this type of application where on-the-car space available is very limited, the routing of the pipeworks is first optimised by performing CFD simulations.

Unlike other metal forming techniques, hydroforming allows for increased part strength, lower part weight and greater design flexibility, while also improving overall part quality. In our factory we can count on a 1,000 tonne hydraulic press equipped with an injection system able to achieve a pressure up to 2,200bar.

And how about cost?

You might think hydroforming technology is not suitable for small and medium-sized production runs, due to the initial high tooling investment. However, the competence developed by V System Srl in designing and manufacturing the steel dies necessary for the process in house, the design philosophy of combining multiple components during forming and the use of universal clamping systems allows us to be competitive in terms of price, being able to offer customers effective and sufficiently inexpensive technical solutions, regardless of quantity. Moreover, we can perform accurate thickness analyses on hydroformed components using an ultrasonic thickness gauge, specific intermediate and final vacuum heat treatments and NDT testing.

V System Srl is able to supply any type of hydroformed parts according to the customer's requirements, and also more complex TIG-welded assemblies made from different types of components, such as simple curved or hydroformed pipes, CNC-machined parts or items obtained through additive manufacturing technology processes.

Increased part strength, lower part weight and greater design flexibility

For further information, please contact V System Srl via
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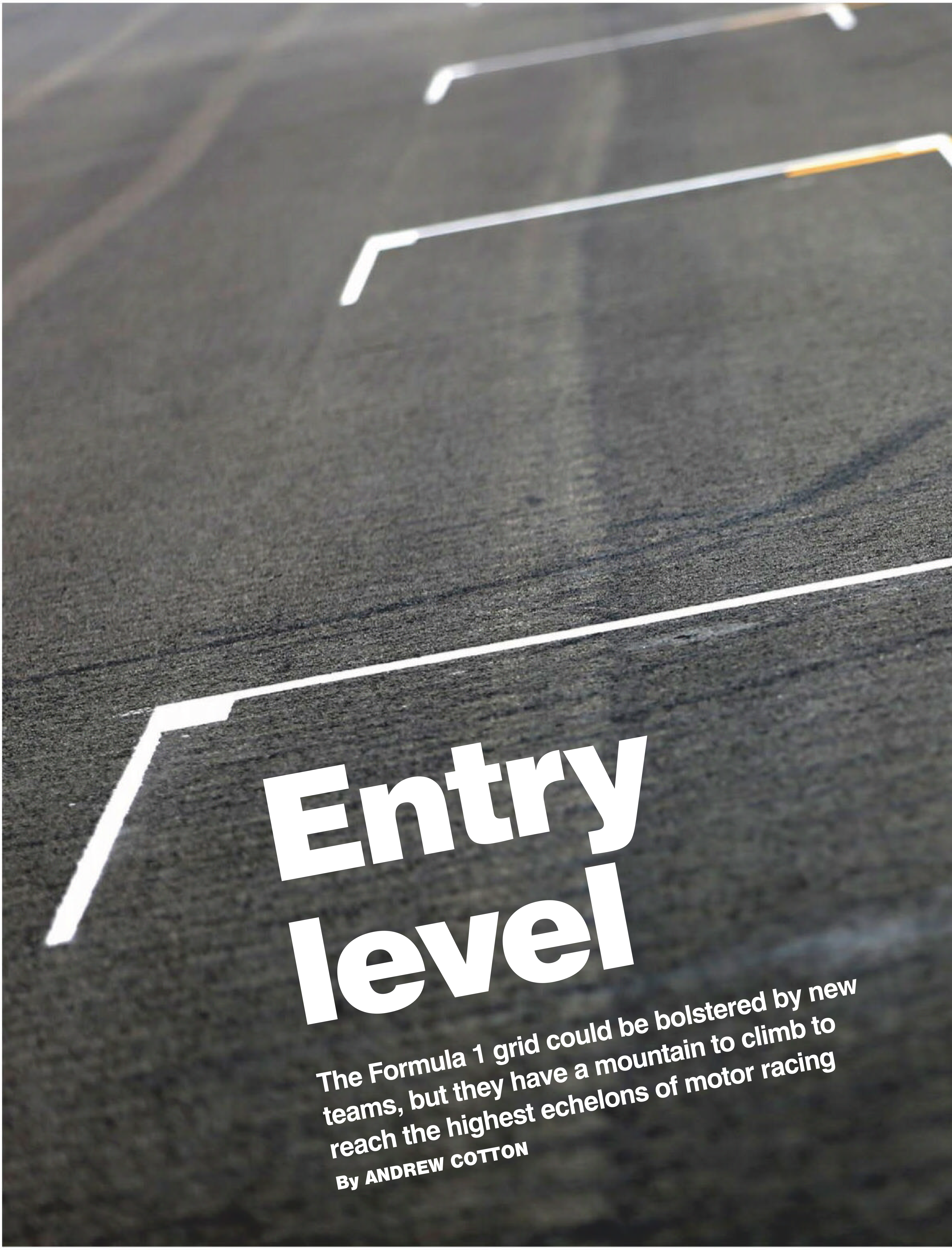
email: info@vsystem.it
'phone: +39 0536 035 111

THE NAME OF HIGH TECHNOLOGY



Entry level

The Formula 1 grid could be bolstered by new teams, but they have a mountain to climb to reach the highest echelons of motor racing

By ANDREW COTTON

XPB

'The reality is you cannot build a Formula 1 car and a Formula 1 team in half a year'

Peter Bayer, FIA general manager – sport

Formula 1 is close to reaching the solution to a conundrum that has bothered the series for more than a decade. How to make the category accessible to the very best new teams, without compromising the quality of the existing grid?

The category has 10 teams on the grid this season, providing 20 cars using power units from three suppliers. The numbers are encouraging on the face of it and there is certainly strength in numbers, but there are threats to the established competitors that have highlighted to the FIA the importance of opening up the possibility for new teams to join the series.

For the motor manufacturers supplying power units and factory teams to Formula 1, there is a lack of assurance regarding their continued racing programmes. Whereas in the past they could rely on petrol, now they need hybridisation or full electric to sell a racing programme to their board. Formula 1 has addressed this issue, introducing hybrid in 2014, but at a cost to the customer teams with no corresponding return.

Pressure on these manufacturer programmes has increased further recently. OEMs now face the disapproval of the general public, not only for CO_2 and NO_x emissions, but also a further attack on personal mobility following the dieselgate scandal in 2015 that continues to rumble on and expand to other manufacturers and transport. A dramatic fall in personal journeys in Covid lockdown has put further pressure on manufacturers to produce 'clean' motoring, and governments are responding by offering heavy subsidies for new electric car sales.

The threat to Formula 1 manufacturers and customer teams is real, and the FIA's first priority under the new regulations that start to be introduced in 2021 is to protect those already there. However, it also has a responsibility to ensure new teams have the ability to step up, should any of the established teams or manufacturers fall, and that is an unenviable task.

The gap between a team competing in Formula 3, or even Formula 2, and Formula 1 is huge. It is not only the technology that needs to be addressed – running a spec engine, gearbox, chassis and hybrid system, compared to development in all these areas – but also one of cost. There is as much as a US$50m gap between an F2 team and a team competing in F1. While the return for competing in F1 is considerably larger than F2, the leap from one to the other, and the process a team has to go through with the FIA to even reach the grid, is extraordinary.

Seeking approval

There are three things a team needs to achieve: first is to actually be granted FIA approval, second is to recruit enough personnel and expertise to compete, and third is to raise the money in order to fulfil the first two, plus demonstrate the cash flow is sustainable for the short-to-medium term.

On top of this, there is a larger number of races in which to participate and, although the revenues from television are higher than ever before, those that are competing in the championship are highly protective of their own investments and are in positions of such power that they can make life extremely difficult for a new contender.

For teams looking to join Formula 1, access to money has been possible but, with the banning of tobacco advertising in 2006, motor racing took a hit from which it has never fully recovered. From grass roots events to such as the Marlboro Masters Formula 3 event in Zandvoort, and the support given to driver development schemes and advertising in large racing series such as Formula 1, tobacco sponsorship was prevalent in the sport. Money from more socially acceptable sources has been harder to come by.

Against this backdrop, the FIA has been working on a revised budget cap that will be introduced in 2021. The latest version of the budget cap was originally set at US$175 million (approx. £138.5m / €154.5m), but that was reduced to US$145m (approx. £114.7m / €128m) and will fall by a further US$5m (approx. £4m / €4.4m) in 2022 and 2023. That's the first stage that is designed to help the existing teams, but the gap from there to a new team that currently operates on a far smaller budget is still mind bending.

Timelines

Of the four teams that entered Formula 1 in 2010 under Max Mosley's proposed budget cap, one failed to make it to the grid and the other three failed relatively quickly. It is not uncommon for new Formula 1 teams to fold, but for four to enter under an agreement specifically targeted to help them, and then fail, was unexpected, and signalled the first of the warning signs that Formula 1 would be inaccessible without further changes.

The first of the challenges is one of timing. The best time to enter a formula is, arguably, when there is a change in regulation and everyone is starting from a relatively clean sheet of paper. With an 'all-new' regulation set due in 2022 that features radically different cars, it would appear to be an ideal time for a new motor manufacturer to consider entry for the 2022 season. For them, though, the task is similar to that of a private team such as Panthera F1, that is also looking to enter Formula 1 in 2022.

In order to even have a car on the grid, a potential team would have to answer a call for an expression of interest from the FIA before entering a rigorous selection process. For a team to respond fully to the FIA's call, it would need to provide a description of the

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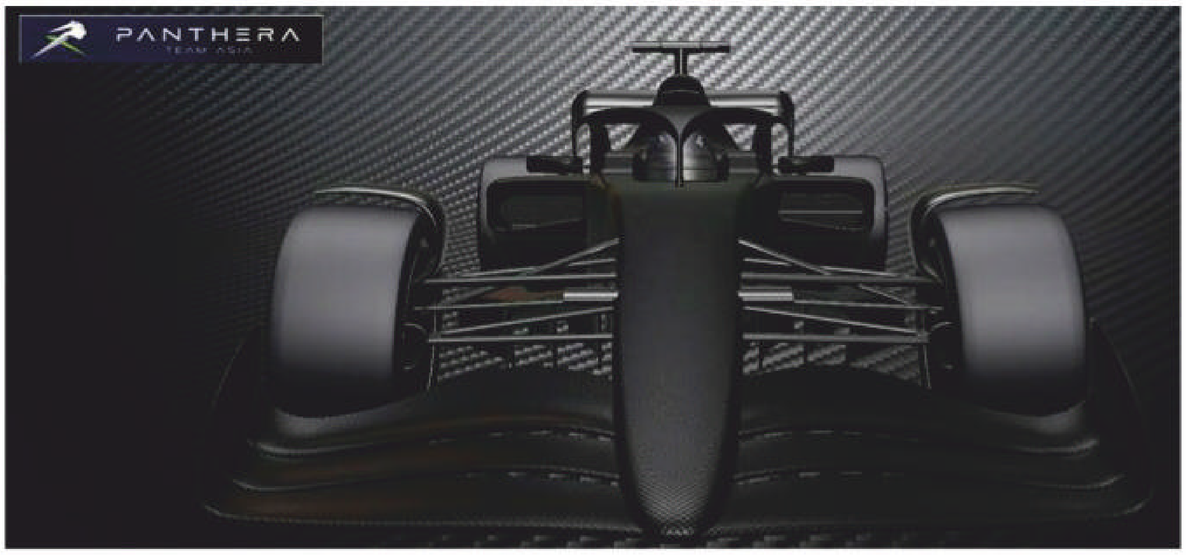
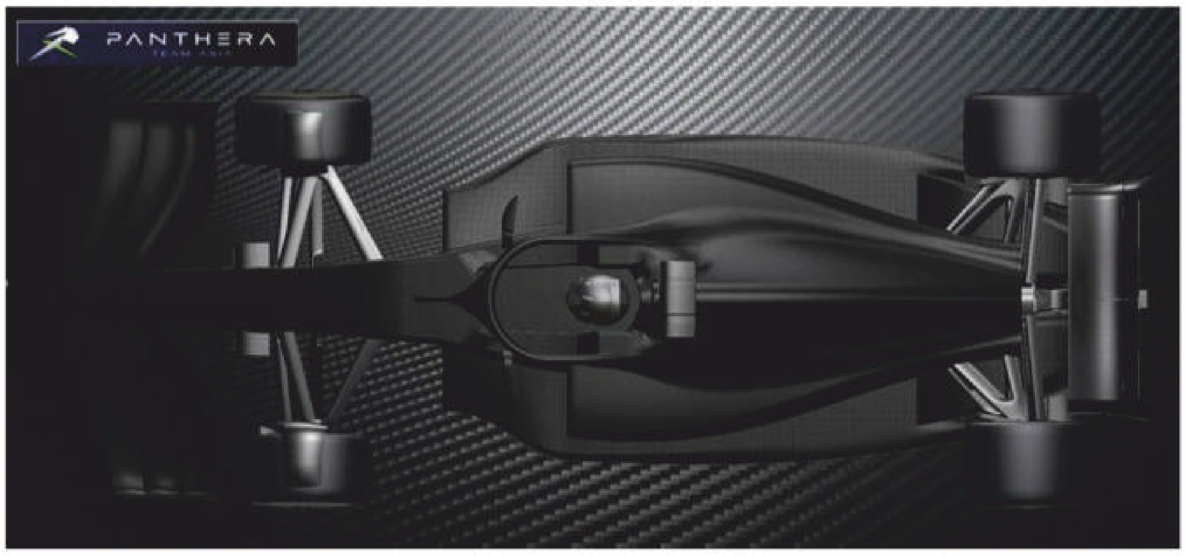
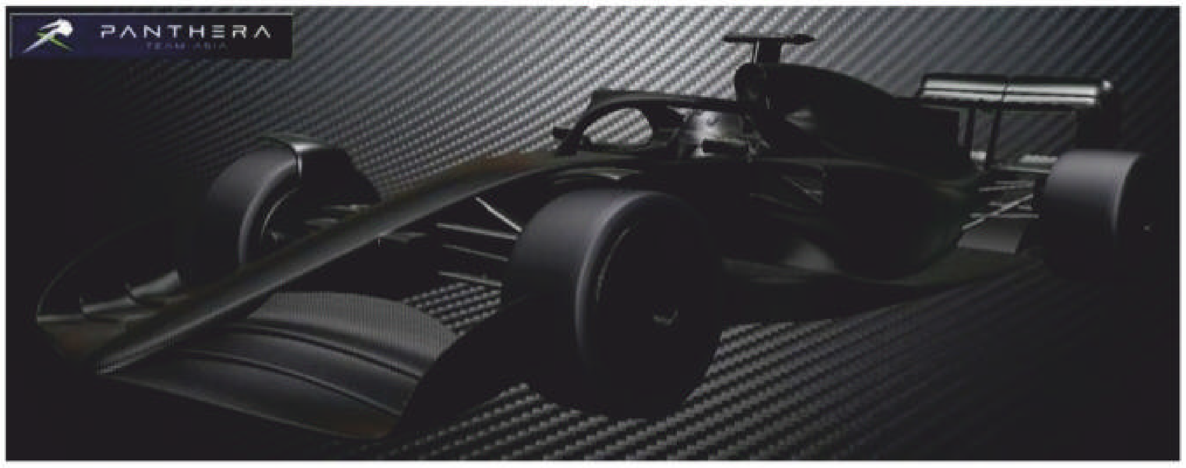
It is not just the difference in operating costs from feeder series such as Formula 2, the process of applying and gaining approval from the FIA to step up to Formula 1 is extraordinary

Of the four teams that entered Formula 1 in 2010… one failed to make it to the grid and the other three failed relatively quickly







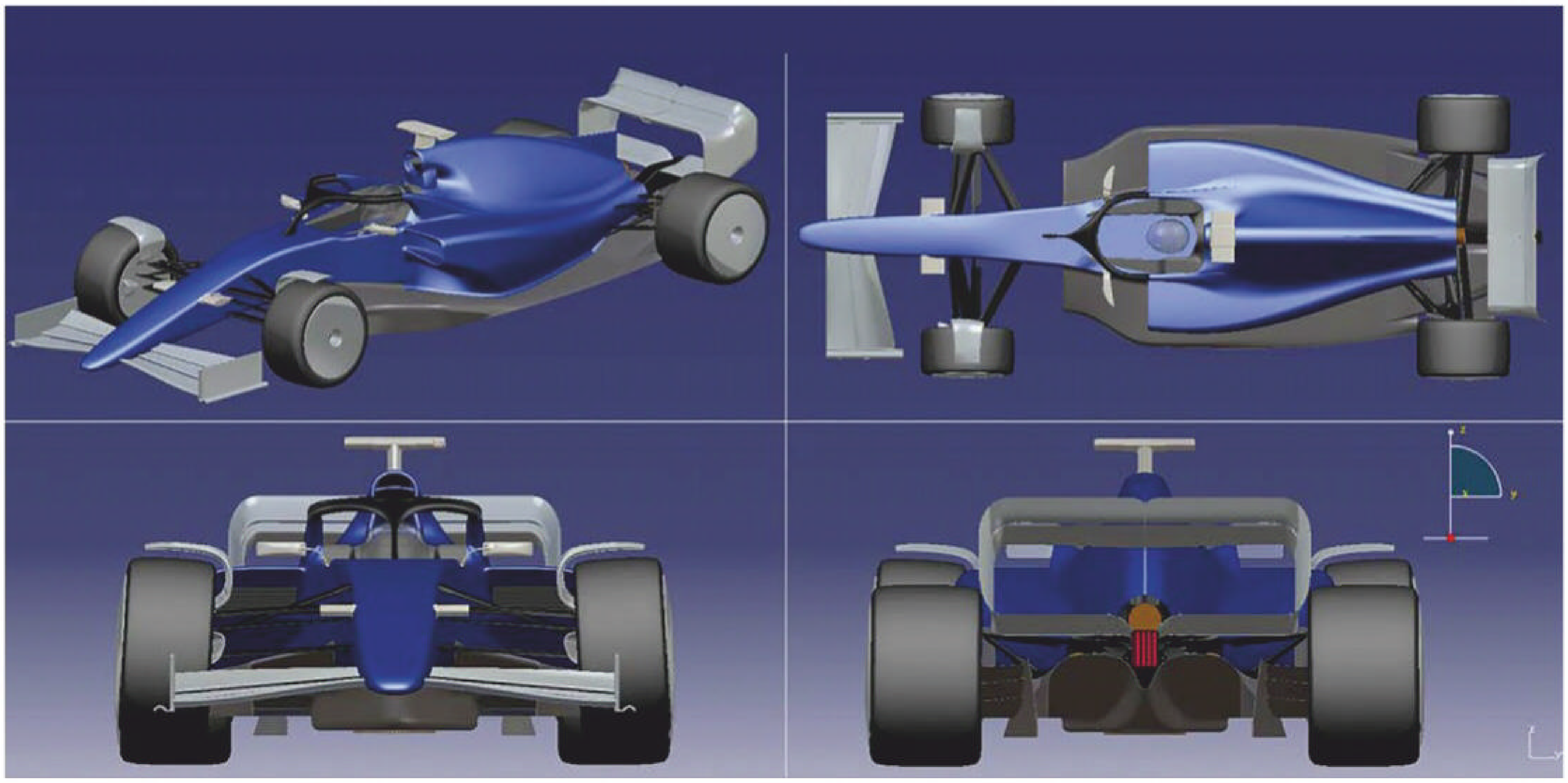
project, the team, the investment structure, the technical abilities of the team and its engineering manufacturing abilities. It also has to show that it can both start up the business, and maintain it financially for years.

Not only is time now tight for a new team looking to join the series in 2022, the FIA is not in a position to call for an expression of interest because the framework is not in place from an organisation point of view.

'What they used to call the Concorde Agreement, or commercial agreements, are not done yet,' confirms the FIA's general manager – sport, Peter Bayer. 'Currently, the FIA and Formula 1 has decided not to launch this expression of interest.'

For a manufacturer or a private team looking to come in cold, or to step up from a feeder series, the infrastructure must be built. The process of car design and development is both costly and time consuming.

'The timescale is not something we have defined,' says Bayer. 'The reality is you cannot build a Formula 1 car and a Formula 1 team in half a year. It is such a highly sophisticated racing machine, you cannot simply put one



Having access to a standard car for the first years of entry into F1 could make life easier for a team looking to step up while they design their own contender for year three

together in that time because you have to go through various processes where you design your parts, and other processes where you have to source the parts required.'

The speed at which a team can pull together a programme is clearly an area of concern for the FIA. Standardisation of some parts has been discussed in order to reduce the development cost to teams, but for any new team coming to the market that would also reduce the time needed to prepare the car. The FIA actually has the chance to go further, with the standardisation of computing power and, crucially, producing an engine and chassis combination a team would be able to use in the short term.

Formula of innovation

The DNA of Formula 1 is innovation, and teams have the ability to develop their own chassis and aerodynamics according to their own studies. However, for a team just entering the championship, asking a new technical team to come together and nail it straight away so their car can run within two per cent in terms of overall lap time of the Mercedes is possibly too much to ask.

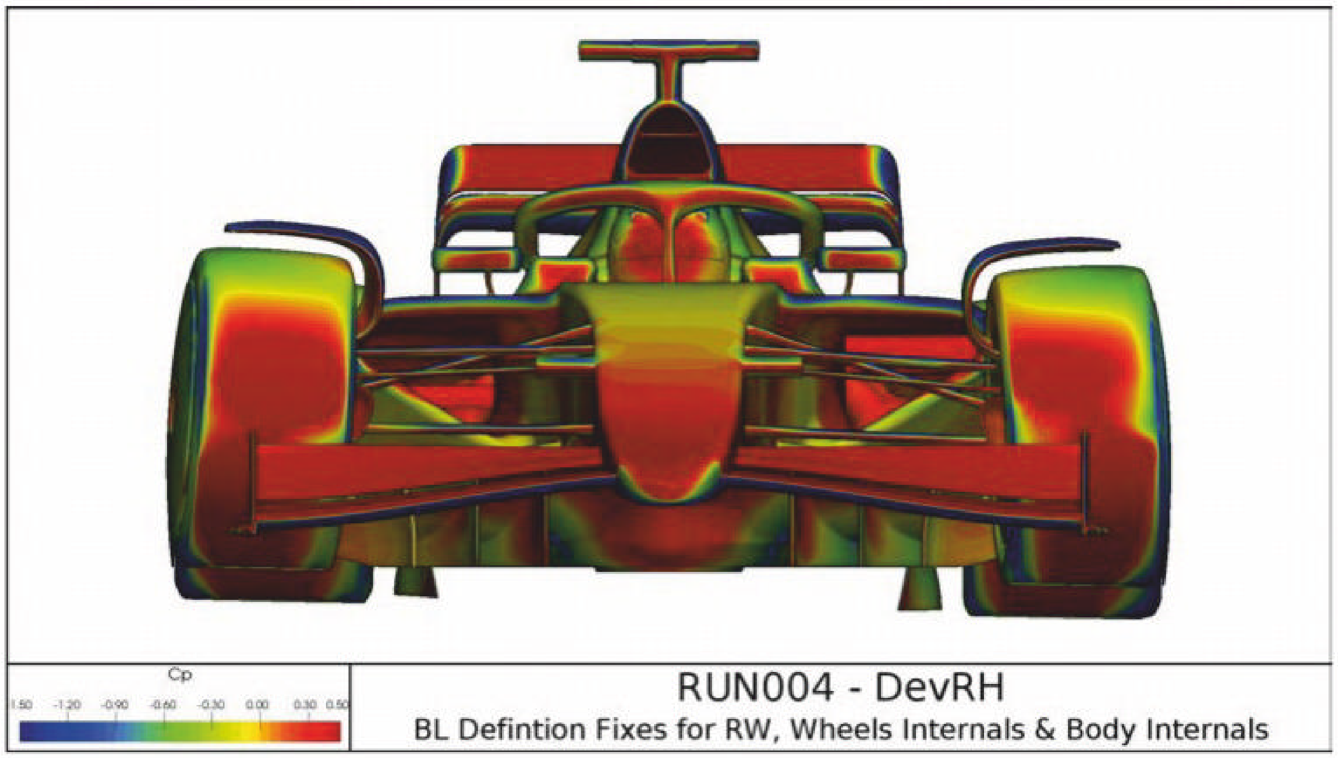
One possibility that could be considered is adopting a methodology closer to the WEC's LMP2 solution of having access to a standard chassis, engine and standard aero in order to hit the ground running while development of their own car takes place behind the scenes.

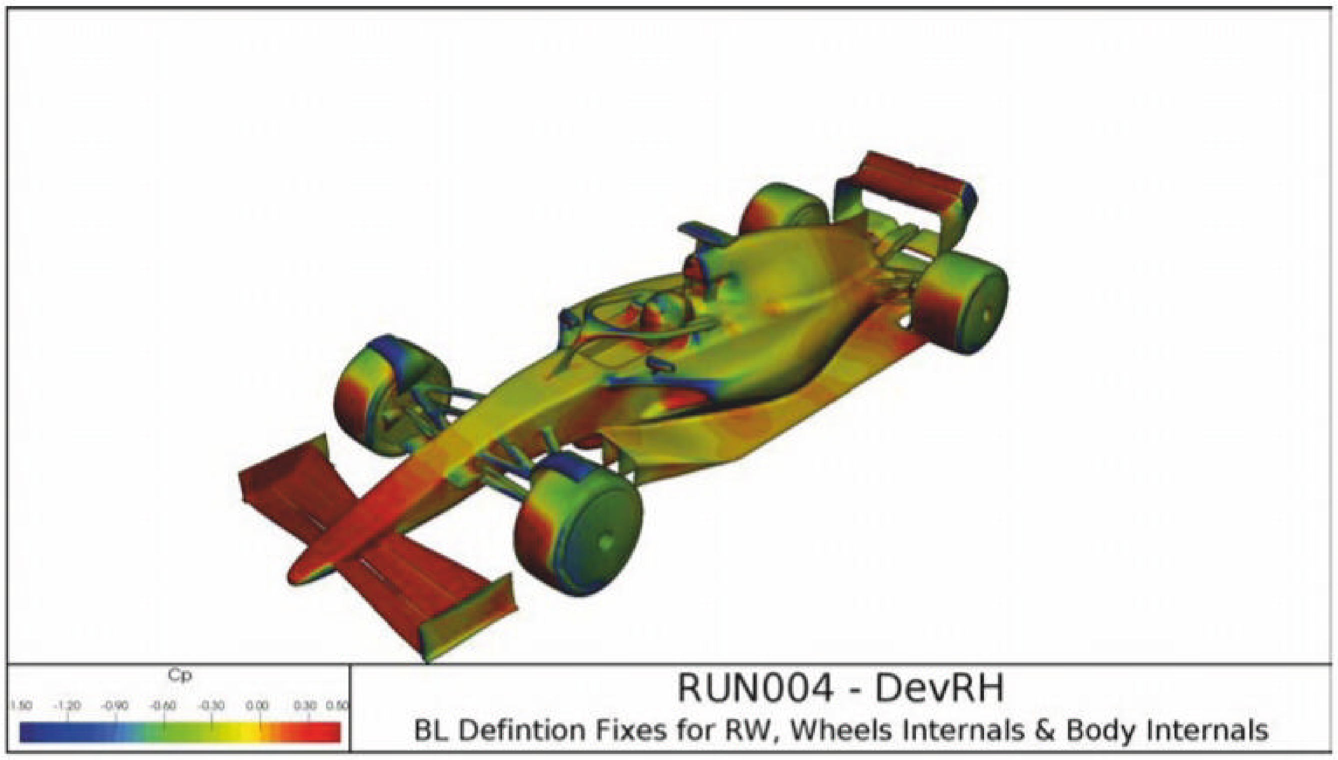
A chassis from a supplier such as Dallara, or ORECA, would not be front of the grid in terms of performance, including torsional stiffness for example, and nor would it be the most efficient in terms of aerodynamics, but it would be good enough that the team, with the right driver, could perform to a satisfactory level. Teams could have access to it for the first two years of their F1 entry while they gather data and design and build their own competitor chassis.

This approach mirrors the US endurance series for its DPi category, where a manufacturer is able to buy the spine of the car, fit its own engine and aero and race. In this case the cars are performance balanced, which is how the road car styling cues are able to be introduced. This would not be necessary in F1, or even possible.

The gap between Formula 1 and the rest of motor racing is arguably larger than ever before. Ever since Eddie Jordan stepped up from F3000 to Formula 1, others such as Manor have tried to make the leap but without the same level of success.

There are a variety of reasons for this, and not all of them are cash related. Much of the speed in Formula 1 is about tyre performance and managing Pirelli rubber mounted on 13in rims with its peculiar (and deliberately designed) characteristics. Formula 1 and Formula 2 will both soon move to an 18in rim,





Teams have to master complex computing in order to produce a competitive car within a short timeframe to enter F1

but the tyre technology is different between the two categories and the mechanical tuning requirement still a long way apart.

Teams competing in the feeder formulae also have to use a standard Dallara chassis, a standard engine and a standard gearbox. They therefore don't have the design and development capacity to step up immediately to create their own chassis and aero. The leap to understanding an automated CFD process that the top teams have spent years developing is too large to expect any new team to achieve in the first two years.

Recruitment drive

The top Formula 1 teams also have upwards of 1,000 personnel in different departments and, although the cost cap will bring that number down, it is still a far cry from any racing department for any other type of motorsport. The recruitment drive required for a team wishing to enter the arena is impressive, but there is no guarantee that the number of fabricators, designers, engineers and machinists will be up to the standard needed to compete in F1.

One possibility is adopting a methodology closer to the WEC's LMP2 with standard chassis, engine and aero

'The main issue is they're running at around US$2m per year and, if you add that up to compare it even to the lowest budget in Formula 1, it is still miles away,' admits Bayer. 'In terms of operational knowledge, [teams that] have experience in running Formula 2 or Formula 3 teams, that is simply bonus points when you do your evaluation.

'So how can we, as the FIA, help them? Our focus is to have sustainable sport, which remains attractive and which will bring the necessary quality and quantity of teams.'

There is no way of introducing more technology into the lower formulae without

SET UP EQUIPMENT

SET UP WHEELS

PROJECT SPECS
BASED ON THE CAR MODEL

SET UP PADS WITH LOAD CELLS

NEW SPECS
NEW GENERATION TOUCH SCREEN 10"
OR 7" FOR SOME VERSIONS

CUSTOMIZED VERSIONS

SET UP BARS AND ASSY

COMPLETE WITH
DIGITAL GAUGES OR
TOE-RIDE HEIGHT-CAMBER
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'There is no way of introducing more technology into the lower formulae without dramatically increasing costs'

Peter Bayer

XPB

Lotus joined F1 in 2010, but with the twin benefits of experienced ex-Toyota F1 personnel and a developed aero programme

dramatically increasing costs, and the knock-on effect of that would put those series out of reach of the smaller teams that have a totally different funding model – be it driver, sponsor or sugar daddy.

When Lotus joined the F1 grid in 2010, it was on a tight time schedule, but it took staff from the defunct Toyota team and therefore had knowledge of F1. With Aerolab, it had a head start on the aero numbers, too.

But chances like that are extremely rare. Right now, a team will be looking at 18-24 months to get to the grid, all the while having to placate investors who are essentially funding an engineering R and D programme before seeing any kind of payback.

Due diligence

The FIA itself takes six months to complete its due diligence on a team before any real build or development work can take place. 'We go into a very detailed due diligence process,' confirms Bayer, 'which will check and analyse the whole project in detail from sporting, staffing, human resources, facilities, execute capabilities, what kind of agreements are in place, what can be sourced and produced. And then there is a joint proposal to the FIA World Motorsport Council to accept a new team or not. The team would then have to sign a commercial agreement with Formula 1, and then they can go and race.'

One of the clear barriers that needs to be overcome is one of cash, and not only the total amount that needs to be found to the satisfaction of the FIA. What also needs to be considered is the timing of the delivery of money. The team must have access to it in terms of its ability to answer the call of expression, but also have to manage the expectations of their investors.

'There are two types of investor,' says Benjamin Durand, team principal of Panthera F1. 'There is the passionate one that knows already about Formula 1, knows about motorsport, and is involved in one way or another, and there are the ones that don't. They are making purely a business investment and you have to educate them.

'On the other hand, Formula 1 is a business, and it's quite understandable how it works. But you have to explain you don't just buy a car. You have to build one, or at least build the listed parts like Haas is doing.'

One of the keys is the return on investment, and that will come from television revenues. However, without the Concorde Agreement in place, that calculation is not yet decided. Under the previous regulations, a team would not have access to a prize fund for the first two years. Under new rules, following a much larger initial fee, a team will have access to a prize fund from day one. While this will help a new team that makes it to the feast, it could be to the detriment of other teams who are already there, and force them over the edge.

The FIA is under pressure to finalise its rules so a team such as Panthera will be able to make a decision whether to invest or not.

'We have been waiting for a year and a half for the rules to be complete and the Concorde Agreement,' says Durand. 'If they ask for US$300m (approx. £237.4m / €265.1m) for the entry fee you can say yes, I can do it, or no I cannot do it. Right now, we don't have any idea, so the best thing the FIA can do is to try to make a straight rule for the future. Then we can see if we can come or not.'

The future

There has been a lot of discussion recently surrounding the future of Formula 1, and the effect of the electric Formula E series on manufacturer priorities. With the VW Group, Mercedes, Renault and others veering more towards battery propulsion, there is an undeniable threat to the top category.

Meanwhile, Covid is the latest threat to the motor industry. With factories shut down for an elongated period in the second quarter of 2020, and only limited production in the third quarter due to social distancing, coupled with the obvious squeeze on wallets, the industry is going to face a tough time.

'There are a lot of people right now looking for opportunities, and some of them are thinking Formula 1 could be a good opportunity'

Benjamin Durand, team principal Panthera F1

That, together with European governments offering to heavily subsidise the sale of electric cars over ICE, puts the emphasis firmly on battery-powered cars. However, Panthera and others do not believe that the threat is coming in the short term and are hoping to put together a programme.

'People know Formula 1 is not going away,' argues Durand. 'Obviously, the risk is that the more we wait, the more finance will be dedicated to something else. We have people who are committed to this project, but we don't know what the world will be tomorrow, and some investor might have their resources re-directed. That said, there are a lot of people right now looking for opportunities, and some of them are thinking Formula 1 could be a good opportunity.

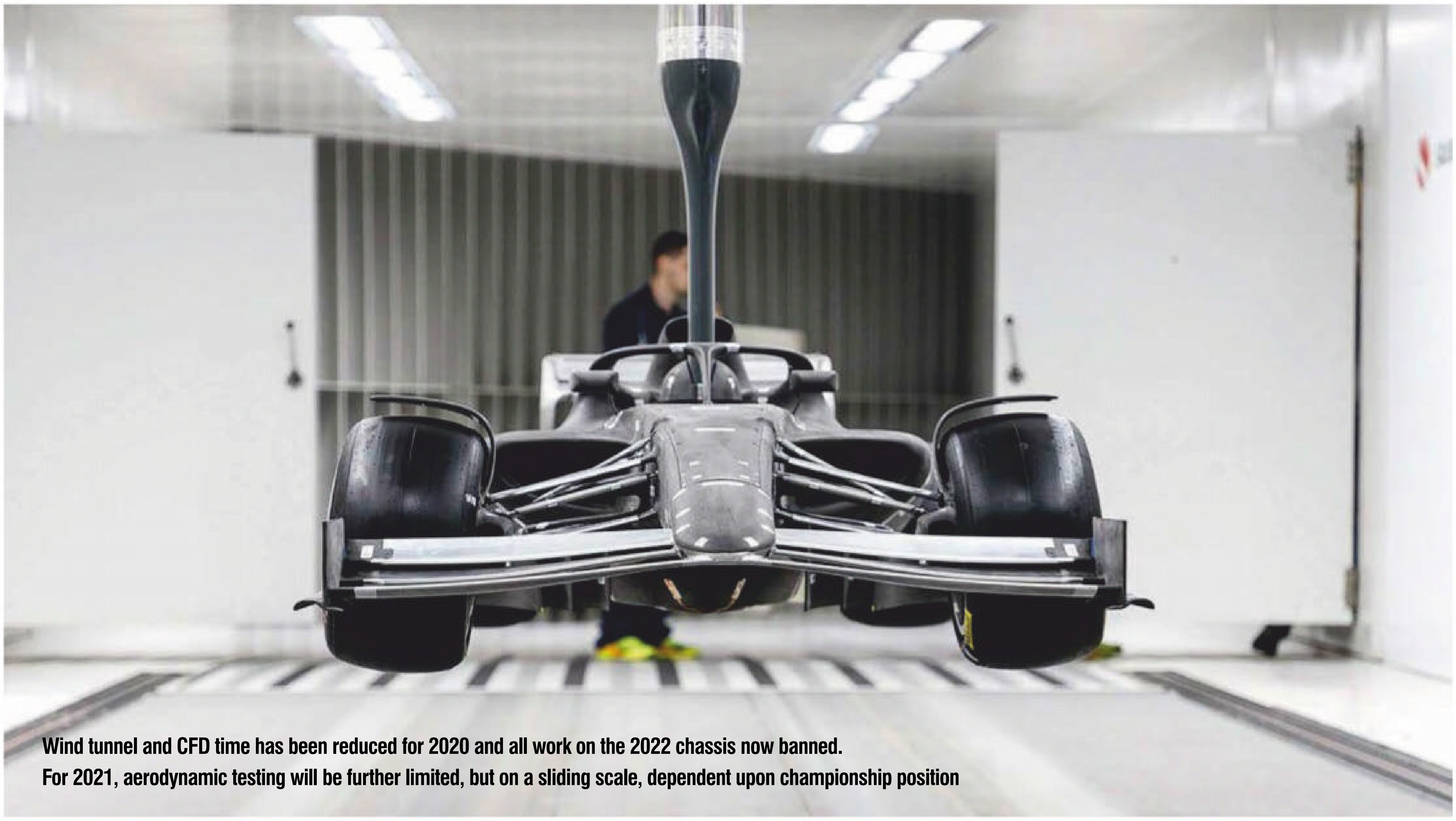
'I think the [entry] process is difficult, but it should be difficult,' says Durand. 'I don't want to have 50 teams coming to Formula 1.'

The Formula 1 grid currently has space for three more teams, six cars, and there have been rumours of new teams for the past year. However, the mountain they have to climb in order to even reach the grid is steep. The FIA is looking at ways of making it possible, while at the same time protecting what they have. It's a tough balancing act.

Limiting factors

With the introduction of the 'all-new' technical regulations now postponed to 2022, *Racecar* looks at F1's latest round of interim changes

By GEMMA HATTON



Wind tunnel and CFD time has been reduced for 2020 and all work on the 2022 chassis now banned. For 2021, aerodynamic testing will be further limited, but on a sliding scale, dependent upon championship position

In the wake of the Covid-19 pandemic, the financial, sporting and technical regulations for the 2020 season and beyond have seen some significant changes, all with the aim of securing the future of the Formula 1 grid.

The headlines are that the 'revolutionary' 2021 technical and sporting regulations, aimed at reducing costs and generating closer racing, will now be delayed until 2022. However, the new financial regulations that specify the details of the budget cap will still come into effect at the start of next year. As a result, this year's cars will be carried over to the 2021 season, along with some slightly tweaked technical regulations.

For whatever is left of the 2020 season, teams will no longer be able to work on their 2021 (now 2022) chassis, with the FIA banning all wind tunnel and CFD activity on any car geometry that relates to the 2022 technical regulations. All 18in tyre tests

For whatever is left of the 2020 season, teams will no longer be able to work on their 2021 (now 2022) chassis

have been cancelled for this year, and the maximum number of engine, MGU-H, MGU-K, turbocharger, Energy Storage (ES) and Control Electronics (CE) units will change in accordance with how many races actually go ahead in what's left of the 2020 season.

Aero testing

Another change made to the 2020 sporting regulations concern the aerodynamic testing restrictions. This limits the amount of allowable wind tunnel and CFD time a team can utilise, and both have been reduced for 2020. Normally, teams need to operate their wind tunnel and CFD facilities according to a 'limit line'. This effectively restricts total testing time, whilst giving teams the flexibility to balance this time between their wind tunnel or CFD facilities. The limit line is defined by the equation below for an aerodynamic testing period (ATP) of eight weeks.

$$WT \le WT\_limit\left(1-\frac{CFD_A}{CFD_A\_limit}-\frac{CFD_B}{CFD_B\_limit}\right)$$

Where:

WT = wind on time
WT_limit = 25 hours
CFD_A = CFD MAUh usage
CFD_A_limit = 10MAUh
CFD_B = CFD TeraFLOP usage
CFD_B_limit = 25TeraFLOPs
$MAUh$ = mega allocation unit hours used for CFD

However, for 2020 this limit line has changed, with the values of WT_limit, CFD_A_limit and CFD_B_limit altered in accordance with new ATPs and the extended shutdown period, as shown in **Table 1**.

The first ATP started on 10 February and ended 'on a period of days after 5 April of the same duration as the shutdown period.'

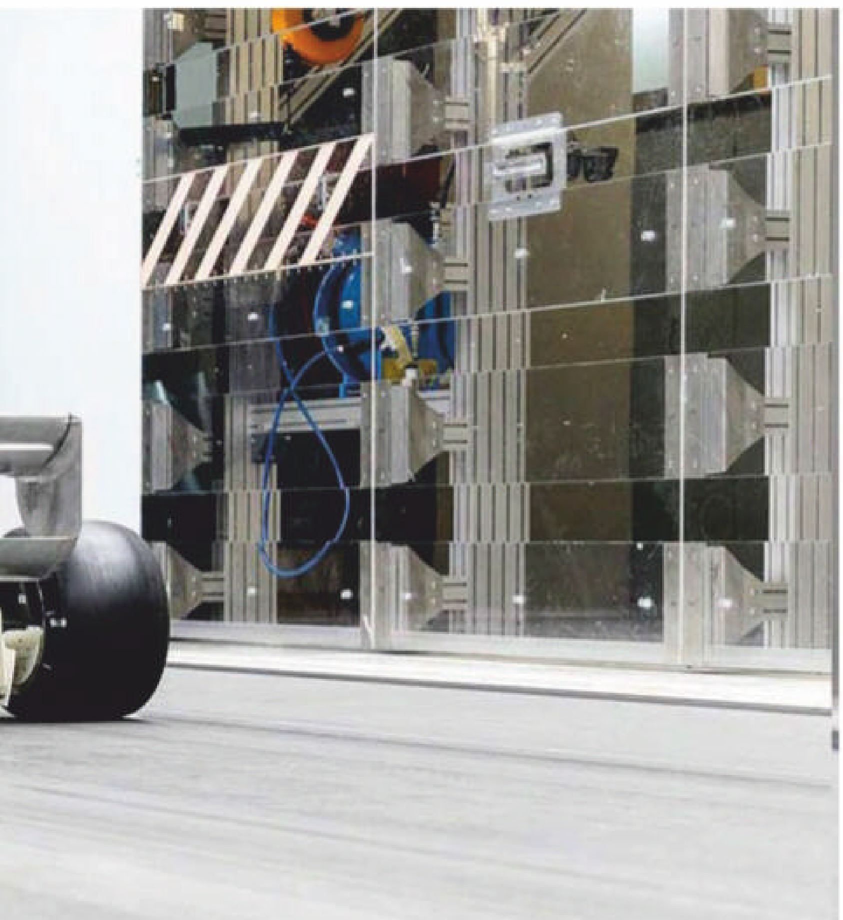


Table 1: Aerodynamic testing period changes running for five weeks and four days

Value	Units	Until end of ATP 1	For ATP 2 onwards if shutdown period <=21 weeks in duration	For ATP 2 onwards if shutdown period >21 weeks in duration
WT_limit	hours	25	20	25
CFD_A_limit	MAUh	10	8	10
CFD_B_limit	Tflops	25	20	25
RWTT Runs	#	520	410	520
RWTT Occupancy	hours	480	390	480

Table 2: Wind tunnel limits for C=100 per cent

RWTT Runs	#	320
RWTT Wind On Time	hours	80
RWTT Occupancy	hours	400

Table 3: CFD limits for C=100 per cent

3D new RATGs used for solve or solve part of all RCFDs	#	2000
Compute used for solve part or parts of all RCFDs	MAUh	6

Table 4: Coefficient C as a function of championship position, P, in 2021 and 2022-2025

Championship classification	P	1	2	3	4	5	6	7	8	9	10+ or New Team
Value of C for 2021	%	90	92.5	95	97.5	100	102.5	105	107.5	110	112.5
V of C for 2022-'25	%	70	75	80	85	90	95	100	105	110	115

Wind tunnel and CFD testing parameters are multiplied by 'C' to calculate the allowable limits for each team, according to its championship position

The final period will be a minimum of four and a maximum of 12 weeks' duration, ending on 31 December. For example, if the shutdown period lasts nine weeks, ATP 2 would start on 8 June and run for eight weeks. ATP 3 and ATP 4 would also run for eight weeks.

Moveable budget

Looking ahead to 2021, the most significant regulation change is that of the budget cap. Initially set to $175million (approx. £139.2m / €153.7m) this has now been reduced to $145million (approx. £114.5m / €127.4m), assuming 21 race events take place before 31 December 2021. If there are fewer races, the budget cap will decrease by $1.2million (approx. £947,500 / €1.05m) per race that is cancelled. If more than 21 races take place, the budget cap will increase by the same amount per additional race.

For 2022, the budget cap will then decrease to $140m (approx. £110.5m / €122.9m), and drop further to $135m (approx. £106.6m / €118.5m) in 2023.

For 2021 onwards, aerodynamic testing will see further revisions, with the introduction of a sliding scale, where the percentage of allowable restricted wind tunnel testing (RWTT) and restricted CFD simulations (RCFD) will depend on a team's mid-year championship position, as shown in **Tables 2**, **3** and **4** above.

The FIA has defined a percentage coefficient 'C', which varies with each championship position, 'P'. This championship position is defined as 'the final position in the Constructors' Championship of the previous year for the period 1 January to 30 June, or the position in the current Constructors' Championship at the end of the day of 30 June for the period 1 July to 31 December.'

Testing the limits

The various wind tunnel and CFD testing parameters are multiplied by C to calculate the allowable RWTT and RCFD limits for each team, according to its championship position. In other words, for 2021, a team in first place will only be allowed to conduct 90 per cent of

F1 is set for even more changes over the coming years than initially expected

the set amount of aerodynamic development testing, while a team in last place can complete 112.5 per cent. This scale becomes more dramatic from 2022 to 2025, with the first placed team allowed to conduct just 70 per cent of this aerodynamic testing, while the last placed team can do 115 per cent.

Bench testing

Another major change that will come into effect from 2021 onwards is new restrictions on power unit bench testing. This has been divided up into engine dynos and ERS dynos, and each are restricted to a maximum number of test benches, occupancy hours and operation hours.

For engine dynos, the allocations include both power unit test benches (running an engine alone) and powertrain test benches (running an engine together with a transmission). The total occupancy hours (OCH) is the sum of each test bench's individual occupancy hours, which is defined by the formula:

$$OCH = \sum_{n=1}^{n=N} NOCHn$$

Where:
N = number of test benches
$NOCHn$ = number of occupancy hours during the period for bench number n

The operation hours (OPH) are defined as the time when the engine speed exceeds 7,500rpm, and the maximum limit is calculated with a similar formula:

$$OPH = \sum_{n=1}^{n=N} NOPHn$$

Where:
N = number of test benches
$NOPHn$ = number of operation hours during the period for bench number n

Further restrictions have been placed on power unit and Energy Recovery System bench testing from 2021 onwards

The ERS dyno restrictions apply to ERS, power electronics and MGU test benches, with the same formulae applied. The maximum values for both engine and ERS dynos for each year until 2025 are shown in **Tables 5** and **6**, with each year divided into 10-week periods. The time limit for each of these periods may be exceeded twice by up to 20 per cent, as long as the overall yearly time limit is not exceeded.

For power unit manufacturers that supply teams who design their gearbox or exhaust in-house, or have their own fuel and oil supplier, an additional 30 operation hours will be allocated per calendar year, per customer team. If a team switches a fuel or oil supplier, once it has been approved by the power unit manufacturer, then another 30 operation hours will be allocated to allow the team to test and validate these new fluids. However, this extra allocation can only happen twice per championship season until 2023, and only once from 2023 onwards. All

Engine dynos and ERS dynos…restricted to a maximum number of test benches, occupancy hours and operation hours

in all, Formula 1 is set for even more changes over the coming years than were initially expected. But what is most impressive is that F1 and the FIA, along with the teams involved, have adapted these regulation changes extremely quickly.

As ever, we will watch with interest to see which teams best exploit these regulations, and what innovative technologies and approaches come from this unique and extraordinary situation.

Table 5: Engine dyno changes 2021-2025

Year	2021	2022	2023	2024	2025
Max test benches	9	9	9	9	9
Max occupancy hours	6,400	6,000	6,000	5,600	5,600
Max operation hours	800	750	750	700	700

Table 6: ERS dyno changes 2021-2025

Year	2021	2022	2023	2024	2025
Max test benches	4	4	4	4	4
Max occupancy hours	1,600	1,600	1,600	1,600	1,600
Max operation hours	400	400	400	400	400

Stairway to heaven

Peter Bayer is the FIA's Secretary General – Sport, and takes the time to explain to *Racecar* the opportunities created by the governing body for young engineers

By ANDREW COTTON

Interview by Dieter Rencken

Motor racing has undergone a dramatic change in the past two decades. Breeding grounds for young engineering talent such as Lola and Reynard have closed in the UK, racecar builders such as Van Diemen have been soaked up by larger companies while, at the other end of the spectrum, motor manufacturers are unsure as to what will be the next propulsion fuel, and are therefore cautious about making investment in any race series, particularly one featuring immature technology such as hydrogen or electric.

In the feeder formulae, standardised parts reduce the variety of component suppliers, while long homologation periods for top level cars has rather limited the options. Unsuccessful applicants for a tender are locked out for years, rather than being given the opportunity to develop something better and go back to the market.

For a young engineer looking to start a career in motor racing, the market is certainly different to how it was at the turn of the century. Some would argue the companies that receive applications are more robust and able to employ, while others argue that variety is key to the future of racing.

Even a job opportunity at a race team has limited options. Previously, an engineer might have access to a variety of areas within a race team, whereas now specialist knowledge is far more attractive. Such large teams that exist in Formula 1 mean the option to work on multiple parts of the car is a thing of the past.

Under the presidency of Jean Todt, now nearing the end of its final term, the FIA's push for the highest possible technology in international motorsport has increased pressure on manufacturers, teams and suppliers to target their racing programmes towards a predefined goal.

Employment opportunity

Racecar Engineering was therefore fortunate to catch up with Peter Bayer, the FIA's Secretary General – Sport, to ask him about the opportunities he believes are still available to apprentice engineers looking to gain experience at the track, and to explain why the FIA was pursuing the policies it has implemented under Todt's presidency.

The conversation began by talking about how the FIA was able to help young engineers find a foothold on the ladder. 'For young engineers, once they have completed their education, I believe there are a huge number of opportunities,' says Bayer optimistically. 'And despite the fact we are closely monitoring the cost development, aiming at reducing development budgets and trying to make sure motorsport remains sustainable, I believe that through securing the sustainability of our championships, we guarantee the sustainability of the jobs of many, many people.'

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Susie Wolff's Dare to be Different project aims to show young girls the variety of careers on offer within motorsport, from driver to all facets of engineering, science and technology

Bayer insists motorsport has a future, but technology must be relevant

For young engineers, once they are through education, I believe there is a huge amount of opportunity

This is a well-worn mantra – provide one company with a guaranteed income and that company will thrive. Yet variety meant that companies pushed their own technology development and made the cars more interesting, while at the same time provided engineers with a vibrant training ground.

For manufacturer OEMs, seemingly at the heart of the FIA's long-term plan around motorsport, there is a clear set of parameters the FIA needs to deliver to give them the best chance at securing the funding from their board members to go racing. Earlier this year, the FIA conducted a survey with its manufacturers to establish what they needed.

'The outcome was very clear and very simple,' says Bayer. 'They said number one: cost in motorsports needs to be controlled. They were asking us to freeze regulations, or even in some areas to try and see if we can take a step back to make sure we're not asking for additional development.

'The second one was that motorsport has to be innovative. We have to tell new stories with motorsport. We have to reach out to new markets. We have to think about the impact of everything happening around digital, around diversity, male / female participation, and about potentially even going further down into mass participation events, which have proved to be very successful and popular in other sports.

'The third very clear message was that motorsport, in order to receive manufacturer backing on a substantial level, needs to run on sustainable, environmentally-friendly technologies. So, just looking at that detail, I think we have a huge amount of work in front of us, and we have big engineering challenges and questions.'

This drive towards 'environmentally friendly' racing has led to the birth of Formula E as the top-level series, while others are developing cost-controlled hybrid regulations that will meet this manufacturer demand.

Energy supply

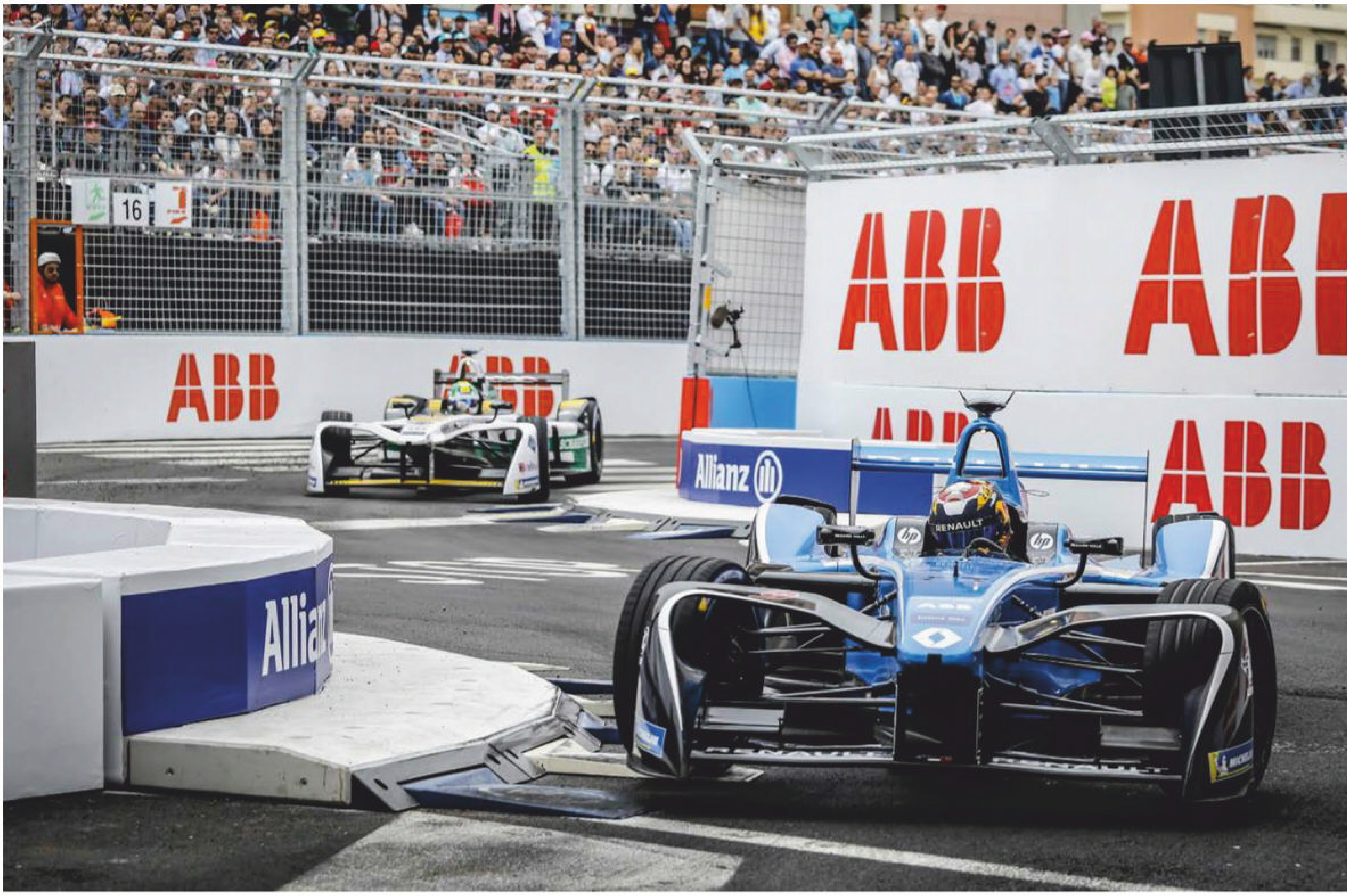
'I believe there are lots of areas of innovation coming for us,' states Bayer. 'We have to adopt to new realities. We will see new technologies being used more and we will see electrification continue to grow. We will also see potentially new forms of energy supply making their way. People are saying hydrogen might make its way back, actually initiated by Covid. So, we will have to see where the direction is going.'

This mention of hydrogen as a energy source is important. The OEM world appears to agree that a replacement for petrol and diesel *must* be found, and that electric is not the only solution. Right now, hydrogen offers the most viable alternative, but there are problems with its use.

'Hydrogen can be interesting in areas where you have enough space, and you go long distance. For example, in cross country,' says Bayer. 'However, I don't think that on the circuit hydrogen will be something we'll see in the near future. On the more adventurous side, though, we could potentially see hydrogen racing in the mid-term.'

This is clearly an area of development and the Automobile Club de l'Ouest is working on a hydrogen future, led by former technical director, Bernard Niclot.

'What is 100 per cent certain is that motorsport will continue to exist, to flourish and give plenty of opportunities for engineers to showcase their genius. And then perhaps to add one element to that, we know that by



making the sport sustainable, you open the door again to new entrants, potentially to new ways of developing parts. So people still have the opportunity to look at those open source parts and come in with an idea.

'I don't want to just draw or paint a rosy picture, but I do believe the impact is not as linear as you would expect.'

The heart of the matter

The FIA has clearly identified motor manufacturers as the heart of top-level motorsport and left little room for smaller, independent teams to race. Where these independent teams dominate is in the feeder formulae. The FIA has identified that, in order to increase the possibility for teams to compete, the cost of racing for a competitor must be driven down and has achieved this by implementing standardised parts such as the chassis, suspension, tyres and engine.

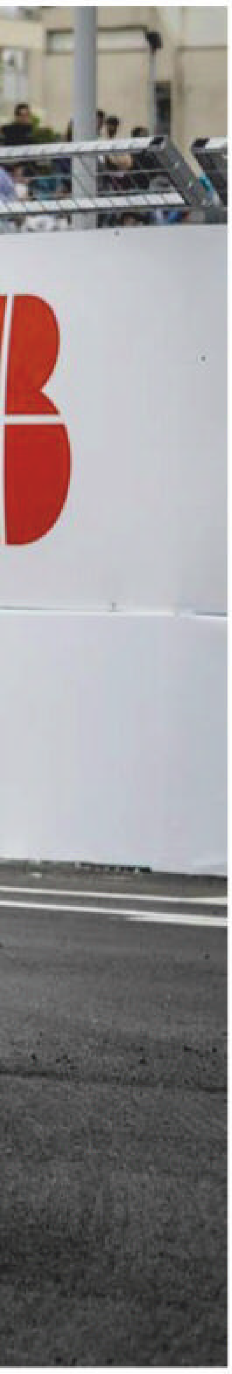
In the past teams have been able to choose the best components to create the perfect package, but that now seems a distant past as the FIA focusses more on the design and build technologies, rather than the track-based inspiration. Arguably, that does not adequately prepare teams for Formula 1 where choice is still open.

The battle for innovation between Formula 1 and governing bodies is nothing new: from the high wings of the 1970s to the sliding skirts of the Lotus 79 in 1978; from the active suspension of the Williams to the modern-day equivalent, Mercedes' DAS system, which changes the camber of the front wheels dependent upon whether the car was on a straight or in the corners. There is always room for creative interpretation of the rules, but the FIA has pushed hard to crack down on the less obvious ones.

'I think I can wholeheartedly say I'm a die-hard motorsport fan. Given the opportunity, I will watch motorsports from early in the morning until late in the night,' admits Bayer. 'But certain elements, such as the [blown] wheel nuts – honestly, I don't think I care too much about what kind of wheel nuts they put on a car, as long as the wheel remains on the car. To do that to improve performance, and to spend a lot of money doing so, is something that needs to be balanced. There needs to be balance in everything in life and we believe that what we do with the cost cap and introducing certain standardised parts is a way of trying to balance Formula 1, and adapting to a new humbleness, which we probably see happening globally.

'That does not mean Formula 1 will be dumbed down. The class has the biggest budget available to innovate and to develop, and to showcase leading-edge technology.

Nuts and bolts engineering will still exist in the future, but series such as Formula E are showing how data engineering could play an increasingly important role in the motorsport of the future



But with diversification, potentially people might not have a job any more solely developing wheel nuts.'

Bayer remains convinced that not only will 3D printing and other relatively new practices be a feature of the modern racing team, but actually the future could be more digitally led, and with an even greater increase in simulation. 'There might [still] be nuts and bolts engineering, but I believe engineering around data software, the impact of the interface and how you make sure you achieve what we are always looking for – which is ultimate performance – I believe there are a lot of things happening in that area.

'We know in the FIA we are going to heavily invest in that area, both in terms of human resources and in terms of material. And we will actively look for young software analysts and developers to help us manage the enormous amount of data a racecar is producing nowadays.'

Certainly, motor racing will not survive if it continues to peddle the idea that it's just about drivers going round in circles. The danger element is reduced, so the drivers are no longer considered the daredevils of the past. Instead, the engineering ability of teams, and its wider applications outside of the sport, must take centre stage.

'Motorsport has been contributing towards the good of society ever since its inception,' says Bayer. 'Through safety innovations, better communication, through spin offs and the examples of McLaren [Applied Technologies] or Williams Advanced [Engineering] and all the amazing things they do. There are thousands of engineers behind the curtain, and giving them visibility could be an interesting topic for us to discuss, because all are actually serving one ultimate objective, which is racing.

Motorsport has been contributing towards the good of society ever since its inception

'We want to make sure we race for a purpose, and the purpose is the development of values. It's providing entertainment, competition and it's all the contributions that are coming out from what we do. So to give visibility to a pathway [forward] could certainly be interesting.'

Promoting diversity

Anyone who has met or interviewed Todt could not be left in any doubt that he is keen on promoting female involvement in the sport. He even berated the journalists who did turn up to an interview at Le Mans a few years ago for the lack of diversity in the crowd, not that there was much they could do about it at the time.

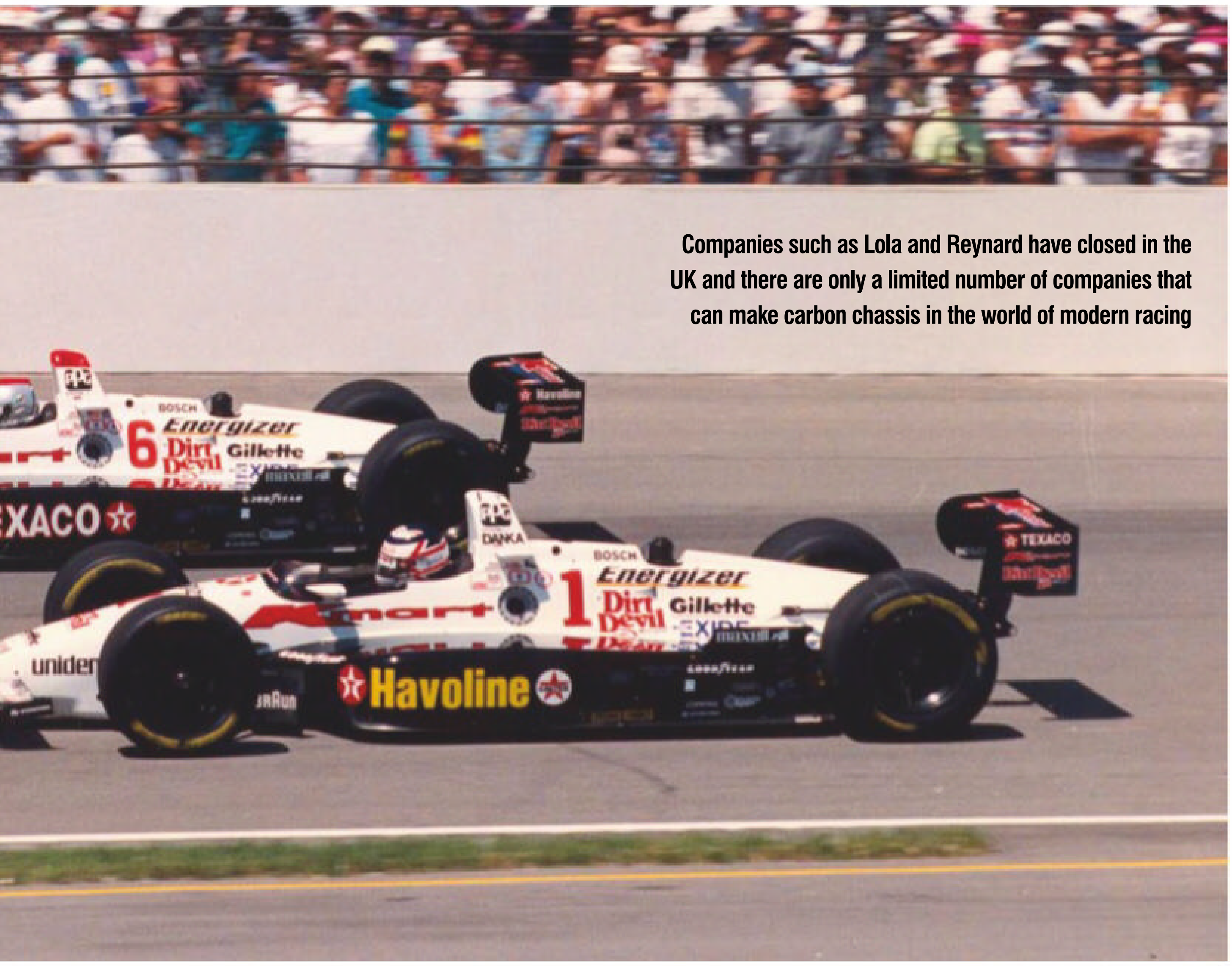
The FIA has, with various initiatives led by the likes of Michelle Mouton and Susie Wolff, identified a number of ways of encouraging young female engineers to see motor racing as an attractive career path.

'We have a number of very interesting world championships in which we believe there is a huge amount of interesting work for young engineers,' concludes Bayer. 'It is probably a goal for many engineers, but only the very best will end up in motorsport, simply because you need this ultimate dedication to the detail, and the passion to win. And it obviously asks a lot of sacrifice from people, be it in travelling, spending days and nights making sure you are improving every single weekend, throughout the year.

'We try and diversify as much as we can the opportunities for young engineers. We are running a successful project under the leadership of Michelle Mouton in the Women in Motorsport commission. It's called Girls on Track, and is in close collaboration with Susie Wolff's project, Dare to be Different, which is aimed at young girls starting a career in motorsport. Not only as a driver, we're also focussing on everything around the topic of STEM [Science, Technology, Engineering and Mathematics]. In collaboration with our friends from Formula E, this programme is proving hugely successful.'

The message is clear from the FIA then: reduce the cost to the teams of motor racing and encourage new technologies, new fuels and new methods of construction. On top of that, promoting motorsport's value to a wider community, and increasing diversity within.

That is where future technical challenges lie, and the more great minds take part, the faster this development can take place.



Companies such as Lola and Reynard have closed in the UK and there are only a limited number of companies that can make carbon chassis in the world of modern racing

Racecar says:

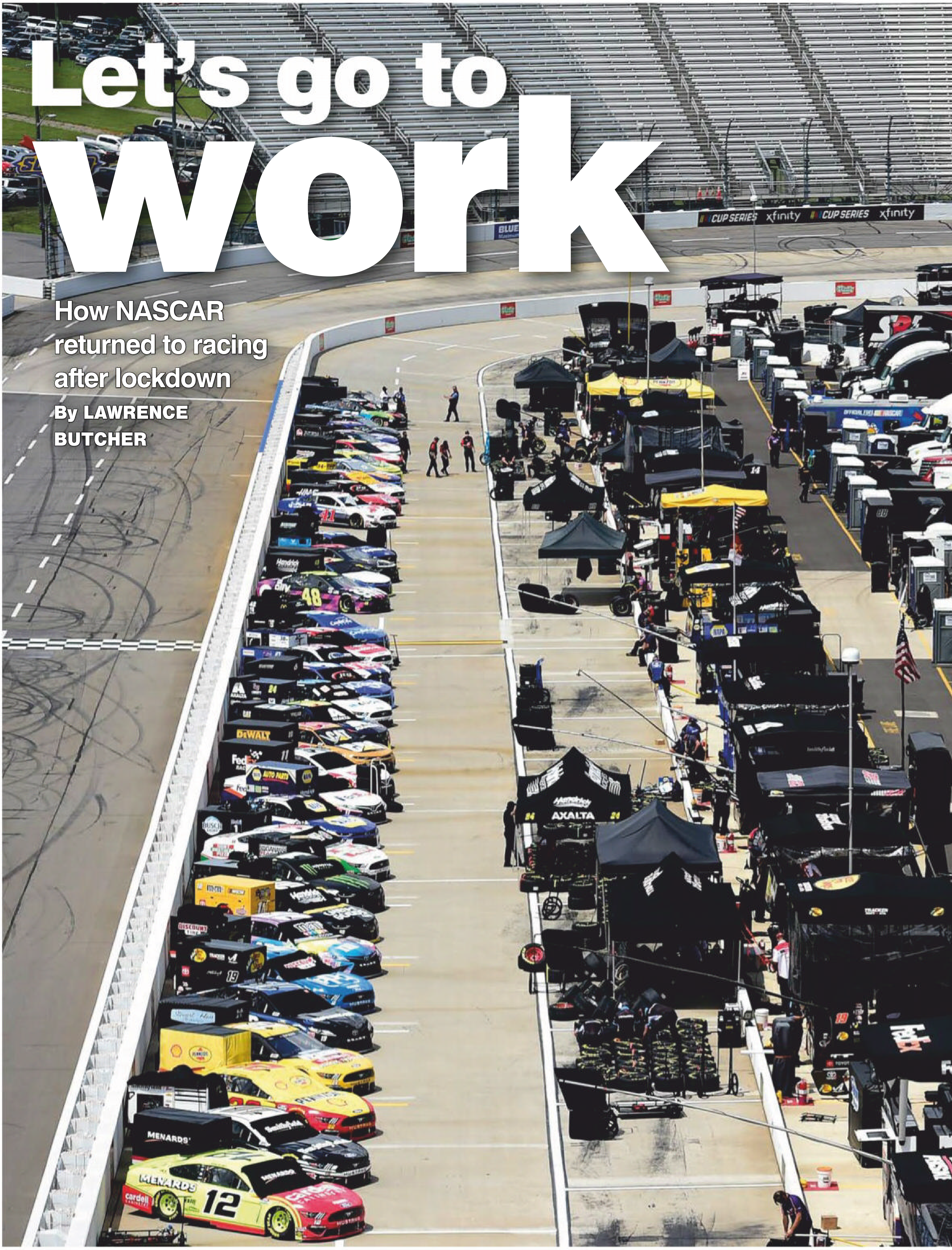
Locking companies out of series through long homologation periods is not beneficial for the sport, or for young engineers seeking a career in motor racing. For motivated young engineers who do find a job in a large team, the threat of being 'pigeon-holed' into a single part of a racecar is not inspiring. Also, the fact that small teams no longer exist in F1 means there is no proving ground for young, inexperienced engineers.

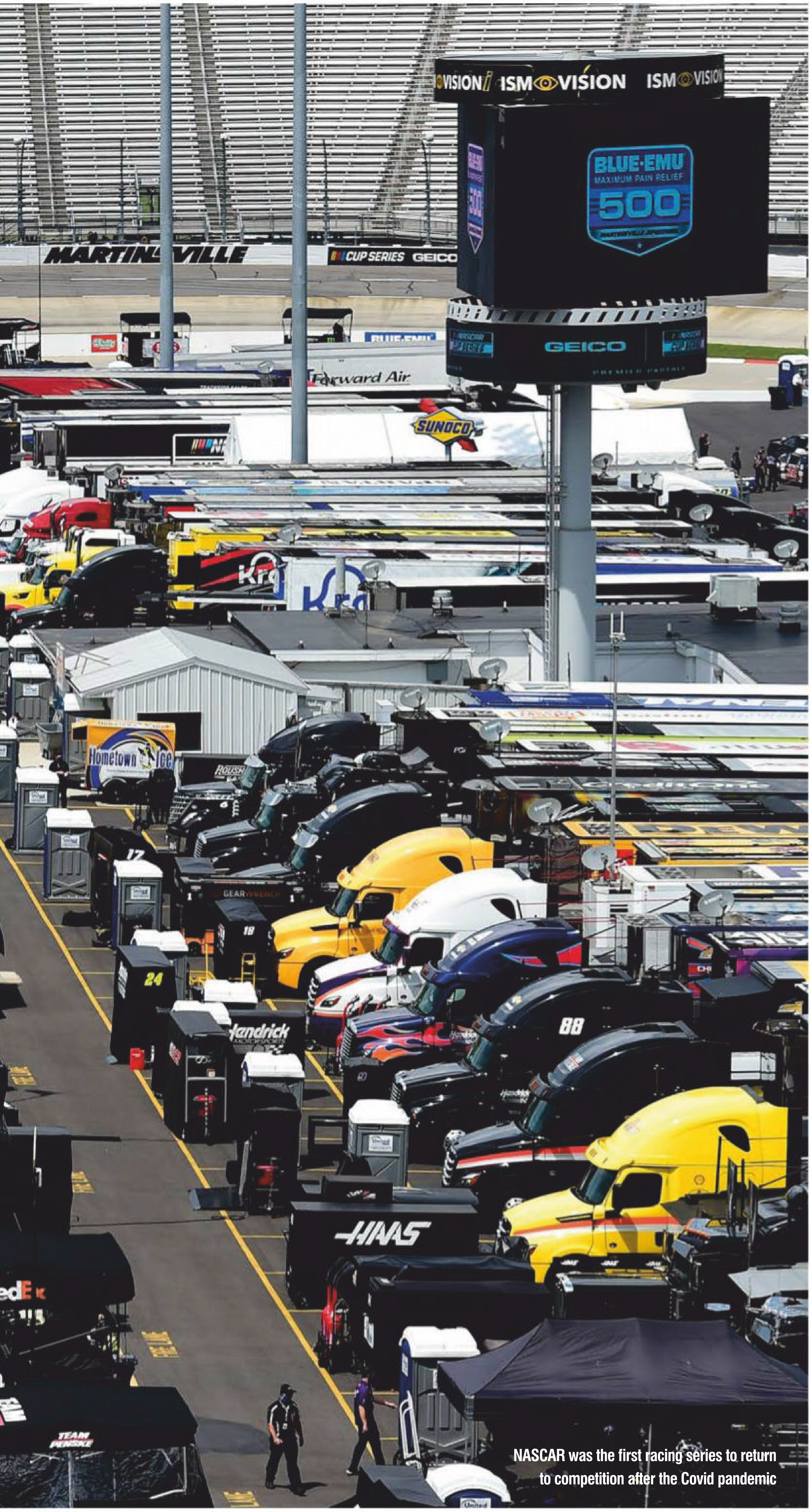
However, motor racing has thriving arenas for young engineers, particularly in Formula E and LMP, as well as the World Rally Championship, but the sport needs to beware that mechanical and aerodynamics graduates have the option to go to road cars, which offers more consistent work, more stable hours and better pay. Motorsport needs to offer young, enthusiastic engineers something different, and cultivate that competitive spirit within.

Let's go to work

How NASCAR returned to racing after lockdown

By LAWRENCE BUTCHER





NASCAR was the first racing series to return to competition after the Covid pandemic

'I'm looking at a video of racecar I'm not allowed to touch until I get to the track' says Cliff Daniels of Hendrick Motorsports, crew chief to Jimmie Johnson who drives the no.48 Chevy.

So it was that NASCAR led the motorsport world back to racing after the Covid-19 lockdown. But the way teams must operate in the current environment is very different to how it was when they downed tools in March.

Fortunately, racing is the sort of industry that attracts flexible individuals, and this adaptability has placed NASCAR teams in good stead during the current situation. They have had to handle both social distancing protocols in their race shops and at the track, which has necessarily changed the dynamic between various team members.

In the case of Hendrick's shop operation, Daniels explains: 'We split our entire company into two separate teams – a blue team and a red team. The red team works Monday through Wednesday every week, the blue team works Thursday through Saturday, and then red and blue alternate working on Sundays. It has been incredibly challenging, but it has worked out.'

The workload has increased by 200 per cent on a regular season

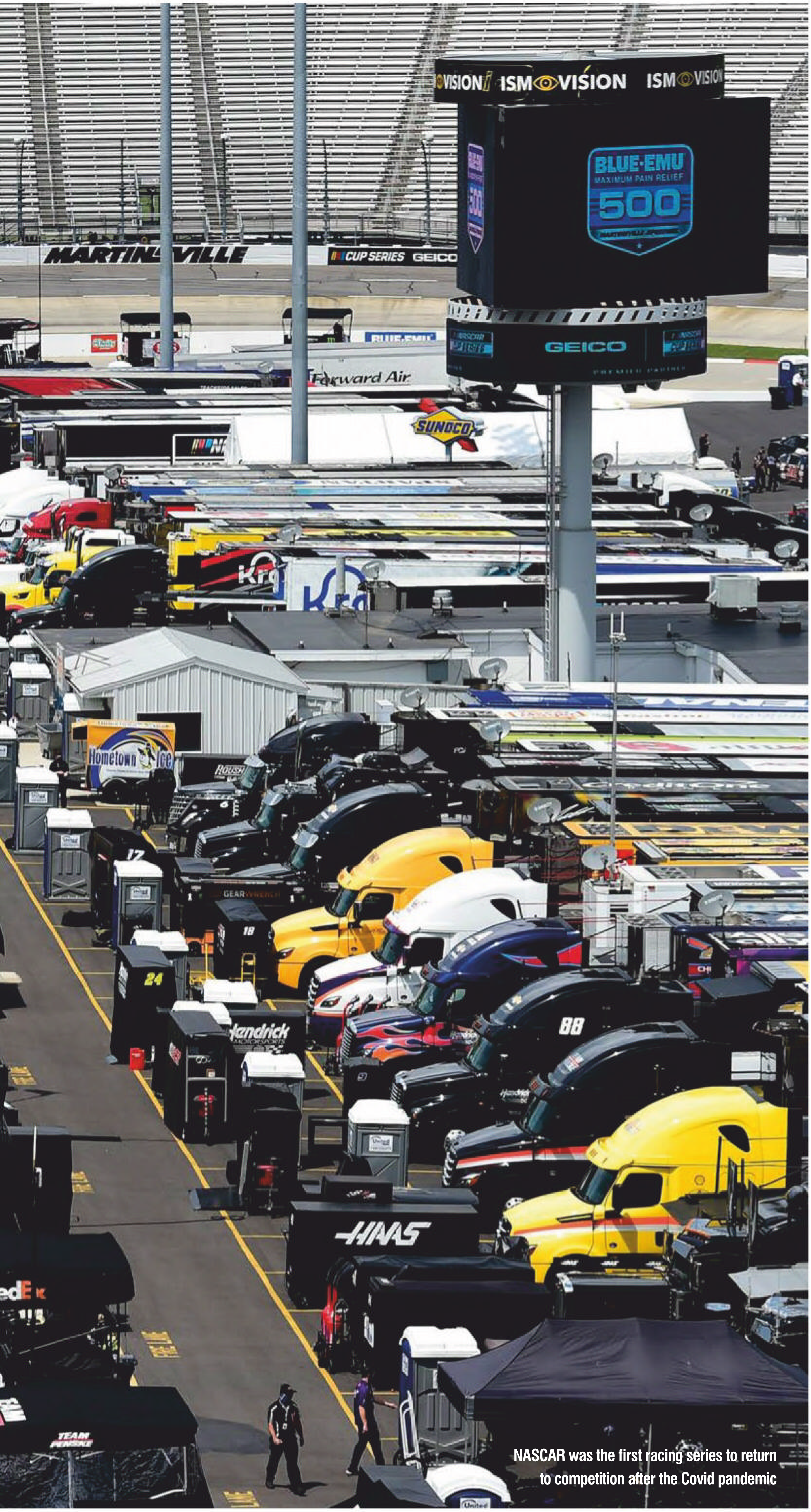
Daniels believes the Hendrick team is back to around 85-90 per cent of the efficiency it usually runs at, which sounds like a significant achievement, and it is, but all is not quite as rosy as it might seem. Due to the compressed season, NASCAR is now racing twice a week, so the workload has increased by 200 per cent on a regular season.

Increased demand

Even with moves in recent years to reduce the number of chassis teams build each year, the demands of different tracks still require a number of specific car builds. For the first races out of lockdown, the calendar fell favourably for teams in this regard.

'There were two races, Atlanta and Homestead, that were coming straight after Phoenix [the last race before lockdown] in March. The cars had already been built, and we did not run either,' explains Daniels.

This meant that when the lockdown began, those cars were just sitting there, almost ready to race. 'They were just left there for 10 weeks,' he continues. 'Fortunately, those cars were prepped in a similar way as they



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The schedule fell kindly for the teams with only small changes required from pre-Covid races to run Darlington

‘Now we don’t have that validation loop with the tunnel, so we are relying heavily on our CFD being accurate’

Cliff Daniels, crew chief Hendrick Motorsports

we need to judge how much to trust those results. That has been a bit of a change, too.’

Further complicating matters for Hendrick and other Chevy teams has been the arrival of the new Camaro ZL1 1LE body for 2020 (covered in detail in *Racecar Engineering* V30N2). Though an evolution of the 2019 ZL1 body shape, it exhibits distinctly different aerodynamic behaviour, with more rearward balance than the old model and so the team’s data was not necessarily accurate for the car.

‘There was still a bit to learn about the mechanical balance to apply with the slightly different aero balance of the new body,’ admits Daniels. ‘The two races at Las Vegas and California before the pandemic showed some indications of that difference, but we still did not have enough of a sample set to draw hard conclusions from.’

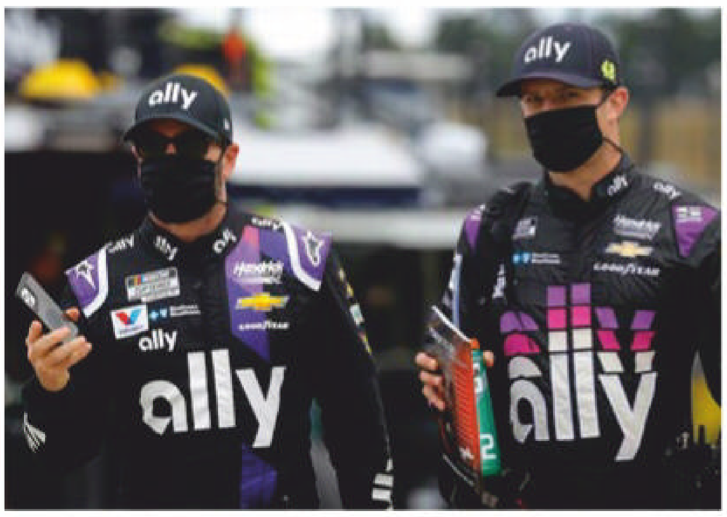
After the four races out of lockdown, that situation has at least improved. ‘We have so much more verification of what the trends are and what the balances need to be to match the new body. From this, I think we can continue to build on what has already been a strong showing for us.’

Despite the difficulties, there have been some distinct positives for teams, not least the speed at which they are able to get into the tracks. Daniels has nothing but praise for the way NASCAR has handled the situation: ‘There are no fans, there is no media, and no one else at the track except for the teams. There is a very regimented way for each of the teams to enter the track one by one. You go to a specific gate, you get screened [checked for symptoms of the virus] and get a sticker to put on your pass to say you’ve been checked.’

Each team has a specific parking space inside the racetrack, and NASCAR calls each crew chief to tell them when to arrive at tech inspection. ‘From the time we get to the racetrack, get inside the track, parked into the garage, through inspection, and the race car is on the grid I think it was an hour and a half, total,’ remarks Daniels.

‘There was so much prep work that NASCAR and their medical teams put in to make the screening process for the temperature checks, the masks we have to wear and the personal protective equipment and keeping distance. Everything, it just works, simply because of how well streamlined the whole process has been.’

NASCAR is evolving its approach as the situation on the ground changes in the US, made more complicated by the fact that lockdown, and post-lockdown measures are by and large dictated at state level. But with other series now planning their returns to racing, NASCAR could provide a successful operational model for teams and support staff until life returns to normality.



Daniels, right, with Jimmie Johnson has praised NASCAR’s approach to ensuring the safety of teams at the track

Mystery machine

Designed by Trevor Harris, Don Nichols' radical AVS Shadow epitomises the engineering creativity of the Can-Am series

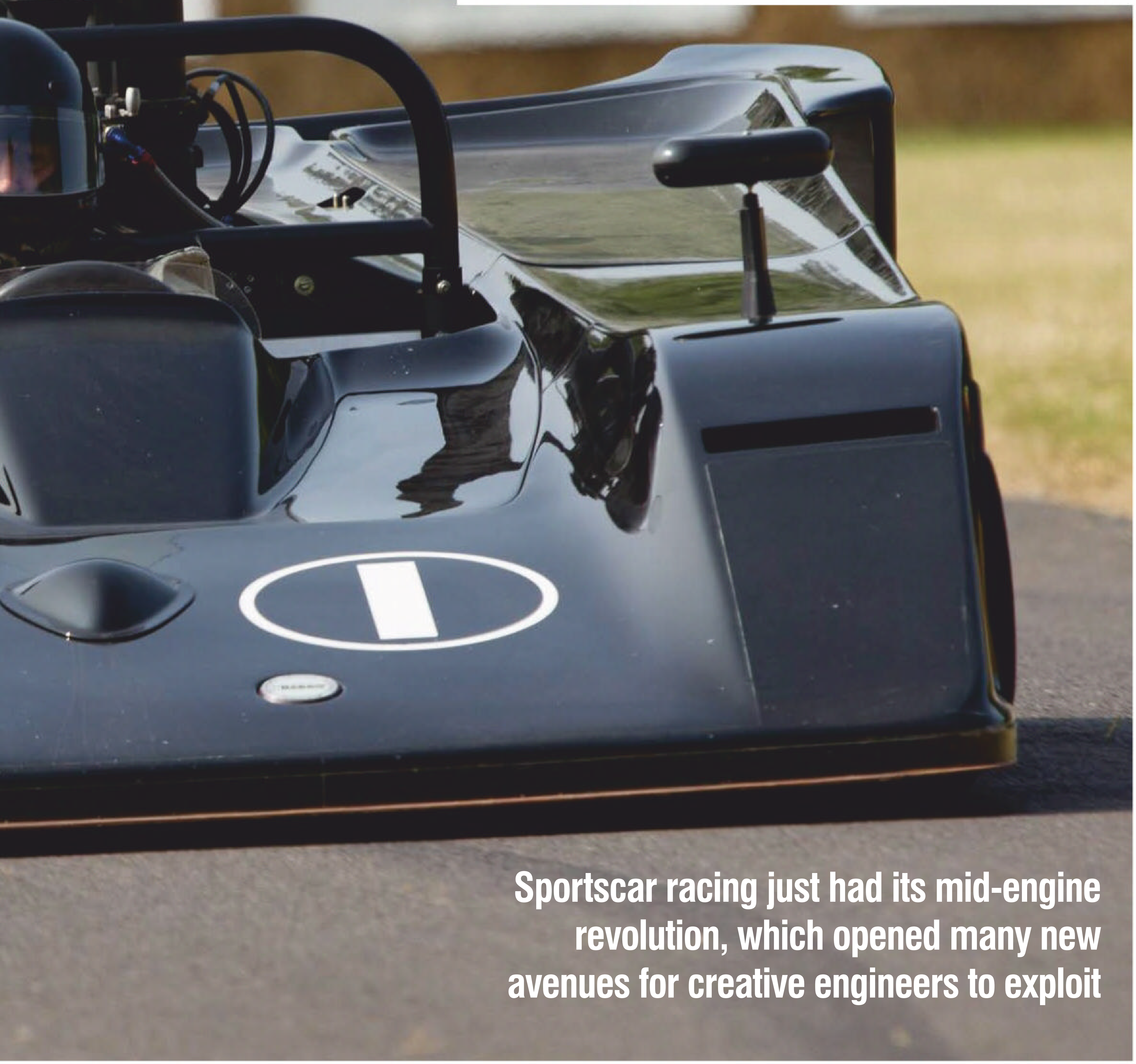
By WOUTER MELISSEN

For many racing enthusiasts and engineers alike, the original Can-Am series, which ran between 1966 and 1974, has gained near mythical status. Known officially as the Canadian-American Challenge Cup, the series was run for Group 7 Sportscars and benefited from a sizeable purse provided by Johnson Wax.

The Group 7 regulations stipulated that a car had to have (room for) two seats and feature covered wheels. Sportscar racing just had its mid-engine revolution, which opened many new avenues for creative engineers to exploit. Aerodynamics also became increasingly important. Above all, the engines fitted grew in size and power substantially, which contributed to Can-Am's appeal.

From an engineering perspective, arguably Can-Am reached its peak in 1970. That was despite newly imposed restrictions by the organisation, such as a ban on moving aerodynamic devices, and the stipulation that an aerodynamic devices could no longer be mounted directly on a suspension component due to safety concerns.

The colourful field boasted, for example, the Chaparral 2J with a snowmobile engine strapped to the back to create a vacuum underneath the car; the Bryant with a full titanium chassis and the Mac's It Special, which was powered by four two-stroke snowmobile engines. Also on the grid in 1970 was one of the most iconic of all Can-Am cars, the AVS Shadow pictured.



Sportscar racing just had its mid-engine revolution, which opened many new avenues for creative engineers to exploit

The highly unusual machine was the brainchild of American designer Trevor Harris. Working as a freelancer, he had previously penned a wide variety of front and mid-engined sportscars, among them a Group 6 racer designed and built for Toyota. Fitted with a body designed by Peter Brock of Shelby Cobra Daytona fame, it was sadly never raced. Another stillborn design was the Car "X" designed to race in the inaugural Can-Am season. A rolling chassis was built of this low and lightweight machine, but Harris lacked the resources to complete the car. He pitched a further development of that same design to kindred spirit Don Nichols, who had recently established Advanced Vehicle Systems (AVS) in 1968.

Fascinating figure

Nichols would become one of motor racing's most fascinating figures. He was a Korea War veteran and later worked in military intelligence, reportedly even in the CIA. Alluding to his former occupation, he would call his racecars Shadow, and the brand logo featured what looked like a cloaked spy.

Nichols could afford to set up his own racecar company due to the small fortune he had earned as a businessman working in Japan. He was the local representative for Goodyear and Firestone tyres. While living in Japan, he also helped with the development of the Mount Fuji racetrack.

Once back in the United States, he set about upsetting the status quo in Can-Am racing with a truly unconventional machine.

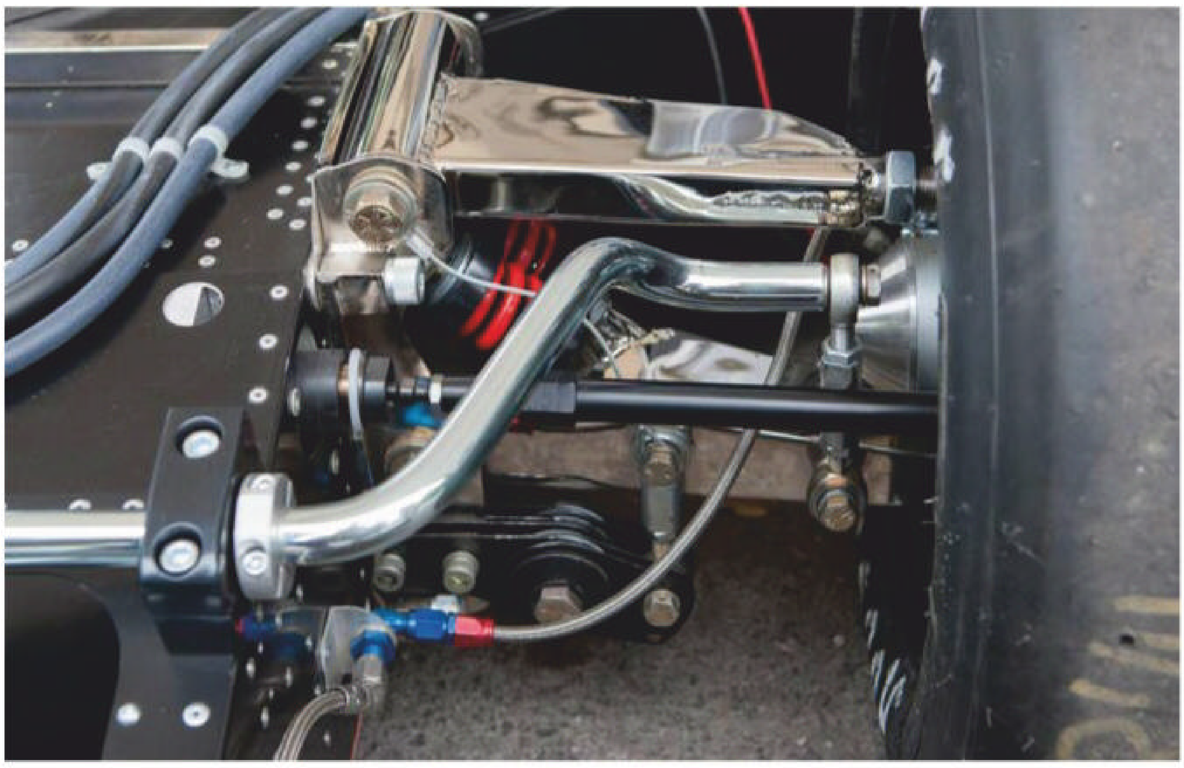
Simply put, the idea behind Harris' design was to squeeze the largest engine possible in the smallest and lowest chassis in order to minimise the frontal area. While this may have been the objective for most racecar designers, Harris pushed the envelope much further than most. The design he pitched to Nichols was more akin to a Go-Kart than a full-sized Group 7 sports racer. It was also exactly what Nichols was looking for, and he commissioned Harris to build a mock-up in 1968. A clay model was subsequently made, and Nichols invited the likes of Jacky Ickx and Mario Andretti to take a look.

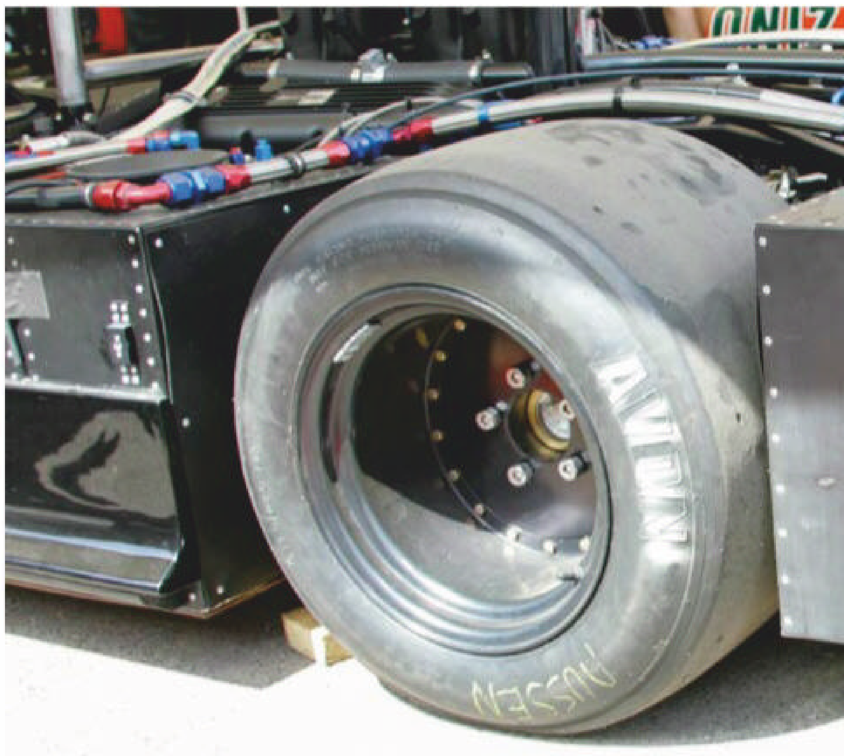
Encouraged by the positive feedback, Nichols pressed ahead and the construction of the first actual car was started with an eye to enter Can-Am in 1969.

Bespoke rubbers

In order for the design to work, Harris needed racing tyres in a size that simply did not exist. Thanks to his connection with the major tyre companies, Nichols turned out to be the right person to solve this problem. He convinced Firestone to create bespoke tyres 17in tall at the front and 19in at the rear. By comparison, conventional rubbers at the time were 24 and 26in tall respectively. The tiny tyres were mounted on wheels 10 and 12in in diameter, the rears being almost 1½ times as wide as they were tall at 17in.

Over these, Harris laid down an aluminium monocoque so shallow it could not accommodate conventional suspension. The coil springs normally fitted to a racecar were

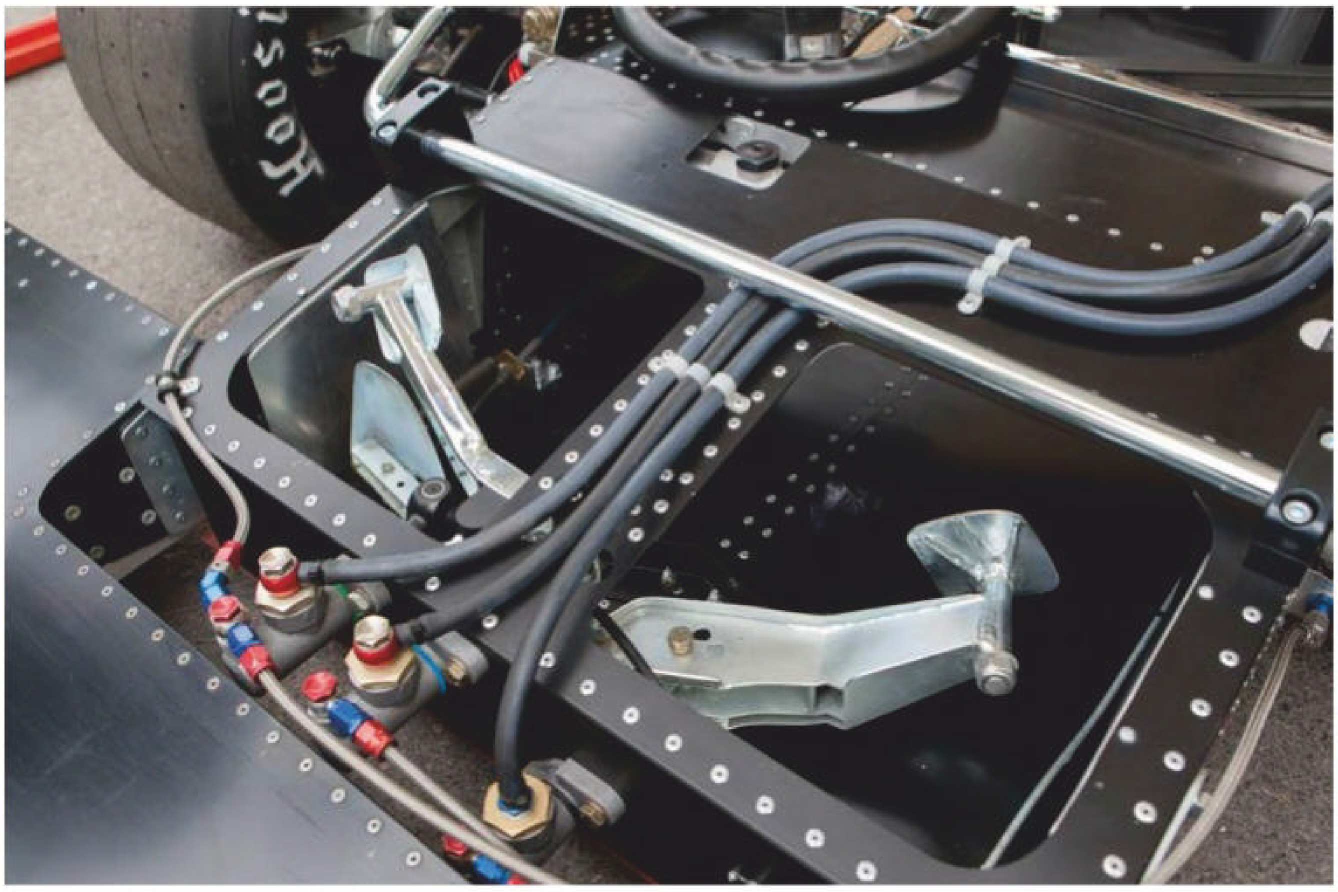




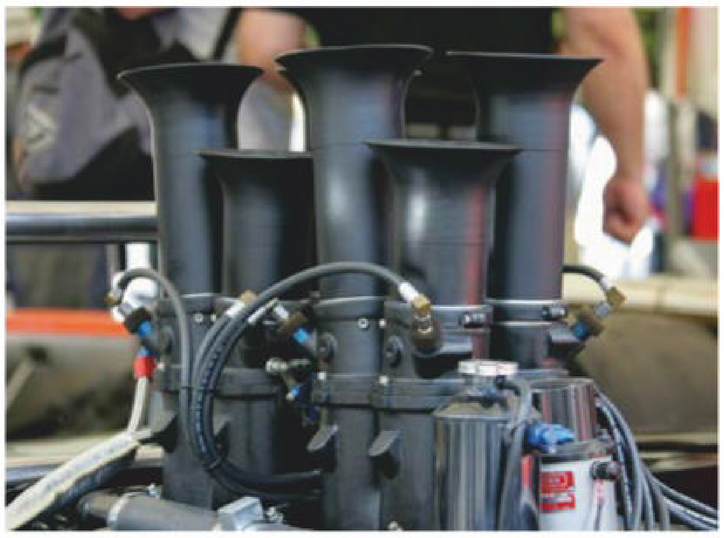
So small was the car's frontal area that conventional single coil spring / dampers would not fit so slimmer twin coils and friction dampers were used instead

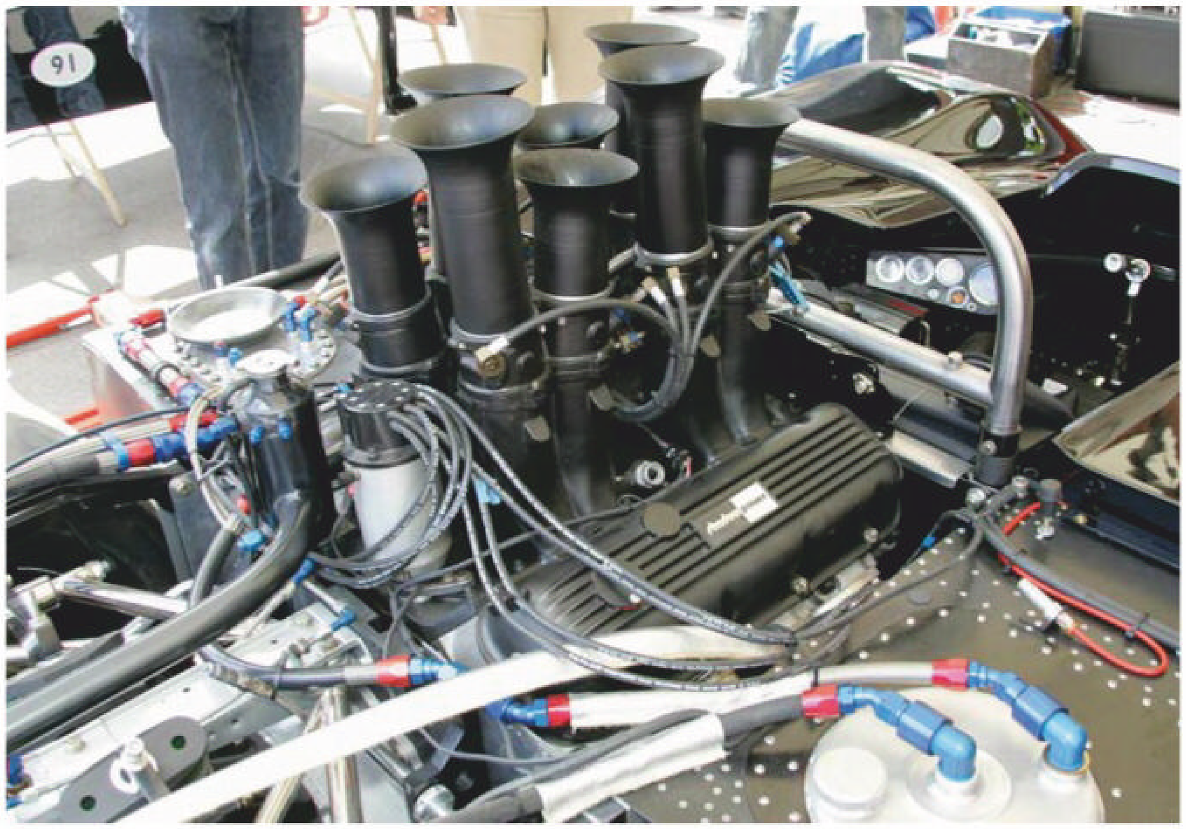
Driver foot controls were limted to a brake and throttle, bizarrely mounted either side of the chassis centreline. Clutch was hand operated

Rear-mounted radiators assisted with the car's ultra-slimline profile, but didn't help with weight balance or effective engine cooling



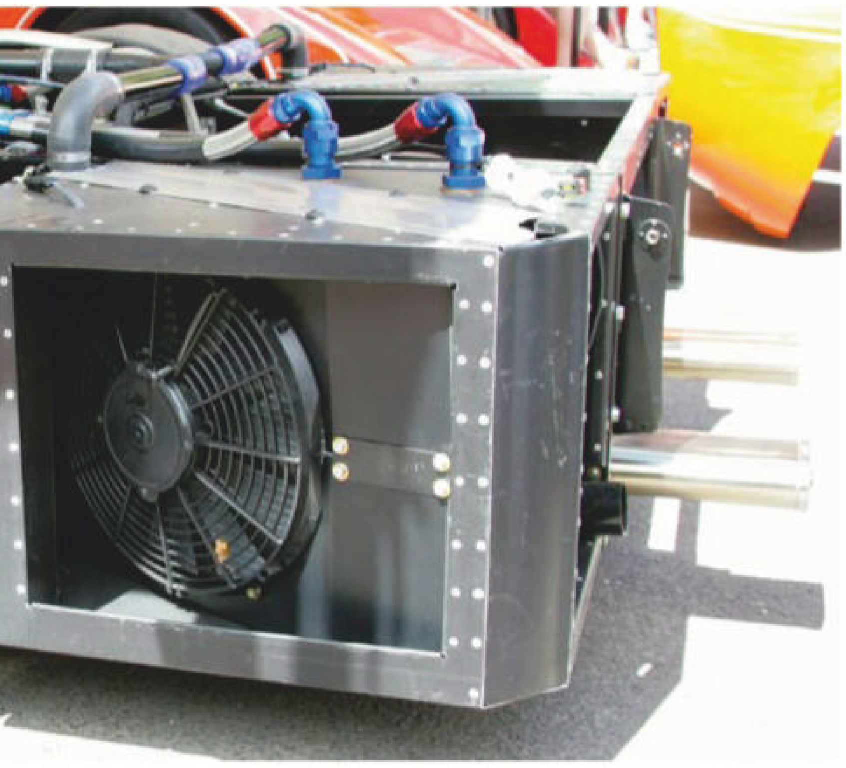
More akin to a Go-Kart than a full-size Group 7 sports racer



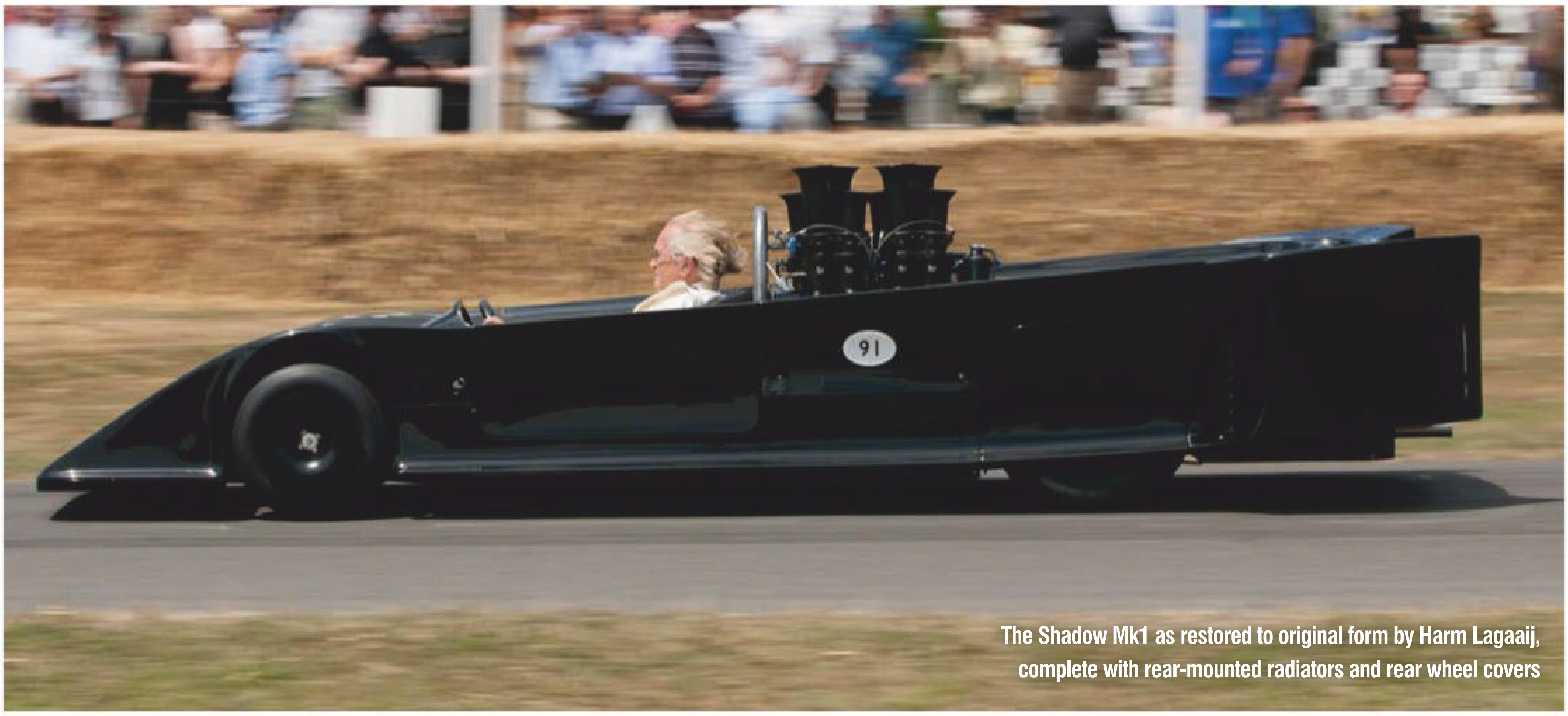


Power came from a brutal big block Chevrolet V8 with Kinsler / Hilborn constant flow fuel injection

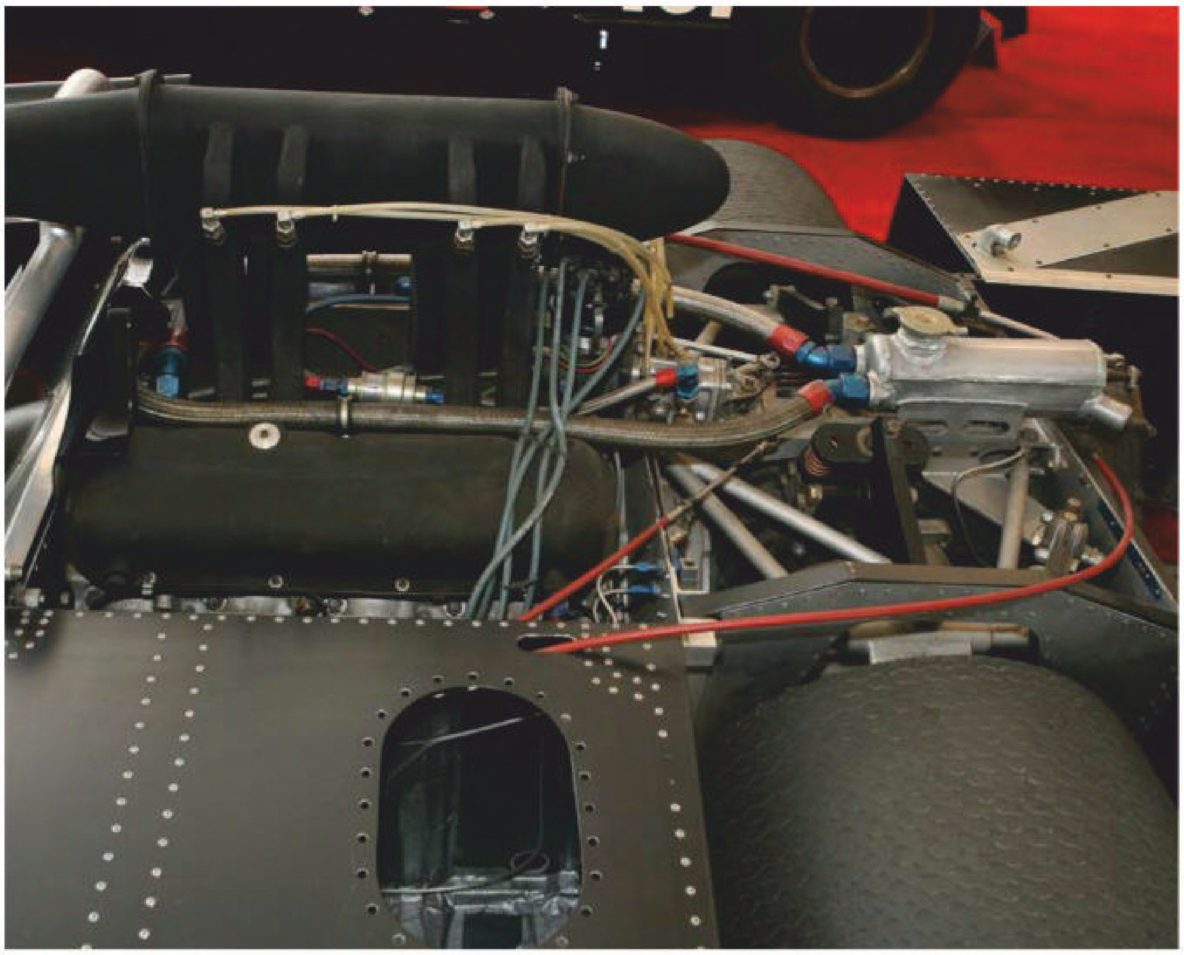
The idea behind Harris' design was to squeeze the largest engine possible in the smallest and lowest chassis



The rear suspension used three small coil springs each side, mounted inboard and with pushrod actuation



The Shadow Mk1 as restored to original form by Harm Lagaaij, complete with rear-mounted radiators and rear wheel covers



The fifth chassis built for Peter Kaus was faithful to Harris' design, including the 'slimline' induction system

Built in 1990, chassis number five has since been sold at auction and now resides in a private collection in America

too tall for this design so instead, two small springs were fitted at each front corner.

The rear suspension featured three small springs mounted side-by-side and inboard, actuated by a push rod attached to the top of the upper wishbone. As there was no room for tubular shock absorbers, Harris addressed this by reverting to pre-war technology and fitting friction dampers.

Nervous brake down

The compact wheel dimensions also meant that only small diameter brakes could be fitted. In Harris' original design, this was overcome by using a moveable air brake, but the rule change outlawing moveable aerodynamic devices meant a different solution had to be found.

The largest disc brakes that could be fitted inside the tiny front wheels were just eight inches in diameter. Naturally, these would be prone to overheating, and there was no room for conventional brake cooling ducting in the nose of the car. Harris' answer was to fit the front wheels with centrifugal fans lifted from an air-cooled Chevrolet Corvair engine. These worked, dramatically increasing the cold airflow to the brakes. The rear brakes were mounted inboard, which allowed for regular size discs to be used.

For designers, drivers are often a necessary evil and Harris made few compromises in his design to accommodate for one. The driving position was virtually horizontal, and what made matters even more complicated was the absolute lack of space for a normal pedal box. Just two pedals were fitted, mounted at a sharp v-angle to the left and right from the car's centreline. The pedals actuated the brakes and throttle, while the clutch was operated by a separate hand lever. The clutch would really only be used when pulling away, with the drivers expected to perform seamless up and downshifts without it. The initial design also stipulated a horizontal steering wheel, but this idea was dropped.

The next bit to hit the airflow was the engine mounted directly behind the driver. At that time, the engine of choice was Chevrolet's big block V8 that worked best on the racetrack with a rather tall intake stack. Harris eliminated this in his original design, replacing it with what he referred to as a 'slimline' induction system. Similar in design to the restrictor tubes later fitted to Formula 3 car engines, it was designed to point forward from the engine with the intake located right next to the driver's helmet. The device was tested on the dynamometer but, unsurprisingly, was found to interfere with the breathing of the engine too much. A regular induction system was therefore fitted to allow the Chevrolet V8 to produce the prospected 700bhp. According to Nichols, this would allow the low-drag machine to achieve a 250mph top speed down the back straight at Riverside.

A rather dramatic 25 / 75 front / rear weight balance

The aluminium monocoque chassis ran the full length of the car, with fuel tanks mounted either side of the engine. As that was the place normally occupied by radiators, these were mounted instead behind the rear wheels fed fresh air by scoops in the tail of the bodywork. All this resulted in a rather dramatic 25 / 75 front / rear weight balance.

What also set the chassis apart from the norm was its black anodising. This was done to increase the torsional rigidity of the chassis, but apparently also simply because Nichols believed it looked better. The car was finished off with a very tightly wrapped glass fibre body painted red.

The efforts of Nichols and Harris had not gone unnoticed, and even before the car made its testing debut it featured on the cover of the August 1969 edition of *Road & Track* magazine. Testing eventually commenced late in 1969, with Parnelli Jones and George Follmer doing the driving duties.

Design changes

Among the first changes carried out was the installation of a more conventional steering layout. With all the emphasis of the design on reducing frontal area and, as a result, drag, it was quickly discovered in testing that the car lacked downforce, particularly at the rear. So Harris compromised his original design by fitting a tall, full-width rear wing.

Dubbed the AVS Shadow, the new car was set to race in the opening round of the 1970 Can-Am at Mosport. By that time, the design had been further compromised as the rear-mounted radiators had to be abandoned as the air scoops proved too fragile. The radiators were now mounted across the trailing edge of the rear wing, which naturally served to increase drag.

Despite their more conventional size, cooling of the rear brakes also proved to be an issue, so two tubes were mounted on either side of the intake of the engine.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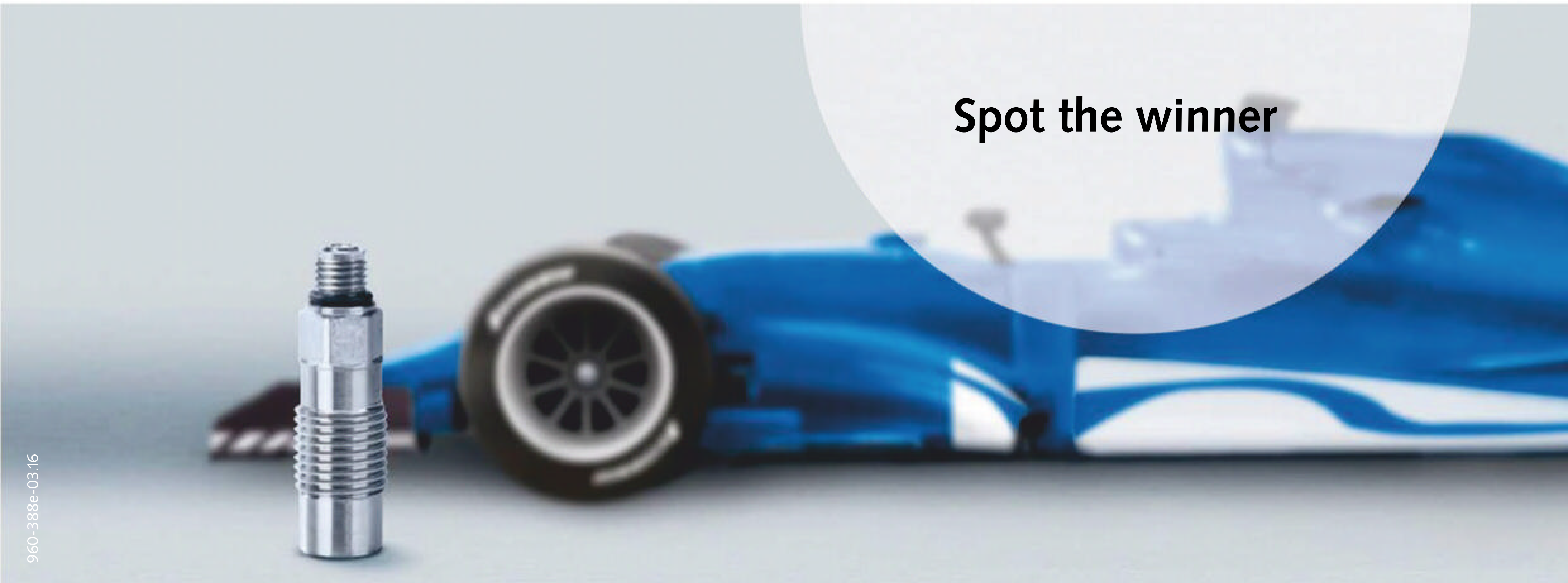
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As much as 20mph faster down the straights than the McLarens

While compromised in design, the car actually seemed to work, with Follmer qualifying sixth and running as much as 20mph faster down the straights than the McLarens. The qualifying result camouflaged some of the issues, such as the extreme sensitivity to potholes of the tiny wheels. Follmer retired early in the race with overheating issues.

Running hot

Not only did the radiator configuration used at Mosport cause the car to overheat, it was also declared illegal. The layout had fallen victim to the regulation limiting the height of the forward-facing air gaps. In time for the St Jovite round a fortnight later, Harris sorted the situation by mounting the slim, full-width radiator *inside* the rear wing. While this made the car legal again, it did little to address the overheating issues.

Follmer qualified 10th on the grid, more than five seconds off the pace of the pole-sitting McLaren, and the race itself ended with a very steamy engine in the AVS Shadow.

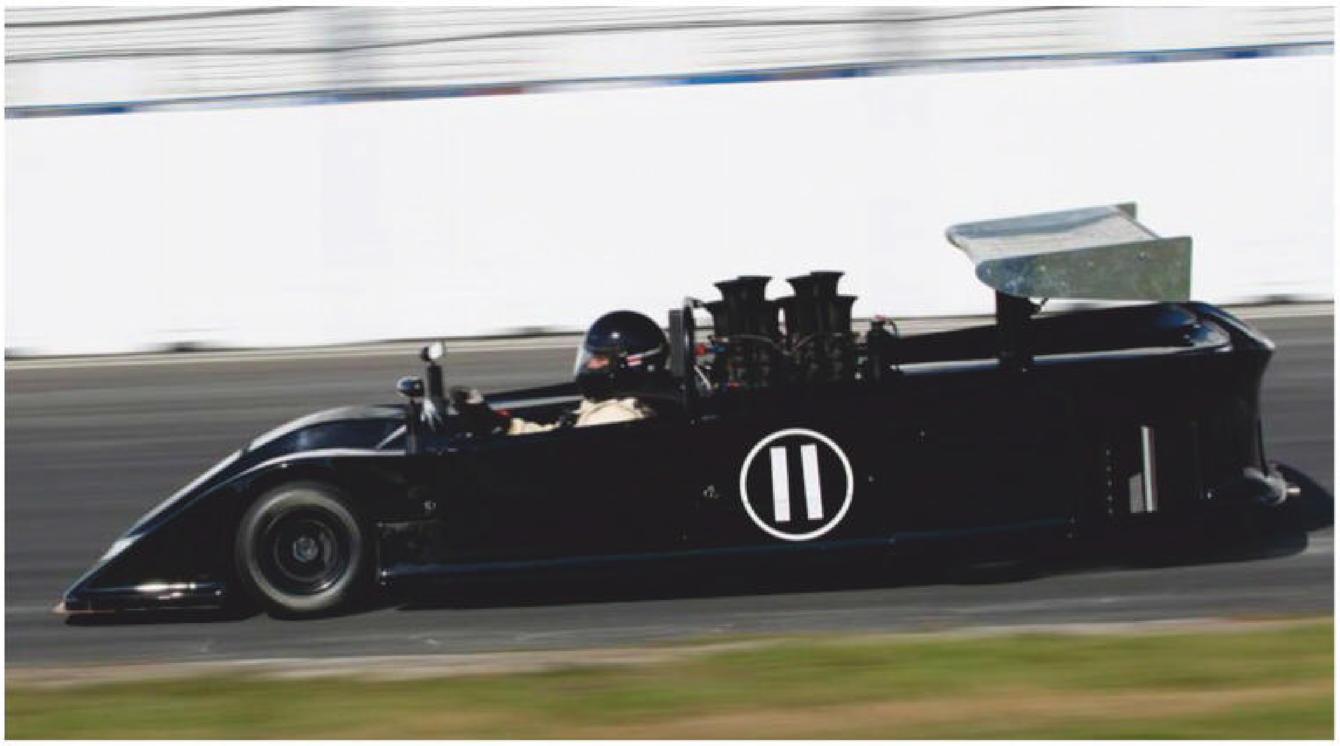
In order to re-group, Nichols decided to sit out the next two races. Two months later, the car was back for the Mid-Ohio race and looked very different. For starters, instead of red it was now painted black, which would remain the colour of choice for the team during the following years.

More importantly, though, almost all of the original design ideas had been thrown overboard. A massive wing was fitted on tall fins and, in the area between the wing and bodywork, a pair of large radiators appeared.

Follmer made it clear he did not want to race the car again, and so his place was taken by Vic Elford. He had tested with the car before the race and made some changes, and in qualifying was just four seconds off the pace. However, in the race itself, he found the car so difficult to control on the straights that, out of fear for the safety of other drivers, he opted to park the car just nine laps in.

Moving on

Nichols had seen enough, and decided to pull the car from the remainder of the season, vowing to come back with a more conventional car the following year. The new-for-'71 Shadow was indeed less outlandish, but it would take until 1974 for the team to hit its stride and win the Can-Am championship.



The first major compromise to the original design was the addition of a full-width rear wing as the car lacked downforce

Out of fear for the safety of other drivers, [Vic Elford] opted to park the car just nine laps in

Harris moved on after the disappointing 1971 season and was involved in a wide variety of projects, predominantly with Nissan. With the Japanese manufacturer, he celebrated some of his greatest successes during the late 1980s and early 1990s when the mighty Nissan GTP cars dominated IMSA racing. He would also return to Shadow in 1979 to pen the team's new Formula 1 car. Between 2001 and 2004, he teamed up with Nichols once more to pitch an amphibious vehicle to the American military.

It is believed four examples of the Can-Am AVS Shadow were built. One was a prototype in 1969, and then three cars were built to compete during the 1970 season. In 1990, Nichols completed a fifth example for German collector, Peter Kaus, to display in his now defunct Rosso Bianco museum. This car was built to the original drawings and featured rear-mounted radiators, as well as the 'slimline' induction system. It was eventually sold at auction in 2006 and is held in an American collection today.

What happened to the first three chassis is not known, but Nichols retained the car as raced by Elford at Mid-Ohio until 2006. It was then acquired by great Shadow enthusiast, Dennis Losher.

Restoration work

Losher set about restoring the car to full running order, but ran into many of the same problems the Shadow team had done originally. Not surprisingly, the biggest issue was procuring suitable tyres. Firestone no longer had the original sizes in stock, so he had to settle for the smallest size available, which fitted 10in wheels on the front and 13in wheels on the back.

The work was completed in time for the 2007 Monterey Historic Automobile Races where it was driven in the Can-Am celebration race. Elford was on hand and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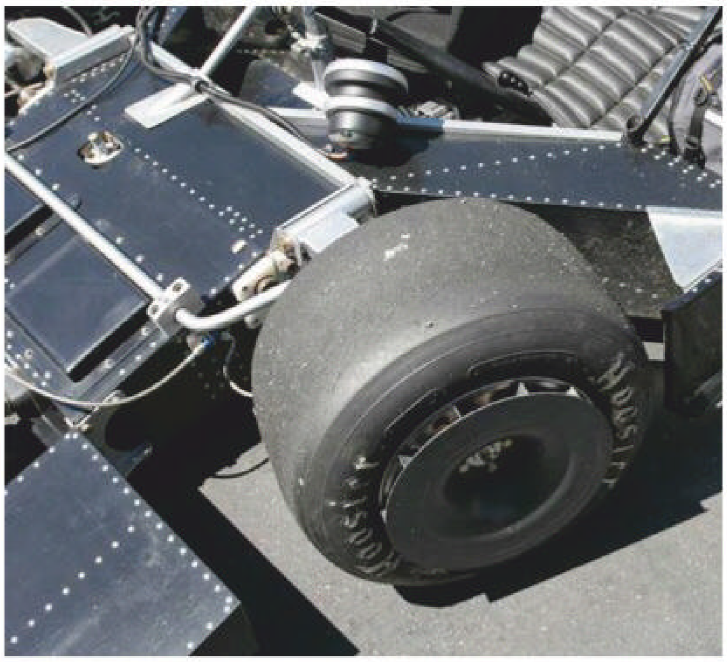
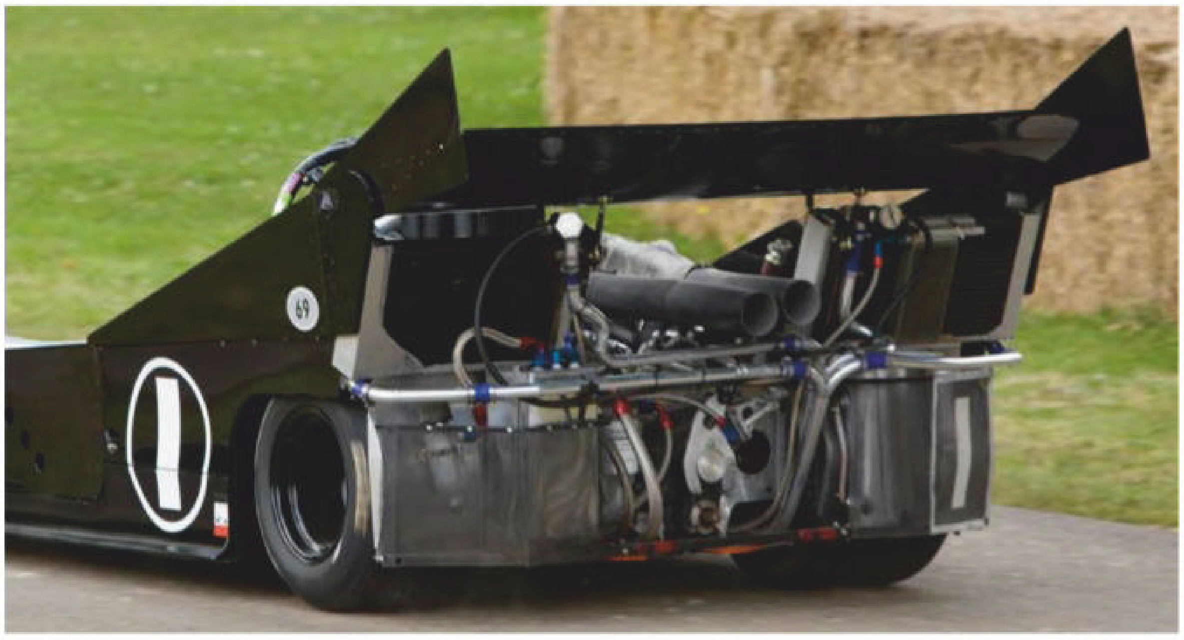
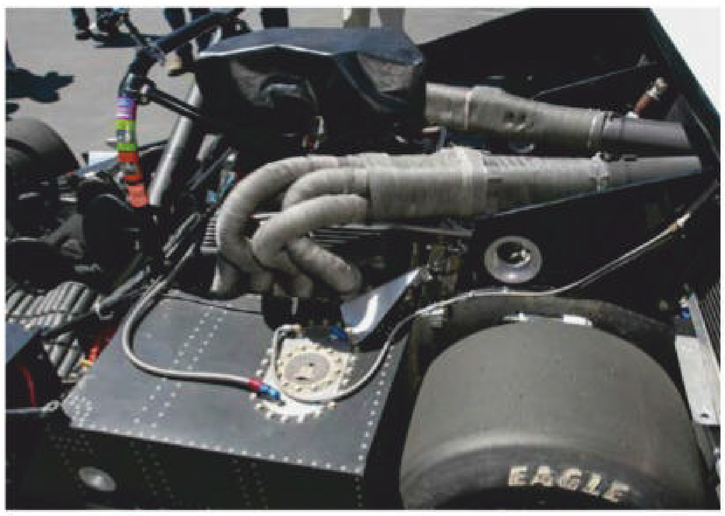
The car as raced by Vic Elford with wing-mounted radiators. It was said to be unstable on long straights



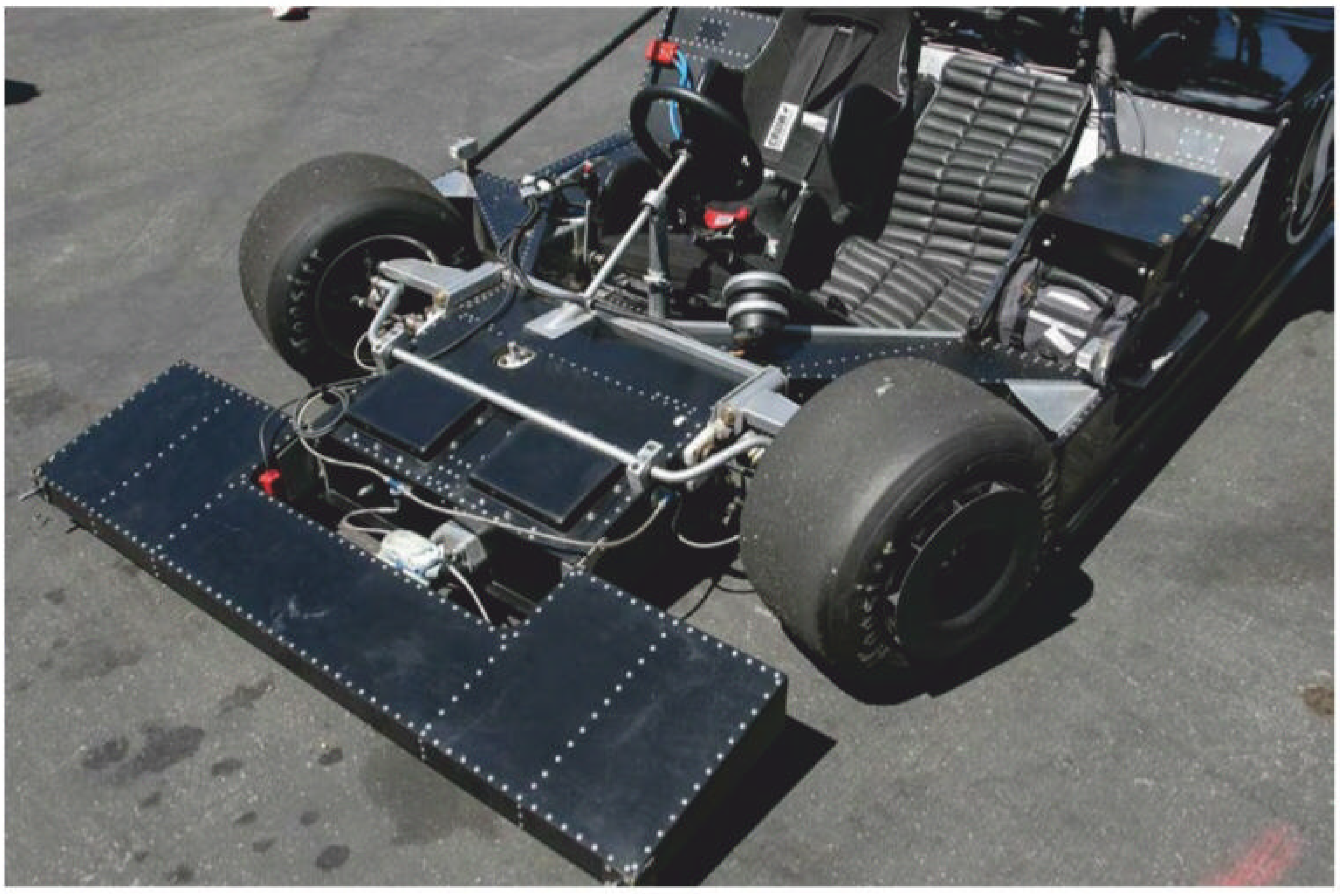
Corvair engine fans on the front wheels improved brake cooling





Engine overheating was a constant problem that was never truly solved, despite trying three different radiator configurations

Embodies everything that makes the original Can-Am series so revered



No consideration was given to driver comfort, with the seat almost horizontal and an unfamiliar pedal layout

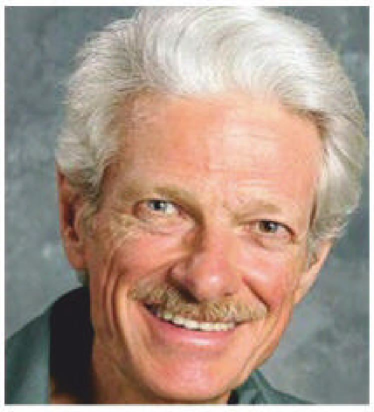
looked at the Shadow from a distance, later telling us that was as close as he ever wanted to be to it again. Losher then brought the car to Europe where it was demonstrated at the Goodwood Festival of Speed.

In 2009, it was acquired by former Porsche designer, Harm Lagaaij, who had been fascinated with the machine since reading about it for the first time some 40 years earlier. He still believed in the merits of the original design and, with the help of Nichols and Harris, re-restored the car accordingly. Subtle changes were made during this process, which included the addition of a third pedal for the clutch. The brake pedal was also moved from the right-hand side to the left.

Lagaaij and his team spent no fewer than 4,000 hours restoring the car, and then a further 1,000 hours making it more user-friendly in order that the Dutchman could not only demonstrate, but also safely race the car. The finished article featured rear wheel covers and an optional rear wing.

Lagaaij used the Shadow regularly from 2010 through to 2018. Since then, the only fully functioning example of the unique Shadow has returned to the United States. While the car was ultimately not a success, the AVS Shadow embodies everything that makes the original Can-Am series so revered.

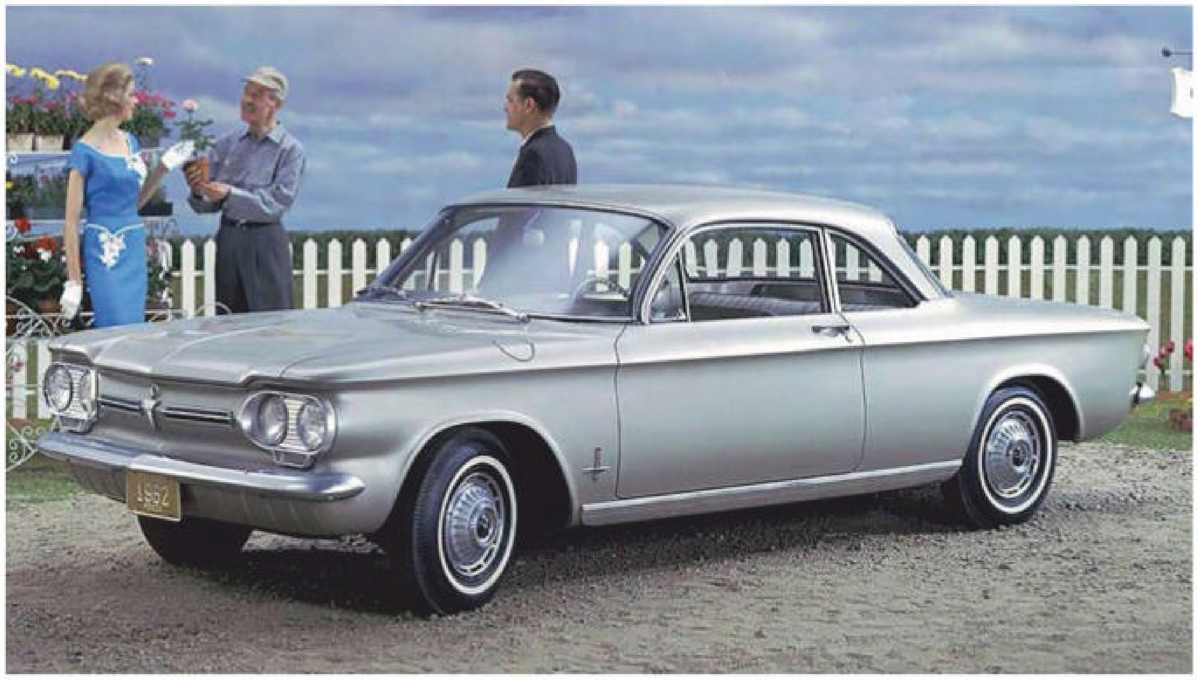
References include Can-Am *by Pete Lyons and research provided by Harm Lagaaij. For more information on Shadow, see Pete Lyons' latest book –* Shadow: the magnificent machines of a man of mystery *published by EVRO.*



Corvair vindication?

Was the car really 'unsafe at any speed', and who knew?

By MARK ORTIZ



Early Corvairs were the subject of Nader's considerable wrath, but the problem runs deeper than suspension

Q What do you think of this Mark? www.hemmings.com/stories/2020/03/19/corvair-vindication-day-aims-to-set-the-record-straight-with-ralph-naders-tort-museum

According to the article, an event is being planned at Ralph Nader's Tort Museum to 'vindicate the Corvair', organised by Nick Gigante, the grandson of Frank Winchell, who was head of R & D at the time of the lawsuits surrounding the Corvair.

What's your take on the Corvair? Was the car actually dangerous?

THE CONSULTANT

A First, fair disclosure: I own a Corvair. Mine is a late model, 1965, with a Crown V8 conversion. I have also voted for Ralph Nader, twice (no, not in the same election). So you could say I'm personally involved, but I don't categorically hate Corvairs, and I don't categorically hate Nader.

From the Hemmings article:

'We showed that there were millions of rear-engine cars…[and] that the Corvair violated neither Newton's nor Galileo's predictions; that the restraining force was proportional to the weight so that, at the limit of friction, the forces were essentially in balance; that neither end was destined to let go first. We showed that it oversteered, but not because of tuck-under. We never denied the Corvair could be rolled, or that it was possible to do so on a smooth pavement if the coefficient of friction was high enough. There were many cars with wide tracks that were harder to turn over. There were also many narrower cars that were easier to overturn.

'In the end, the car was exonerated, but did not survive the ordeal. We didn't win. The plaintiff didn't win, and it cost a lot of money.

'Winchell and Nader did, in fact, meet face to face, according to Gigante. As Winchell told Gigante, GM had invited Nader to tour its tech center after the publication of Unsafe at Any Speed *in 1965. "Grandpa said that Nader was really attentive. He thought he'd convinced this lawyer that he was wrong."*

'Instead, Nader later went on to accuse Winchell of being intentionally deceitful to juries in the cases for which he testified.'

It is unclear from the article who 'we' is, but my focus here will be the assertions themselves.

For a pertinent excerpt from Nader's book, see here: www.ncbi.nlm.nih.gov/pmc/articles/PMC3020193/

Now, let's clarify some basics. There is no hard demarcation between safe and unsafe cars, especially where handling is concerned. Rather, there are differences of degree. But those differences can be considerable, and we can say some definite things about them.

One such definite thing is that a car with limit understeer is safer and more forgiving than one with limit oversteer, especially for the casual driver.

An understeering car is particularly advantageous when the driver accidentally enters a turn too fast and is faced with a need to turn and slow at the same time. When the car is decelerating, dynamic wheel loading – but not mass – transfers forward. This adds lateral acceleration capability at the front and reduces it at the rear. If the front is the end that needs help, the car will often make its best lateral acceleration when decelerating moderately.

On the other hand, if the rear is what limits the car, decelerating is problematic. The usual technique is to stay on the power to load the rear, and with modest power and dry pavement, full throttle may work well. With ample power or less grip, you need to apply enough power to load the rear, but not enough to spin the car due to wheelspin. It can be helpful to modulate the throttle.

Retaining control

It is possible to lift while cornering in an oversteering car, and retain control. I've done it. But it doesn't work if you're already right at the limit, and you have to be prepared to promptly dial in a lot of countersteer, get back on the power and dial the countersteer back out as soon as possible. If your timing is off, you will spin the car, either in the direction of the turn or the opposite direction.

It is important that the car's oversteer / understeer balance, or understeer gradient, not change abruptly. It is particularly bad if it changes abruptly as the car approaches the limit of adhesion, especially if the car goes from understeer to severe oversteer. This is sometimes called snap oversteer.

In addition to the above, it is highly desirable that the car, any car, stay rubber side down at all times. Problems with the Corvair's

There is no hard demarcation between safe and unsafe cars, especially where handling is concerned. Rather, there are differences of degree

handling relate to both directional stability and rollover resistance.

Note there are two distinct Corvair designs, early (1960-1964) and late (1965-1969). The front suspensions are basically identical, but the rear suspensions are very different. Most of the controversy centres on the rear suspension of the early model, but the two versions have similar weight distribution, which is part of the issue.

The front suspension is a conventional short and long arm (SLA) system with coil springs. Until 1964, no anti-roll bar was used. Nader correctly points out that this is a cost-cutting omission, and one that carries a safety penalty. However, many contemporary economy cars – Volkswagens, Falcons, Valiants, Morris Minors – also had no front anti-roll bars.

The difference is most of these cars were moderately nose-heavy and had beam axles in back providing good camber recovery in roll at the rear, with independent front suspension providing little camber recovery in roll at the front. Consequently, they understeered right up to the limit, despite having more dynamic load transfer at the rear than at the front.

The rear suspension of the early Corvair, however, is a cheap, simple swing axle system. The wheel hangs on the end of a single arm that extends about to the middle of the car, with some additional member(s) for longitudinal location and brake torque reaction. The system provides good camber control in pure roll, but poor camber control in heave or ride, and very high jacking coefficients on both wheels.

In cornering, the jacking force is upward on the outside wheel and downward on the inside wheel. This creates geometric roll resistance, and geometric load transfer. When the load transfer is moderate, as in gentle cornering, the ground plane forces at the inside and outside contact patches are not wildly different. Accordingly, the upward and downward jacking forces, and their vector sum is not large, so the car doesn't jack much.

But as we corner harder and load transfer increases, the ground plane forces become increasingly unequal, as do the jacking forces. The vector sum of the two then becomes a rapidly increasing upward jacking force.

Furthermore, the jacking forces and the load transfer synergistically increase when the car jacks up: the c of g goes up, the track gets narrower and the roll centre goes up. Not only that, but the camber on both wheels rapidly moves toward positive. This is what people mean by tuck-under. The net result is an abrupt degradation of rear cornering power and a dramatic change in the understeer gradient, aka snap oversteer.

When the car is sliding sideways and the rear wheels are tucked under, it generally still won't overturn on dry pavement, provided it doesn't hook a rut or a bump. If it does, it is more prone to flip than a car with better suspension, although no car is immune to overturning while sideways.

Swing axles are nasty, and always have been, but they were in widespread use in Europe during the two decades preceding the Corvair, on both cheap and expensive cars, both front engined and rear engined. Some, such as the Allard, Lotus and Hillman/Sunbeam even used them at the front, too. Some of these cars were even journalistically acclaimed for good handling and were raced successfully, including by Porsche of course.

Error message

So, was there anything worse about the Chevrolet? Did Frank Winchell actually say anything false or disingenuous?

The answer to both these questions appears to be yes, although there may be some room for legitimate dispute. As Nader relates, in the early '50s, GM's Maurice Olley did handling evaluations of European swing axle cars and reported the system had bad characteristics, especially when used with tail-heavy weight distribution. Of course, he was only one voice in an immense corporate bureaucracy, but he was right and should have been listened to.

Swing axle jacking becomes more severe as the springing gets softer, and the Corvair is really softly sprung. Really, what works best with swing axles is stiff springing in ride or two-wheel heave, and soft springing in roll, as has been amply demonstrated in Formula Vee.

Even first-generation Corvairs can be competitive in autocross when lowered, fitted with small-diameter tyres, quicker steering, stiffer springs, a front anti-roll bar and a swinging transverse leaf spring 'camber compensator' at the rear. But that wasn't what they wanted from the Corvair. GM wanted architecture resembling a VW, but with a cushy ride and slow but light steering like an Impala. That is an unusually bad combination.

By 1963, partly due to a series of lawsuits, GM set about remedying the problem. For 1964 it added a front anti-roll bar and an aftermarket rear camber compensator based on an idea originated by Joe Vittone at EMPI for tuning VWs. Notably, Porsche did the same that year, realising it too had a problem, and 1964 was the last year either of them produced swing axle cars. Chevrolet continued producing the forward-control van and pick-up versions of the first-generation Corvair for one more year though.

The second-generation Corvair (1965-'69) has a rear SLA suspension similar to a C2 Corvette, but with an added toe control link near the front of each trailing arm. About its only shortcoming is a tendency to pro-squat, and the stock rubber bushings give it quite a lot of compliance camber change. For racing, that can be overcome by substituting a heim-jointed lower link, or strut rod as Chevy calls it.

It still has a fair amount of limit oversteer, though it's a lot more manageable, and fitting larger rear tyres absolutely transforms the car.

Now, did Frank Winchell say anything false or disingenuous? I can't comment comprehensively on that without reviewing court transcripts, but I can say the assertion attributed to him in the article that tyre friction force is directly proportional to load, and thus directly proportional to centrifugal inertial force, so that a car is inherently in balance regardless of weight distribution, is definitely false.

It is true the coefficient of friction is pretty nearly constant between two hard, dry, clean, smooth surfaces, but pavement is rough, and rubber is pliable. The coefficient of friction for a tyre decreases with normal force and friction force increases with load, but at a decreasing rate. Load sensitivity of the coefficient of friction is fundamental to everything we do in suspension tuning, and is the reason cars respond the way they do to weight distribution, roll resistance distribution and tyre size.

GM wanted architecture resembling a VW, but with a cushy ride and slow but light steering like an Impala

I can also say for certain the assertion that swing axle tuck-under doesn't contribute to oversteer or overturning is false, too.

I don't know what year Winchell made the assertions. That might have some bearing on whether he knew better, or should have, but it is worth noting that from 1961-'63, GM also produced the front-engined, swing axle-equipped Pontiac Tempest. It had the same jacking problem as the Corvair, but without the tail-heavy weight distribution that provoked the lawsuits. There is no way Winchell could not have known that.

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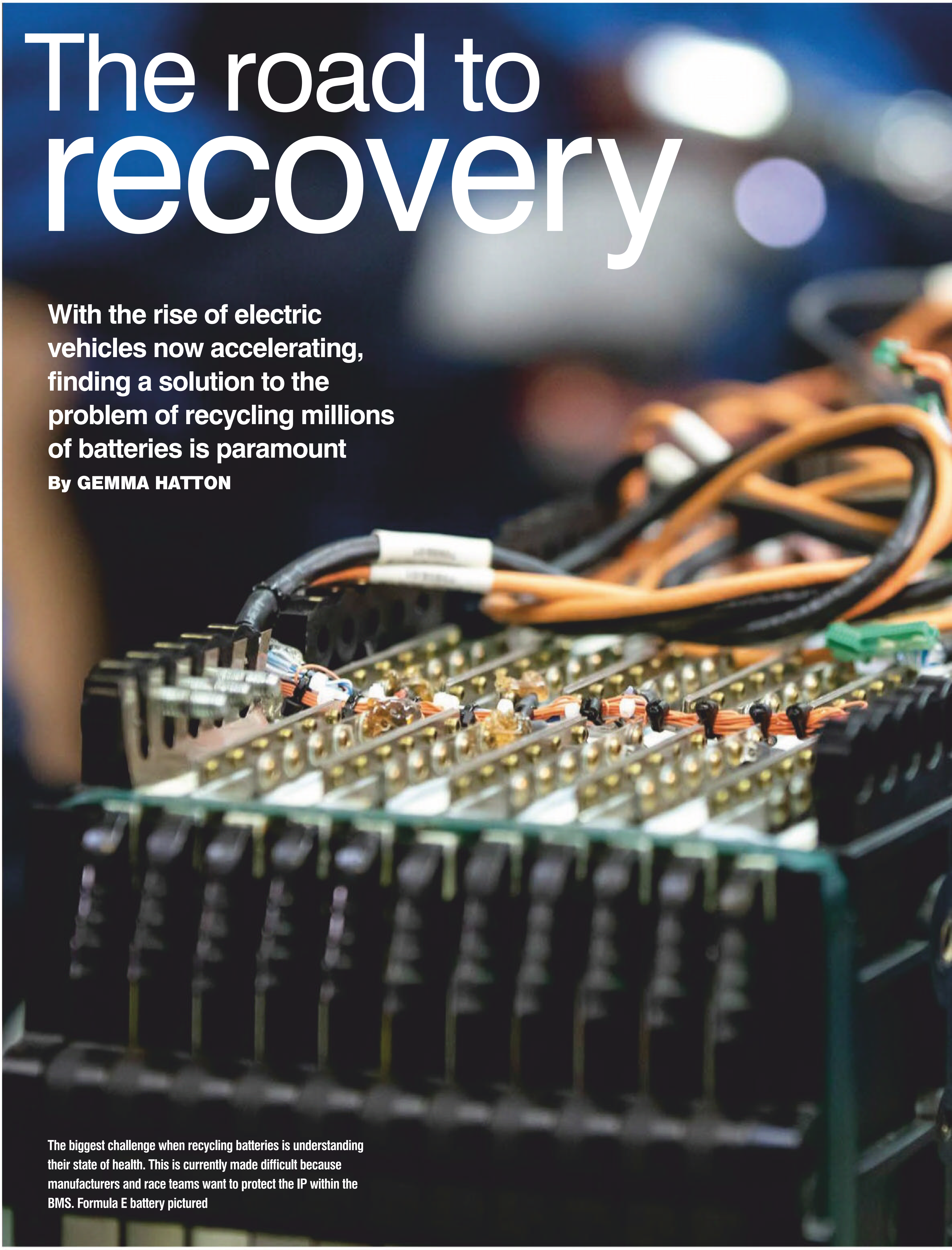
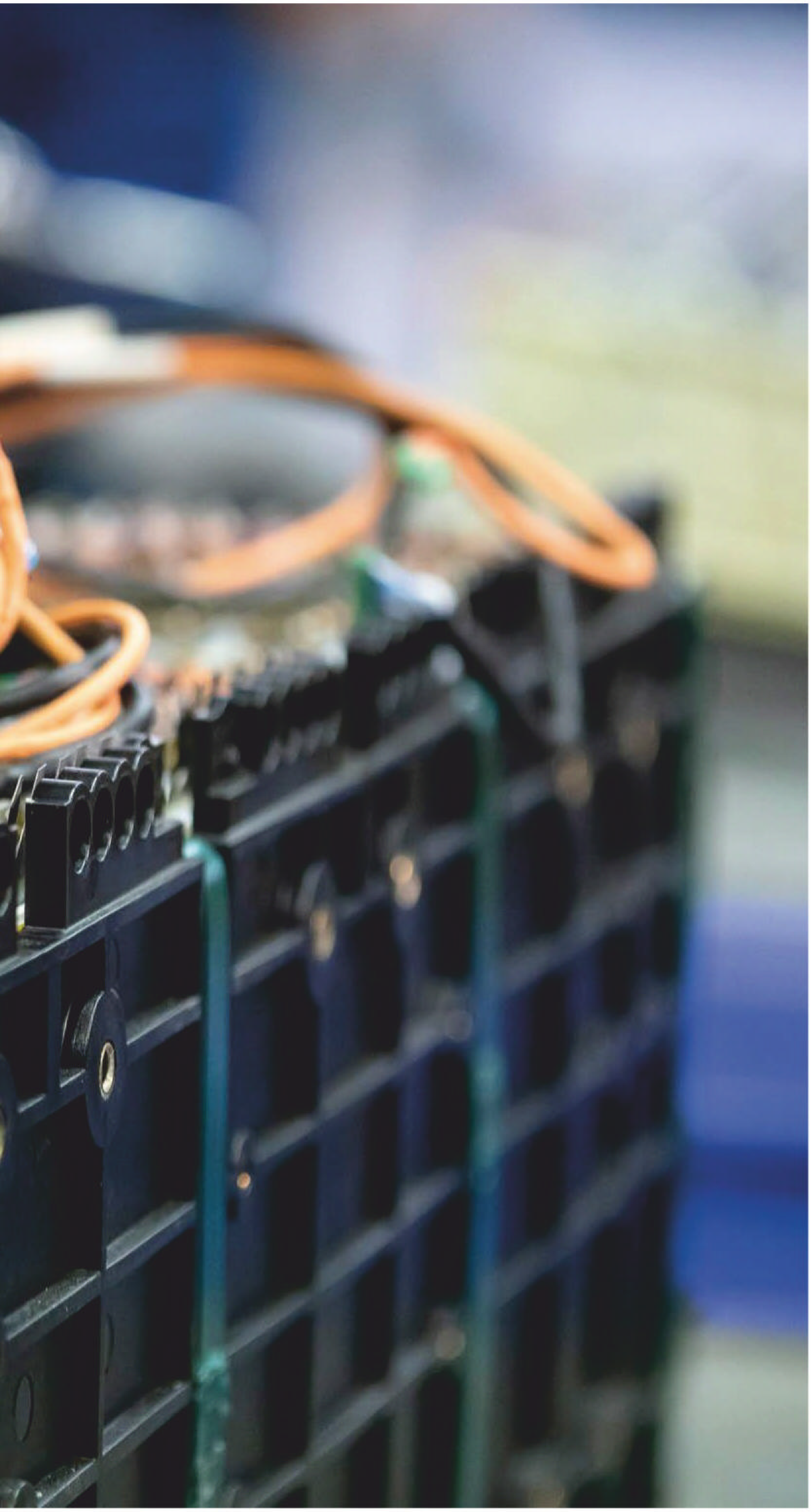


The road to recovery

With the rise of electric vehicles now accelerating, finding a solution to the problem of recycling millions of batteries is paramount

By GEMMA HATTON

The biggest challenge when recycling batteries is understanding their state of health. This is currently made difficult because manufacturers and race teams want to protect the IP within the BMS. Formula E battery pictured



Earlier this year, the UK government announced that the sale of new petrol, diesel and hybrid vehicles would be banned from 2035 onwards, five years earlier than initially planned. Other countries continue to follow suit as the world pushes towards the targets set out in the Paris Agreement, which aims to keep the global average temperature increase below 2degC per year.

With both countries and car manufacturers continuing to ban internal combustion engine vehicles from their repertoire, the reliance on electric vehicles (EV) is growing. Experts are now predicting there could be over 140 million electric cars on the world's roads by 2030. This expected boom will leave us with over 11 million tonnes of used lithium-ion batteries that need to be recycled between now and 2030, so researchers across the globe are racing against time to develop an efficient and economic automotive battery recycling process the world can quickly adopt.

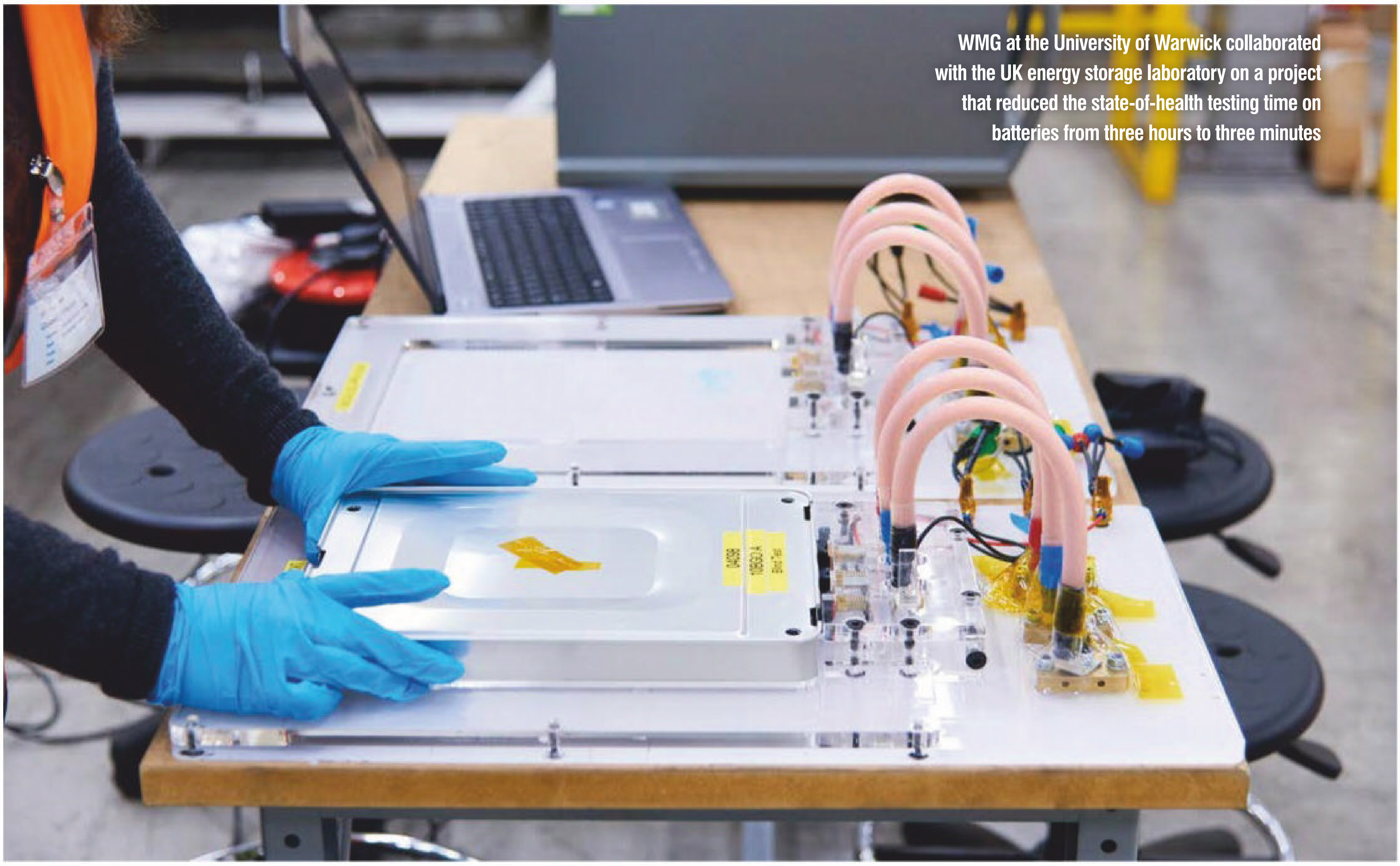
So why is recycling batteries suddenly so important? 'As batteries continue to appear in vehicles, we're moving from batteries that weighed 100g in a 'phone to something that weighs 100kg, or even 1,000kg,' highlights David Greenwood, professor at Advanced Propulsion Systems, WMG at the University of Warwick. 'Those batteries embody large amounts of valuable and sometimes rare materials. To extract those is expensive, and can be harmful to the environment if done wrong.

'Therefore, as we move into this kind of second generation of electric vehicles, it's important that we're not continuously reliant on the extraction and refining of new materials, but instead are reclaiming materials from the waste products of the previous generation of batteries.'

From a carbon footprint perspective alone, recycling is a better alternative to mining, as Kristof Gabriël, commercial director refining and recycling at Umicore explains: 'In general,

'It's important we're not continuously reliant on the extraction and refining of new materials'

David Greenwood, professor at Advanced Propulsion Systems, WMG at the University of Warwick



WMG at the University of Warwick collaborated with the UK energy storage laboratory on a project that reduced the state-of-health testing time on batteries from three hours to three minutes

external studies show that recycling has an environmental benefit vs mining when it comes to CO_2. Perhaps a better way of looking at it is the difference between the units of CO_2 required to mine a unit of metal and the CO_2 required to recycle it. Here the savings are significant. The CO_2 footprint is limited, and there is not a lot of CO_2 / weight.'

Life cycle emissions

The processes involved in manufacturing a battery are complex, expensive and account for a large proportion of the life cycle emissions of an electric car. Batteries are born out of lumps of rock that have been mined and refined into raw materials. The raw materials are then combined to form the active powders or electro-chemical components of the battery. These can consist of materials such as graphite, along with metals including nickel, cobalt, iron phosphate, manganese and aluminium.

The active powders are then coated onto thin foils, typically made from copper or aluminium, and form the anode and cathode electrodes. Between these electrodes is typically a thin polymer 'separator' soaked in electrolyte. The foils are then either rolled up like a swiss roll and put into a can to create a cylindrical cell or stacked on top of one another like the pasta in a lasagne and put inside a pouch to make a pouch cell. The cells are then grouped into modules, which are used to build up a battery pack.

The contact between the surface areas of all those components allow for an electro-chemical reaction where lithium ions are transferred between the anode and cathode, releasing and absorbing electrons as they do so and converting stored chemical energy into useful electrical energy.

'Just over half of the value of a battery is in the cells, which are the fundamental building blocks of the battery. The remainder is in the conversion of the cell into the pack with all the management systems,' explains Greenwood. 'When you look inside the cell, about half of the value of that cell is the cathode active material. That's where the greatest value effectively lies.'

Intellectual property

Before a used battery can begin its road to recovery, its state of health needs to be fully understood. This is a major challenge as, currently, there is no standardised way of doing this because each battery's BMS (Battery Management System) is a crucial part of its manufacturer's IP.

'That is something they [battery manufacturers] regard as being highly proprietary, and they all spend a fortune on developing it because that's what allows them to either use a greater or lesser capacity of the battery during its life, which gives more or less range for the user,' highlights Greenwood. 'So manufacturers are very defensive of that IP as it's part of their USP.'

Manufacturers are re-purposing batteries to power street lights and back up elevators

With the BMS unable to tell recyclers the status of the battery, alternative test methods have had to be developed in order to establish its condition. 'When a battery comes into the recycling chain, it is a box with two terminals and somebody has to work out what state it's in,' explains Greenwood. 'Typically, you have to conduct a full charge and then a full discharge to measure how much energy went in and how much energy came out. This can then be compared to the original specification of the battery, which details the performance of the battery when new. But this is an extremely expensive and time-consuming process.

'The ability to very quickly identify what the battery is, and what state it's in, would make a significant difference to the recycling process. So having a BMS that can act as a sort of passport for the battery, showing its current state of health, what it looked like when it was new, what it has done since then, what it might be useful for now and, more importantly, the chemistry inside it.


Formula E batteries utilise pouch cells and Umicore has currently recycled all the batteries from the first two seasons of the electric racing championship

This will help recyclers as they store batteries in groups of similar chemistries and then process them in batches to obtain a high yield of a particular material.'

Life cycle analysis

From a life cycle analysis point of view, the ideal solution is *not* to dive straight into recycling, but actually utilise used batteries in second life applications. This is where a battery pack that is no longer suitable for one application is re-used for another.

As battery packs are charged and discharged, the overall performance degrades, which means there is less stored energy available for generating power. In the case of electric vehicles, the end of life is typically when the battery has degraded by around 20 per cent. Therefore, the rest of the battery's capacity can be utilised for lower power, less demanding applications such as domestic energy storage.

In the case of electric vehicles, the end of life is typically when the battery has degraded by around 20 per cent

Manufacturers such as Nissan are re-purposing batteries to power street lights in Japan, while Renault uses old batteries to back up elevators in Paris.

'When we talk about a battery having an 80 per cent state of health, what that means is it can store about 80 per cent of the capacity it used to,' explains Greenwood. In other words, if you have an electric vehicle, the range is about 80 per cent of what it was when it was brand new. That might lead you to think that it's hardly degraded at all, which is sort of true. However, the degradation of electric vehicle batteries is only linear until 80 per cent. After that, it can drop off dramatically. By taking that battery out of the vehicle and implementing it into a more benign use case, the degradation from 80 per cent to 40 per cent is much slower, so you can get much more life out of it.

Giving batteries a second lease of life in this way not only enables companies to benefit from the same product several times over, it also displaces the need for new batteries. Furthermore, with only a few conversion processes required, this strategy retains the maximum amount of value that was originally embedded into the battery during its manufacture.

'You can get another five to 10 years' life out of the battery before you have to move to recycling,' says Greenwood. 'That really helps in terms of life cycle emissions because you're having a whole second use from that same initial investment. So, second life applications are always the first thing we look for.

'But when batteries have completed their second life, or if they are not suitable for that, we still need processes that allow us to access those valuable materials.'

The next level then is re-manufacturing. This uses exactly the same principles as having an engine rebuilt. If a battery fails due to one module, this can be replaced and the battery pack, as a whole, can continue running. 'In terms of re-manufacturing old batteries, there are no moving parts in a battery so, generally speaking, all the expensive parts within a battery degrade at the same rate,' continues Greenwood. 'You may find some companies replacing an odd module to extend the life of a battery for a year or two, but I think re-manufacturing is a short-term opportunity.'

A longer-term solution is recycling, and currently there are several approaches that can be taken, with new technologies being researched all the time.

The recycling process

The first stage to recycling is pre-treatment. This is essentially where the battery is disassembled, which is not an easy process given the complexity of modern batteries. Technicians, or even robots, can manually dismantle the modules, separating the main circuitry from the cells. These are then fed into a shredder, and a separator deciphers the

Ironically, as design innovation continues to reduce the amount of expensive materials needed in battery manufacture, the desire for recycling could diminish because there is less value to recover

metallic components from the polymers. A secondary treatment then follows, which uses a chemical solvent to separate the cathode material from the aluminium foil and the anode material from the copper foil. These active materials are referred to as 'black mass'.

The third and final stage is where the cathode material is dissolved through either thermal and electrolytic reactions, known as pyrometallurgy, or leaching chemicals, known as hydrometallurgy.

The most common approach today is pyrometallurgical, which is effectively where the entire battery is smelted at extremely high temperatures. This eliminates the organic components within the battery such as the separator and the anode, which is often carbon, and leaves a powder from which the desired metallic components can be recovered chemically. Whatever is left after the smelting process is then typically turned into fly ash and utilised in low-value applications such as building materials.

Unfortunately, pyrometallurgy does not recover the likes of graphite, lithium or aluminium. Furthermore, it consumes more energy than hydrometallurgical processes and so is viewed as less environmentally friendly. But it is cheaper and can meet today's legislative requirements for battery recycling.

Hydrometallurgy extracts metals using an aqueous solution. First, the components are ground to a powder, which is then immersed into an acid solution with an oxidising agent if required. This is known as leaching. After that comes the purification stage, which aims to remove any heavy metals through cementation or electro-chemical reduction. Finally, the desired metals are extracted from the solution.

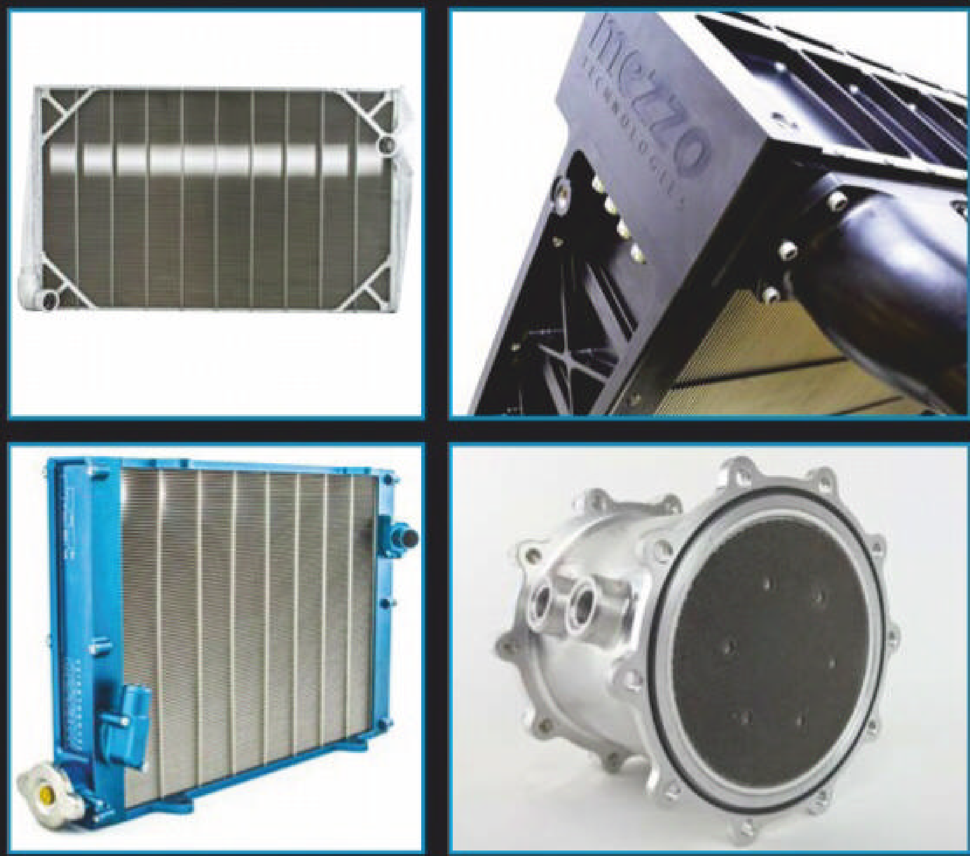
In general, hydrometallurgy extracts metals with higher purity than pyrometallurgy, and consumes less energy, but does require significant quantities of industrial chemicals in the processing.

Hybrid recycling

Another strategy is to combine pyrometallurgy and hydrometallurgy to form a hybrid process that exploits the benefits of each, whilst minimising the drawbacks. One company utilising this approach is Umicore, Formula E's official battery recycling partner. The pyrometallurgical phase uses Umicore's unique UHT (Ultra High Temperature) furnace, which has been designed to safely treat large volumes of different types of complex metal-based waste streams. The furnace is the largest dedicated recycling installation for lithium-ion and nickel metal hydride batteries in the world. With an installed capacity of 7,000 metric tonnes, this furnace is capable of recycling up to 250 million mobile 'phone batteries, or 35,000 EV batteries per year.

Hydrometallurgy extracts metals with higher purity than pyrometallurgy and consumes less energy

'The Umicore battery recycling process combines a new treatment and recycling method with existing refining technology,' says Gabriël. 'Treatment includes the safe dismantling of large industrial batteries, such as EV batteries, without crushing or shredding the cells. This means operators and the environment are not exposed to hazardous battery compounds in the process.

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'After sorting and dismantling, metals are recovered in our proprietary in-house, high-temperature smelting process. Within the smelter, battery materials are transformed into metal alloys containing Co, Ni and Cu and a concentrate containing Li and REEs [Rare Earth Elements]. This fraction is further refined for Li and REE recovery externally.

'The process is energy efficient as it recovers the energy present in the batteries, whilst also treating potentially harmful gases.'

Umicore's process aims to recover and recycle as much material as possible, whilst minimising the impact on the environment by utilising the energy within the battery itself in the process. 'The plastics and other organic compounds, including solvents and electrolytes, are burned as a gas to produce heat for the process,' continues Gabriël. 'This gas is cleaned to ensure all organic compounds are fully decomposed, and that there are no harmful emissions.

'The small amount of fluoride found in batteries is also collected and solidified for specialised landfill treatment. The copper, cobalt and nickel metals are refined, so they are ready to be processed as new cathode materials. The metals can be sold or used in new battery materials or other products.'

The pyrometallurgical phase of Umicore's process effectively converts batteries into three fractions. Firstly, an alloy containing cobalt, nickel and copper, ready for hydrometallurgical processing, where this alloy is further refined to convert the metals into active cathode materials. Secondly, a slag fraction that can be used in either the construction industry or further processed for metal recovery. Finally, clean air is released from the stack after it has been treated by the UHT's unique gas cleaning process.

Closing the loop

'Batteries can be infinitely recycled because they are active materials based on metals and they are recyclable without quality loss,' highlights Tom Van Bellinghen, VP OEM value chain and marketing at Umicore. 'This means that at the end of the recycling process the metals are purer than if you would get them from a mine.

'Umicore's closed loop process is unique in the sense that we combine recycling of end-of-life batteries and the most stringent environmental standards, and afterwards we use these metals again to make high performing cathode materials.

'Our partnership with Formula E proves that today electric cars are high performance and, at the end of the life, the batteries can be recycled. And doing that with high efficiency we can recover all the metals inside.'

Battery recycling has become an important consideration for the likes of Formula E as it combats the opinion that disposing of batteries is wasteful and environmentally unfriendly. The Formula E regulations specify that each car can only use one battery pack for the entire season. However, if there is a fault then the battery can be replaced, but this comes with a 20-place grid penalty for the team, unless the issue can be proven to be the fault of the supplier, McLaren Applied Technologies.

Each Formula E team fields two cars, with manufacturers also allowed to run a test car for private testing. With 12 teams and nine manufacturers involved, this equates to a minimum of 33 batteries, not including any replacements. This is a rather substantial amount for a racing category whose ethos is of sustainability. So this is why Formula E assigned Umicore as its official battery recycling supplier.

Answering his own question, 'What do we do with that technology, especially with those batteries after we use them?' Alejandro Agag, Formula E's CEO, explains: 'The partnership with Umicore is a really important step for the ABB Formula E championship because we need to close the loop by recycling at the end of the life the batteries we use for the race.'

With several standardised battery recycling processes available that are capable of processing both low and high voltage batteries, as well as the likes of electric vehicle batteries from road cars and racecars, why then is battery recycling still not widely adopted? Well, financially speaking, battery recycling still doesn't make sense. Each process required to build up a battery, and then tear it apart only to build it back up again is complex and expensive. Recycling needs to recover a high percentage of material, with a high purity, in an efficient, environmentally friendly and inexpensive way, and that's not an easy challenge.

'Recycling is not a positive value stream in most cases,' reveals Greenwood. 'A battery costs the manufacturer hundreds of euros per tonne to recycle, because it costs money to do it and the products that you get back are worth less than the process it took to get to them.

'At the end of the recycling process the metals are purer than if you would get them from a mine'

Tom Van Bellinghen, VP OEM value chain and marketing at Umicore

'It's currently cheaper to buy the raw materials than it is to recover from a battery,' continues Greenwood. 'The technologies we have today are not very good at economically recovering all of the elements. So typically, the parts of the battery that people tend to focus on are the ones that give the highest commercial returns, like cobalt and nickel.'

Battery recycling makes even less financial sense when you look at recovering lower value materials such as lithium, graphite or aluminium. As a result, quite a lot of the materials within a battery are wasted because it's cheaper to mine the virgin materials, yet this is still compliant with the regulations.

End-of-life directive

'For passenger cars, there is an end-of-life directive that says 95 per cent of the mass of the vehicle has to be recovered or re-used,' explains Greenwood. 'Roughly speaking, 85 per cent of that mass has to be used as materials, and 10 per cent of it is allowed to be burned to create the energy required to drive the recycling processes. So the low value stuff that is not worth recovering is turned into heat, which drives the recovery of the higher value materials.

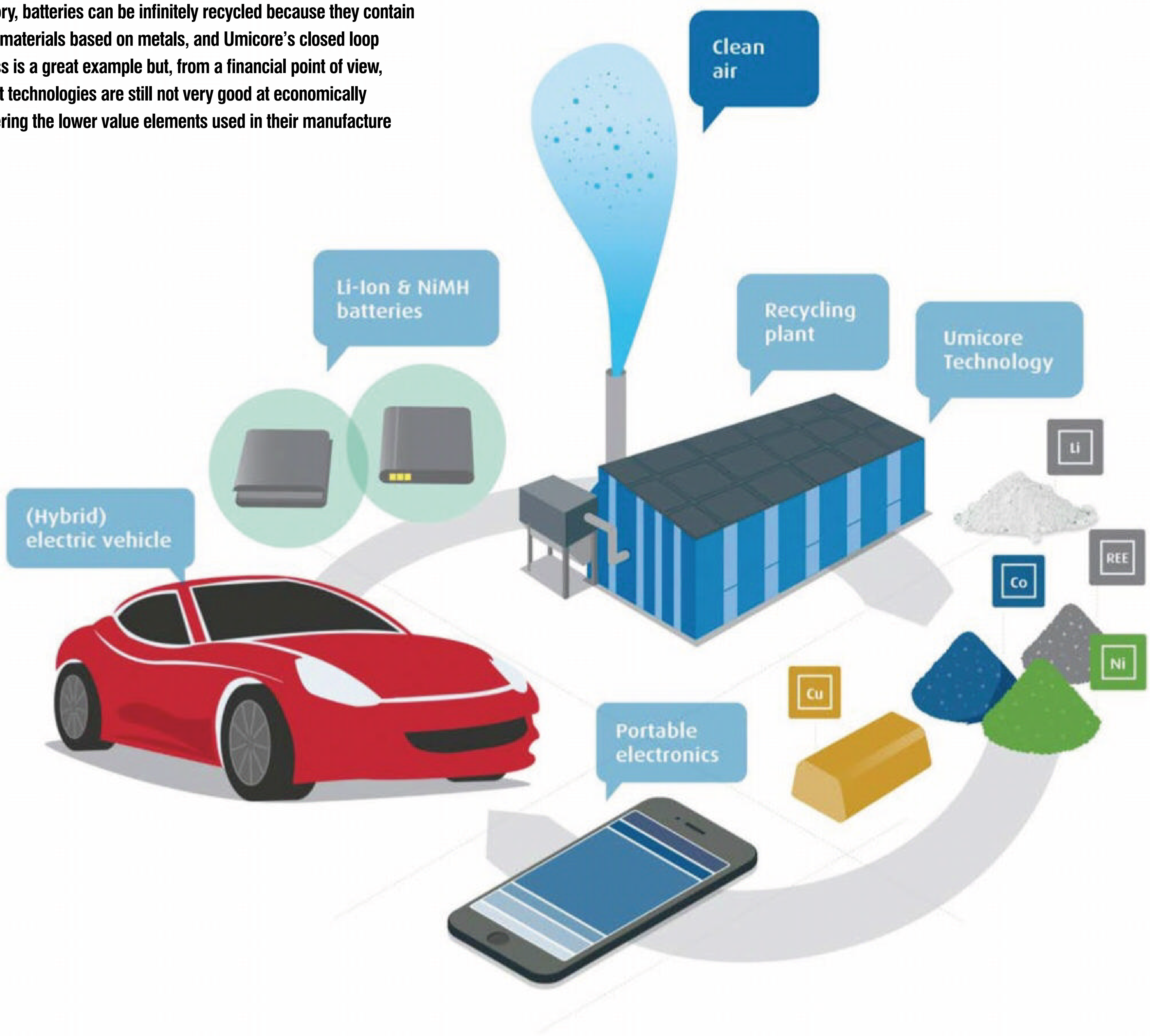
'However, an electric vehicle battery is covered by a separate battery directive, which specifies that 50 per cent of the mass of the battery must be recovered. That means that it is a lower threshold than the rest of the vehicle. Given that a typical battery weighs approximately 400-800kg, that means there is still 200-400kg of material that does not need to be recovered according to the regulations.

'With the battery case accounting for a significant portion of the weight of the battery, that is usually the first thing manufacturers recycle because it's relatively easy to deal with.'

'The low value stuff that is not worth recovering is turned into heat, which drives the recovery of the higher value materials'

David Greenwood

In theory, batteries can be infinitely recycled because they contain active materials based on metals, and Umicore's closed loop process is a great example but, from a financial point of view, current technologies are still not very good at economically recovering the lower value elements used in their manufacture



'It's currently cheaper to buy the raw materials than it is to recover them from a battery'

David Greenwood

However, recent research projects from the Warwick Manufacturing Group show that around 80-85 per cent of the mass of the battery might be recoverable in a way that is economically viable. Beyond 85 per cent requires substantial investment to recycle materials that would be more valuable as fuel.

Once the regulators start to see that there are processes out there capable of recovering more, they will undoubtedly raise that regulatory bar, which will force manufacturers to recycle more battery materials.

Although this first era of battery recycling is driven by regulation, in 10 years' time the drive could well shift to economics. As the demand for materials used in batteries increases, the cost of mining and refining them will increase as less rich reserves are targeted, and the materials within used batteries will become more valuable.

'The UK sells about two million vehicles a year, and industry forecasts suggest we could get to half of those being plug-in hybrids or electric vehicles within about a decade,' says Greenwood. 'Multiply that by the mass of the battery, and the amount of material in there, and that means we've got half a million tonnes of batteries that are going to start coming back into the waste stream about eight to 10 years from now. The value of the materials that went into those batteries is going to be worth about one billion pounds per year. That's the point we start to move from being a waste disposal problem to a value recovery opportunity.'

Of course, what would help the economic argument is the development of more efficient recycling processes capable of recovering more materials. 'You need to recover the materials with a very high level of purity, otherwise it is no use to the battery industry,' says Greenwood. 'We've been researching some new technologies using things like a deep eutectic solvent, which is a fairly complex solvent that can selectively grab the desired materials out of the battery. Another way to recover pure recyclates is to disassemble the battery pack into all its individual components and then recycle each of those through a separate channel so you're *only* dealing with pure materials. Unfortunately, this is very labour intensive, and the reality is that for large scale recycling the battery is shredded and turned into 5mm pellets and then you process those pellets.

'When I look at what's needed to get large scale battery recycling going, I believe this has to be the way we do it because we can't afford the time or money to individually deconstruct each battery. All the work we're doing at the moment seems to indicate there are processes that can separate the elements after the battery has been shredded.'

If shredding does become the more conventional route, then designing the battery for recyclability becomes less of a

Using a battery in an alternative application to that for which it was originally designed is the preferred option, with recycling the raw materials a delayed process due to the environmental impact

priority. However, there are still some good practises that could be implemented to help streamline recycling processes. This includes avoiding the use of wet processes such as adhesives to secure the cells within the battery modules. Although this may be cheaper, and a high-speed assembly method, it makes the battery difficult to recycle, and makes shredding the only option, which means it misses out on being used for second life or re-manufactured applications.

Another aspect which would greatly help battery recovery is identifying its state of health. 'We've been looking at some new technology, based on electro-chemical impedance spectroscopy,' reveals Greenwood. 'This is where we send a series of electrical pulses into the battery at different frequencies, and by looking at how the battery responds you can determine the mode of degradation. You're effectively listening to the echo of those frequencies.'

Growing market

So, what's the future for battery recycling? 'We expect the market to grow by 2025. The average EV battery life is more than 10 years,' says Gabriël. 'Eventually, batteries will have to be recycled as valuable metals like cobalt and nickel should not go to waste, and hazardous components should not end up in the environment. We are testing in our industrial pilot plant, to be ready for environmentally and cost-effective recycling. The pilot plant has a capacity of 7,000 tonnes per year. When the market in end-of-life EVs starts to grow, we will scale up our recycling activities.'

'Manufacturers at the moment retain responsibility for that battery all the way to the end of its life. They have to pay somebody to take the battery away, so there's a commercial incentive for them to make it easier for somebody to extract value from that before it goes into recycling,' highlights Greenwood. 'I think what you'll start to see is manufacturers providing more information on the state of the battery so you don't have to do as much testing.'

But the future will also present some challenges. 'One of the drivers for recycling is the amount of money you can recover from the materials that go into the battery,' says Greenwood. 'But when we're developing batteries at the moment, we're trying to take out all of those expensive materials to make them cheaper. Unfortunately, from a recycling perspective, that means that the size of the prize gets smaller. So actually, the economic case could become more difficult as we get better at engineering batteries.

'The economic case [for recycling] could become more difficult as we get better at engineering batteries'
David Greenwood

'The second challenge is, as chemistries continue to change quickly, the processes you need to recover them also need to change. I think the industries we build up today will be able to deal with the products that have been in the market for the last 10 years, and for the next 10 years. But 10 years or more on from there, we're going to need to develop another set of recycling processes to treat the likes of lithium sulphur, sodium ion and solid state batteries.'

So, if you're like me and have a bag of assorted used batteries patiently waiting by the door, maybe now's the time to take them to the recycling centre.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False reality

There's no doubt sim racing has its place, but it also has its pitfalls that should not be ignored

By DANNY NOWLAN

With racetracks around the world closed for a large part of this season, sim racing was the next best thing. But can it really substitute for the authentic racing experience?

Unless you have been living under a rock during the coronavirus lockdown, it has been impossible not to notice many formulae scrambling to sim racing as a stop gap while motor racing is in hiatus. Some of this has been quite entertaining. For example, I did have a wry grin seeing a V8 Supercar race at Monza. It was also quite refreshing seeing drivers from different categories race each other. This used to be the norm, but it is something motor racing has lost in recent years, so it was great to see its return. It also raises some great 'what ifs?'.

However, some very dangerous fallacies have also emerged about sim racing, and the Covid-19 pandemic has very much accentuated these. These are what this article will focus on.

Before I go any further, this is not a name and shame piece. Firstly, I don't have the time to fight off lawsuits. Secondly, I'm much more interested in exploring the why of this, rather than writing some glorified university student council self-promotion article. Thirdly, not to blow my own trumpet but… given we at ChassisSim have developed both LTS and DIL software that is useable and gets results, we're in a pretty good position to comment on this matter.

Firstly, though, it might be wise to consider what sim racing is good at, and how we got here. If we look back at the mid-to-late '90s, games such as *Grand Prix 2* is when sim racing started to be half-passable. It wasn't until the mid-2000s, though, that things started to get serious. As the computer hardware caught up, you started to see utterly stunning graphics and overall performance close to that of an actual car. This is when the wow factor of sim racing games became apparent. Then you throw in

To assert sim racing is a legitimate substitute for actual racing is a tad optimistic, to put it politely

Once you start talking north of 40rad/s, if you are not using fourth order Runge Kutta techniques, you might as well not turn up

internet connectivity so you can race your mates and this led to a potent combination.

However, all of this seduces you into a false reality because, while sim racing *looks* real, and is very good at simulating a particular set-up, it is rare for them to be used for serious set-up sensitivity analysis. This became painfully apparent in the late 2000s. As the mid-level race teams baulked at the price of the professional versions of sim racing games intended for factory sportscar teams and above, they opted to use their game counterparts instead. It then didn't take very long for a whole cottage industry to emerge that would take the physic definition files of these games and modify them beyond recognition. I was exposed to some of these numbers, and some of them simply defied belief.

Primary drivers

This carries on to this day, and was one of the primary drivers for the creation of the ChassisSim Driver In the Loop [DIL] toolbox. It still didn't stop racing gamers from trying to give me lectures on vehicle dynamics at the ChassisSim DIL launch in late 2018. And that was not an isolated incident. Due to the realistic graphics in sim racing, some gamers became self-appointed experts on vehicle dynamics. Examples of this abound on sim racing discussion platforms.

So what is the current state of play of sim racing? Some driver feedback during this lockdown has been most enlightening. I'll let these driver quotes speak for themselves:

> ***'Our cars are pretty forgiving when they get loose. This thing, when she gets loose – she's gone.'***
> *– Clint Boyer, NASCAR driver.*

> ***'Like, what the heck is going on? It feels like I'm driving on a wet track… This isn't a Mazda Miata, this is an IndyCar'***
> *– Conor Daly, IndyCar driver.*

> ***'Our racecars are a lot easier to control than the sim racing [version]. Our tyres have a lot more room for sliding'***
> *– Josef Newgarden, Team Penske IndyCar driver.*

> ***'Oh WTF?! What happened then?'***
> *– Scott Pye, V8 Supercar driver (after his car rolled from a common or garden low-speed turn).*

> ***'What the friggin'?! It rolled!'***
> *– Scott McLaughlin, 2019 V8 Supercar champion (riding the kerbs on a typical low-speed corner he wouldn't blink about driving in his actual race car).*

Other comments I've come across are less repeatable due to their even more colourful language. That being said, what these comments from professional drivers show is that to assert sim racing is a legitimate substitute for actual racing is a tad optimistic, to put it politely.

For driver training and circuit familiarisation it has its place, and it performs this role very well, due to the very good quality graphics we're now seeing. Beyond this, though, sim racing struggles.

The reason for this lies with the physics engines used in these games, and this comes down to two key reasons. Firstly, due to the graphics processing and network requirements taking priority, the physics engines take a back seat. Having tripped over myself on more then one occasion, I would take an educated guess that most of these game engines are using a second order integration algorithm something like this:

$$k_1 = h \cdot f(x_n, y_n)$$

$$k_2 = h \cdot f\left(x_n + \frac{h}{2}, y_n + \frac{k_1}{2}\right)$$

$$y_{n+1} = y_n + k_2$$

In this instance, x is the state variable, y is what we are trying to solve, $f(x_n, y_n)$ is the differential equation, h is the time step, the subscripts n and $n+1$ represent the steps you are taking and the variables k_1 and k_2 represent intermediate time function values.

The advantage is it executes quickly and is better than the standard Euler integration. It also works reasonably well for average-to-high performance road cars. But for racecars with much higher spring rates, second order integration schemes run out of steam.

To show what I mean, let's take a look at some typical eigenvalues and eigenvectors for the sprung mass modes of an F3 car. For the benefit of readers, the eigenvalues represent the frequency of the mode and its damping ratio, while the eigenvectors tell you how they are acting on the sprung and unsprung mass. This is shown in **Table 1**.

For driver training and circuit familiarisation it has its place, and it performs this role very well

The details of these numbers are in chapter four of my book, *The Dynamics of the Racecar*. If you have a mode with a frequency of, say, 20rad/s, a second order integration algorithm will get you by. But once you start talking north of 40rad/s, if you are not using fourth order Runge Kutta techniques, you might as well not turn up. The tell-tale sign is when the sprung mass modes go out of control due to numerical error. An example of this is the aforementioned car roll overs!

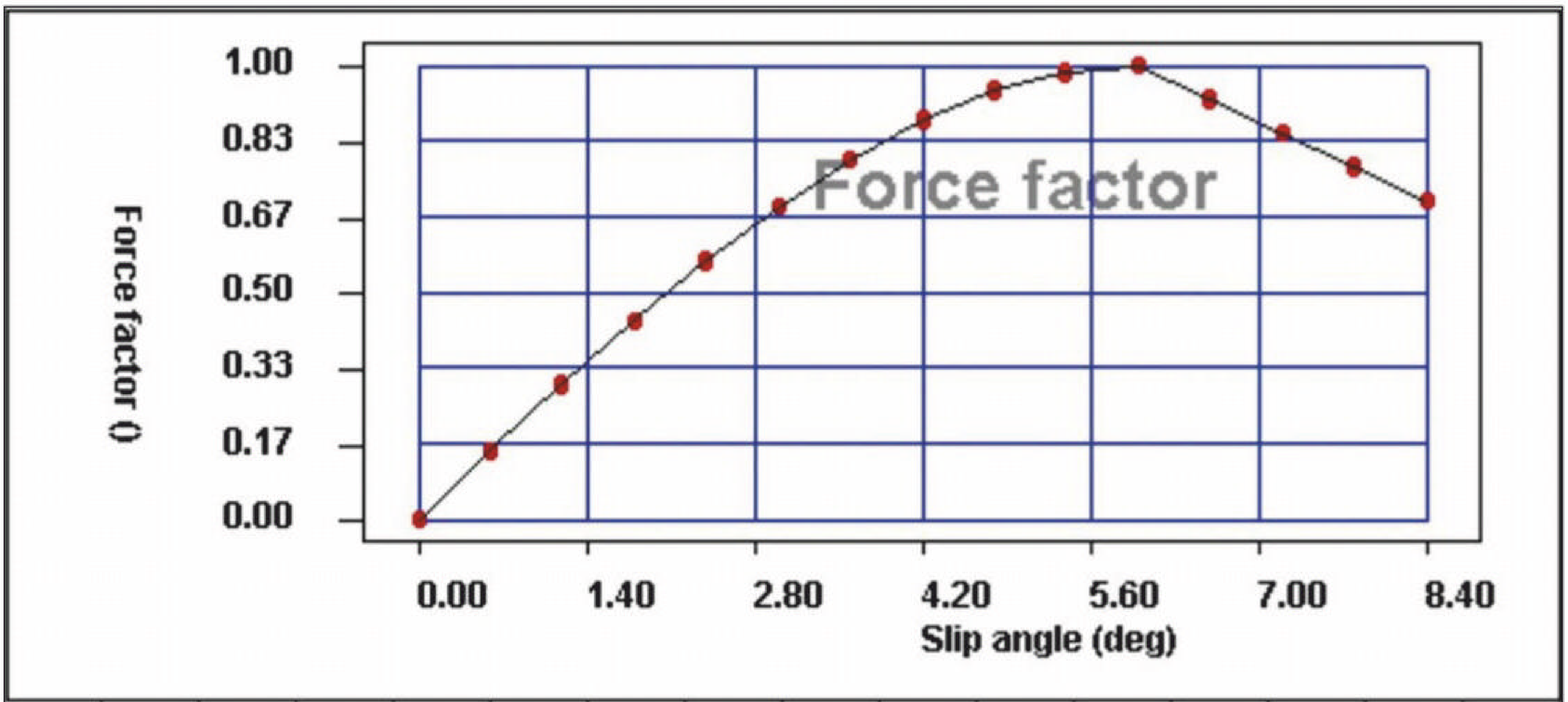
In the late '90s I found that out the hard way. This was the trigger to shift to fourth order integration for ChassisSim v1.5+ in '99.

The other problem you have is many racing game companies are working in a

Table 1: Eigenvalues and eigenvectors for a Formula 3 car

Case	Low-speed damping		High-speed damping	
	Eigenvalue	ω_n/ξ	Eigenvalue	ω_n/ξ
Tyre mode	-695.3	*695.3*	-225.3	225.3/inf
Tyre and body velocity	-6.86 + 42.9i	*43.4/0.157*	-52.5	52.5/inf
Tyre and body velocity	-6.86 - 42.9i	*43.4/0.157*	-11.1 + 33.1i	34.9/0.32
Body velocity	-11	*11*	-11.1 - 33.1i	34.9/0.32

Figure 1: Normalised force plot of force vs slip angle



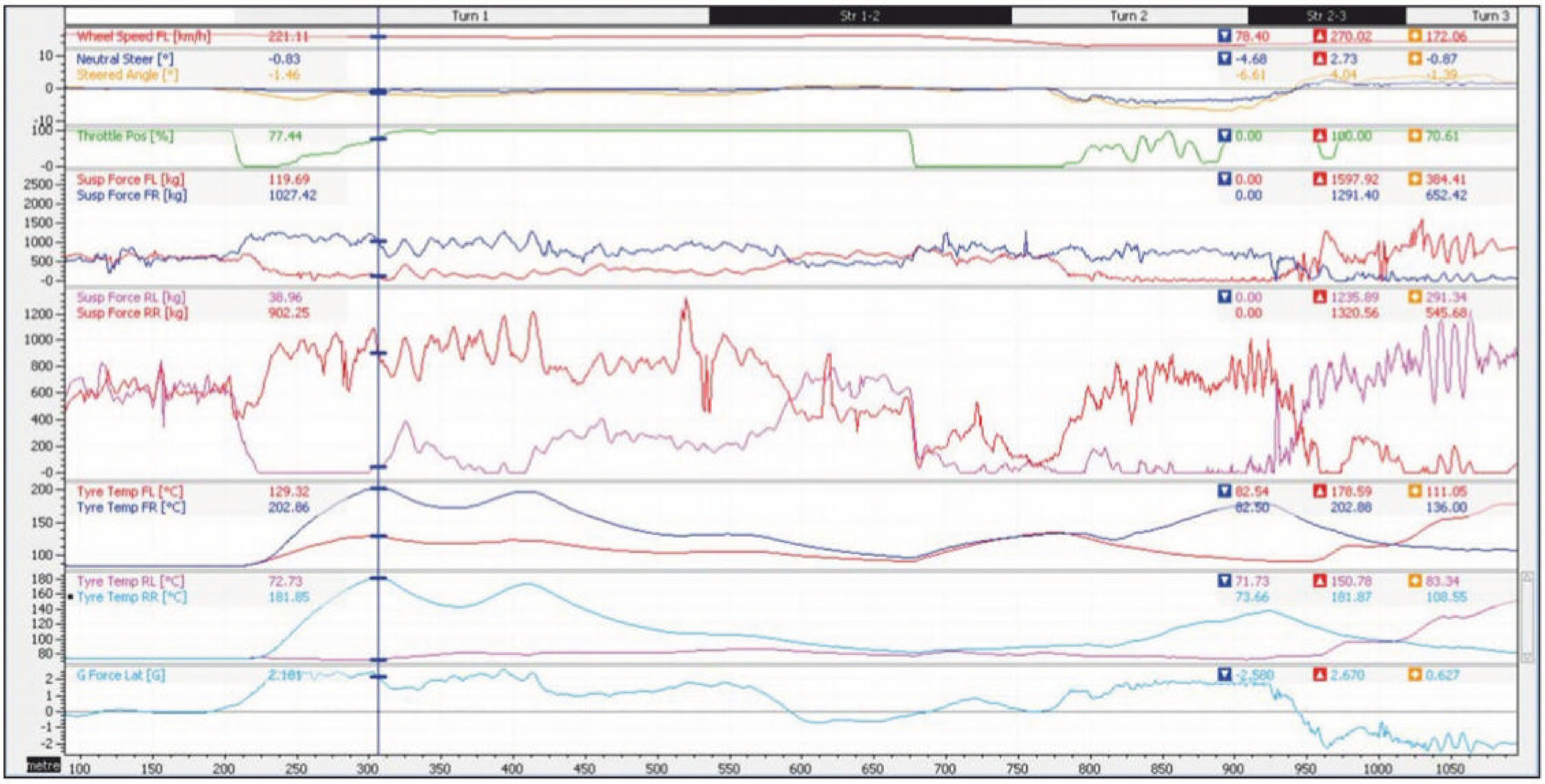
S angle	0.00	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00	6.60	7.20	7.80	8.40
FFact	0.00	0.15	0.30	0.44	0.57	0.69	0.79	0.88	0.94	0.99	1.00	0.92	0.85	0.77	0.70

knowledge vacuum, partly because most race teams keep their data securely in house (it is no accident that in my articles I always redact the scalings when I present actual data). And despite public announcements to the contrary, F1 teams do *not* pass out any meaningful data. Don't believe me? Ask any F1 team for a plot of driver channels for a given circuit and see how far you get. This is brought into even sharper relief when you talk about the channels needed to construct a useable vehicle model.

An example of this is the tyre models most gaming companies use, which are either standard Pacejka models or close derivatives thereof. Combine this with a lack of motorsport street knowledge and it explains the observations noted earlier.

To explore this a bit further, it might be worth digging into those comments about how the car behaves in the post-stalled manoeuvring regime. The first reason for this is the force factor post-stalled isn't correct, and looks something like **Figure 1**.

Figure 2: A badly conditioned thermal model



Note what happens post the peak of six degrees. Beyond this, the normalised force drops quite markedly. This would speak very strongly to what Clint Boyer and Josef Newgarden observed. While **Figure 1** is an over exaggeration, it illustrates what happens when the slip angle curve is wrong.

Another reason the post-stall handling would be off is missing the window on a thermal tyre model. One thing I stress to all ChassisSim users is that while thermal tyre models are powerful, they have to be treated with extreme caution.

Figure 2 is an example of what happens when you get it wrong. What you are seeing is some early testing of ChassisSim Driver In the Loop. Not only was the thermal not dialled in, there were no appropriate guard rails on the slip angle and slip ratio inputs. Note the peak temperature too, which is 200degC. If you plug that into a thermal model, it helps explain the comments made by Conor Daly and Josef Newgarden.

Data access

Make no mistake, having access to actual race data is essential for developing a battle-ready Driver In Loop simulation package. As a colleague of mine observed, simulation without correlation and validation is nothing more then speculation.

Another example is a motorsport university student that approached me

The physics models of these games are its Achilles heel

to see if they could use the aero and tyre modelling tools from ChassisSim on a sim racing game. Within two weeks the project had to be suspended because the returned aero numbers made no sense. To be honest, I was shocked, but the student and I noted it explained a lot of the qualitative handling observations of that particular car model. To save any embarrassment, I'm not mentioning the game or the car, other than to say it's a Formula I have a lot of data on.

When it came to developing the ChassisSim DIL, access to actual data was a life saver, without it the task would have been impossible. **Figure 3** is an example of just some of what I had access to. Unfortunately, most gaming companies don't have access to this kind of data.

That being said, sim racing does have its advantages. Firstly, it offers an opportunity for drivers who can't race to enjoy motor racing again. Robert Wickens and Dale Earnhardt Jr are cases in point. It also forms a great tool to promote motor racing by making motorsport fans, and potential motorsport fans, active participants. This is a good thing, and should be encouraged. However, like all fun activities, it needs to be taken with the appropriate perspective.

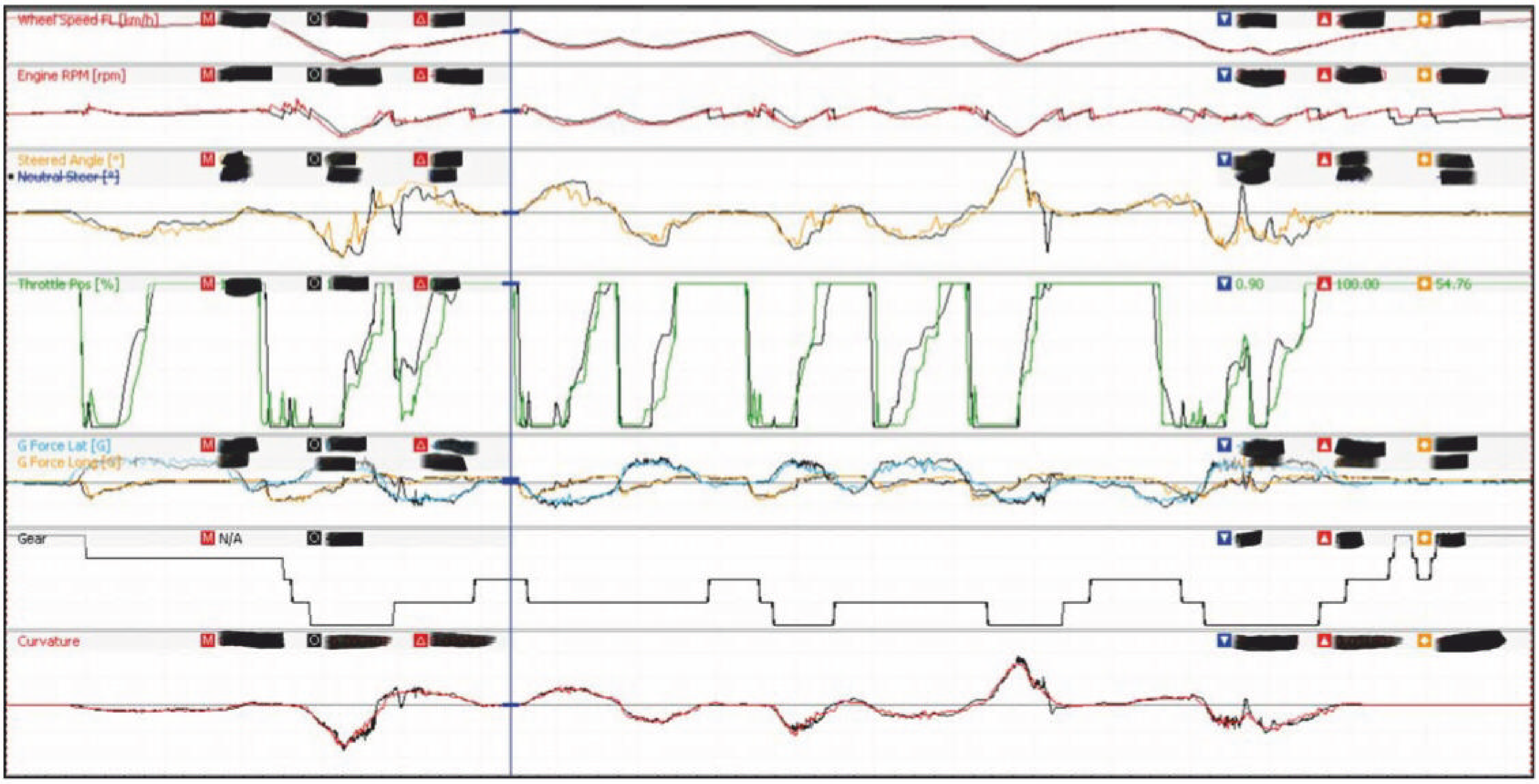
Innate ability

The other thing to comment on is that sim racing will not be for everyone. In order to use it properly, you need to have the ability to translate the visual cues into what the car is doing without the physical cues. If you have grown up with sim racing, or radio-controlled cars and aeroplanes, or just have that innate ability, sim racing needs to be on your radar if you aspire to be a racecar driver. If not, you might as well not even bother.

In closing, while sim racing is undoubtedly fun, it is no replacement for actual racing. The graphics quality and connectivity are testament to the good work done by the game companies, but it would be wise not to let that seduce you into a false sense of reality. Sim racing can represent a particular set-up well, and has a valuable role to play in driver training, the physics models of these games are its Achilles heel. We saw this with the driver feedback quotes, and the cottage industry that emerged to modify the physics definition files to get representative performance. Keep that in mind and you can enjoy sim racing for what it is. But to extend it beyond this is a disservice to both sim racing and actual racing.

Having access to actual race data is essential for developing a battle-ready Driver In Loop simulation package

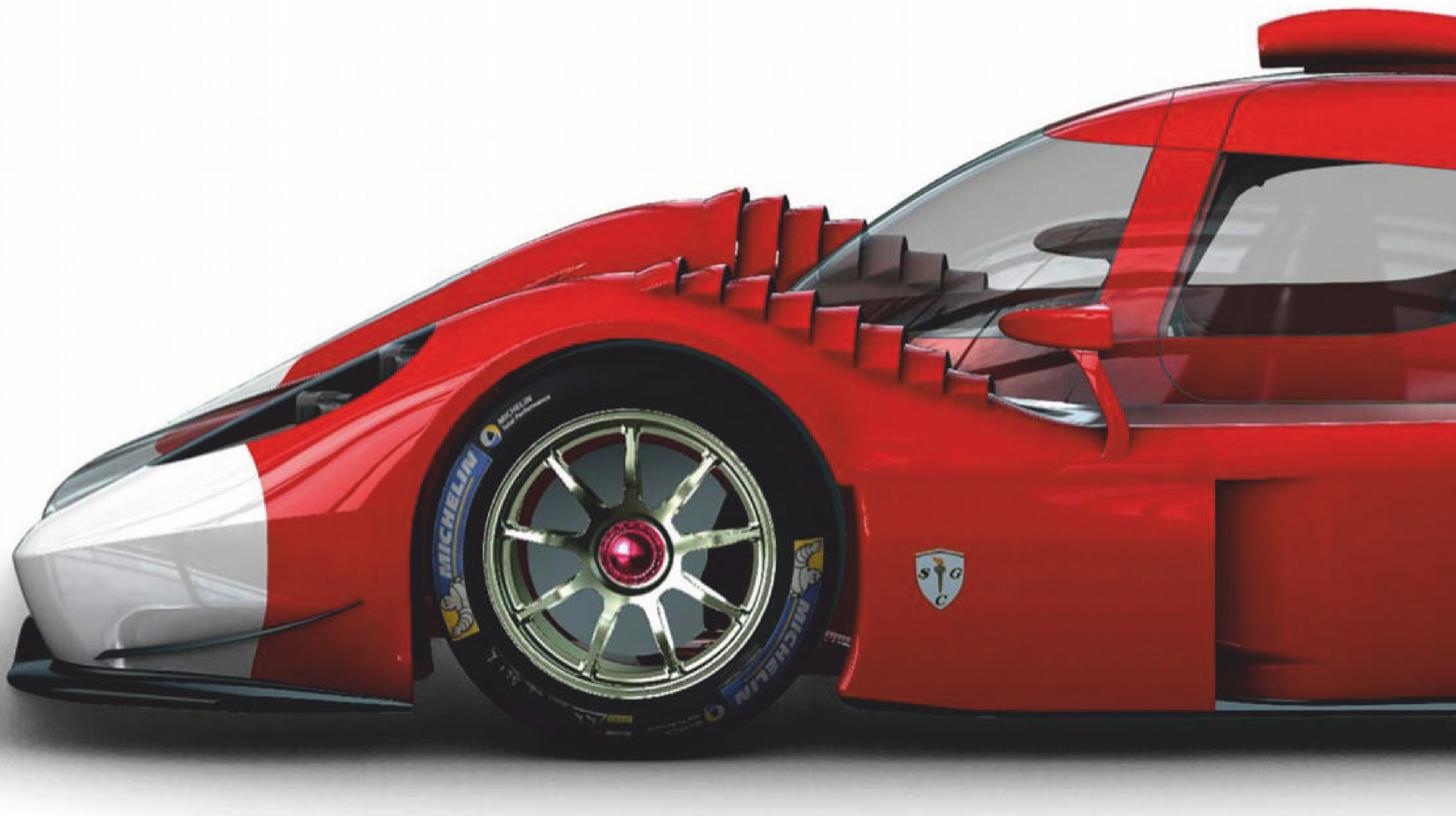
Figure 3: Actual (coloured) vs ChassisSim DIL (black) data for a V8 Supercar



Sales pitch

The Glickenhaus 007C Hypercar has not yet been developed, but the American has a customer for his project and two versions of the now V8-powered car will be on the grid at Le Mans

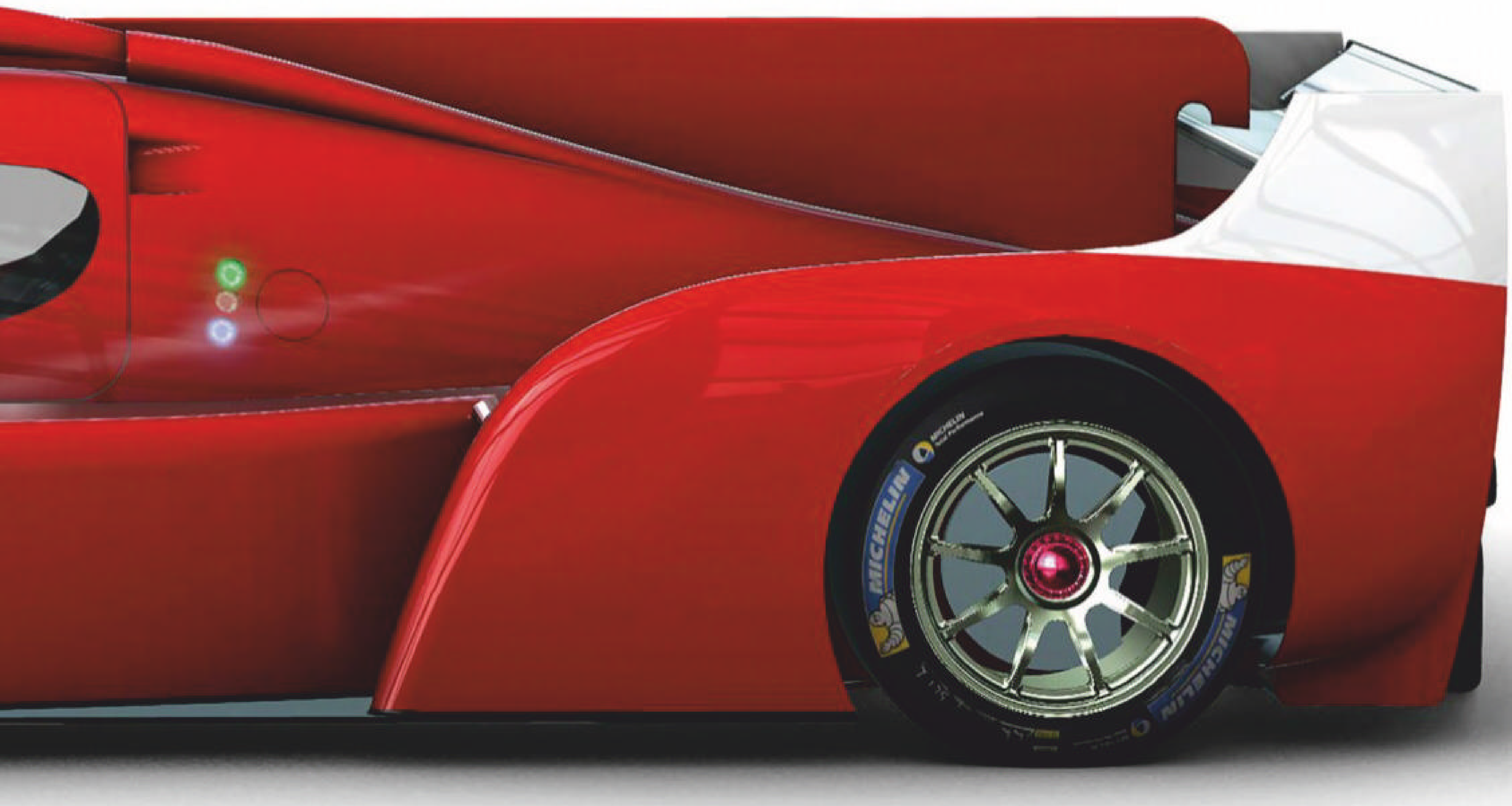
By ANDREW COTTON



We can win Le Mans. I am not saying we will, but we can

Jim Glickenhaus

Digital renderings of the proposed coupé look promising, and Glickenhaus insists the project is a lot further down the line than just a rendering. Chassis engineering is complete, the aero programme has started and the V8 engine is ready for dyno testing



Two Glickenhaus 007C LMP-Hypercars will line up on the grid for the Le Mans 24 hours in 2021 after the US team completed the sale of a chassis to a customer, and recently confirmed it was in negotiation to sell a third chassis in time for the big race next year.

The identity of the customer team has yet to be revealed, but a press release issued early in June confirmed there would be a two-car factory team at Sebring, Spa and Le Mans.

Jim Glickenhaus, who has driven his company's name forward in racing circles in GT3 racing (see *Racecar Engineering* V30N6) announced in 2018 he would prepare a Hypercar for the new generation Le Mans rules, originally due this year, but which have been delayed until March 2021.

The unexpected delay to the regulations actually suited the Glickenhaus team, which was always unlikely to be ready before the first race of the season at Silverstone, originally planned for September this year.

According to a company press release, the engineering of the chassis is now complete, the wind tunnel testing programme has started and the team has "already met several of our engineering targets." Similarly, the engine from Pipo Moteurs in France is said to be almost ready for its first dyno tests.

Clear goal

The opportunity to go to Le Mans and win it overall was too tempting for Glickenhaus to pass up, and in 2018 the team announced it would build a Hypercar to attempt just that. Yet when it announced it was going up against Toyota and, at the time Aston Martin, many wrote it off as a dream that would never deliver. The computer renders that were released of an outstandingly pretty car didn't help. He would simply not have the budget to race against a factory programme.

It was easy to reach this conclusion. In the past, privateers have deserted the top class of the WEC as budgets ran out of control. Under existing LMP1 regulations, it takes more than €10 million (approx. £8.96m / US$11.37m) to compete with a two-car team for a privateer and, with no chance of victory in a straight fight against the manufacturer teams, Dragonspeed, SMP and Rebellion have all either focused on other series or announced their impending withdrawal.

The Hypercar regulations looked set to put those figures into the shade as budgets of more than €30 million (approx. £26.9m / US$34.1m) were discussed at the first presentation to US manufacturers at Sebring. Against this backdrop, Glickenhaus has stepped up to the plate with a clear goal in

We are going to build, design, engineer and race for about $12 million. That's our real budget

Glickenhaus is not happy with the way the ACO and FIA have acted, changing regulations to suit Aston Martin, but is now more determined than ever to succeed

Young guns

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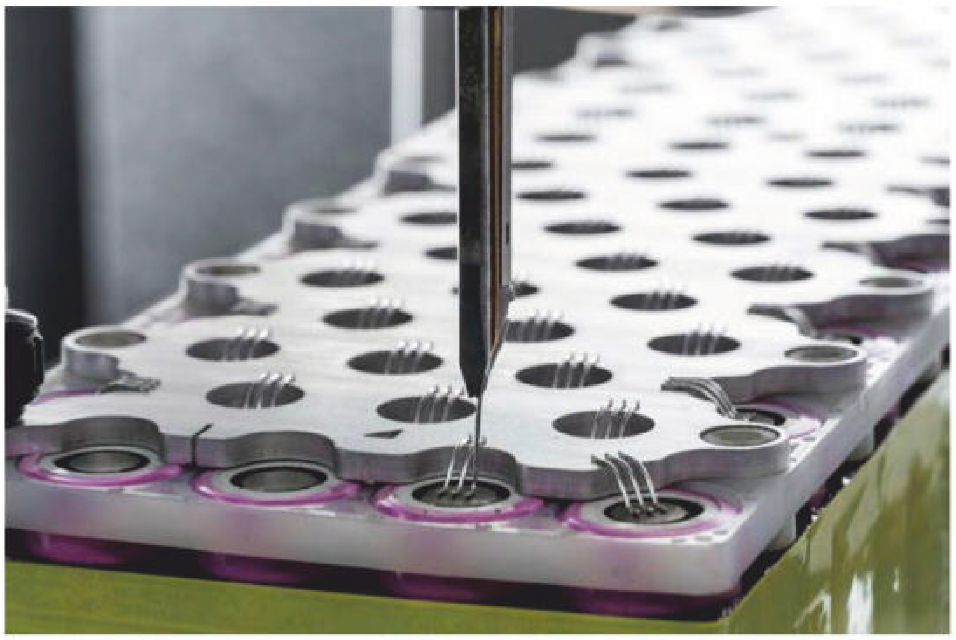

Battery module assembly – detail of ultrasonic wire bonder in action

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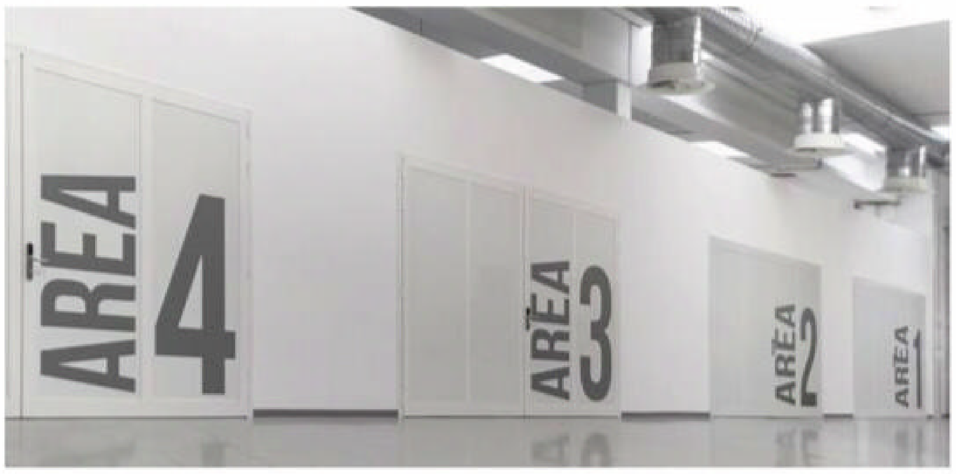

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The new Glickenhaus 004C, developed and built by Podium for SCG, during its first shakedown

A rendering of the Glickenhaus 007C, the new Le Mans Hypercar under development at Podium for SCG

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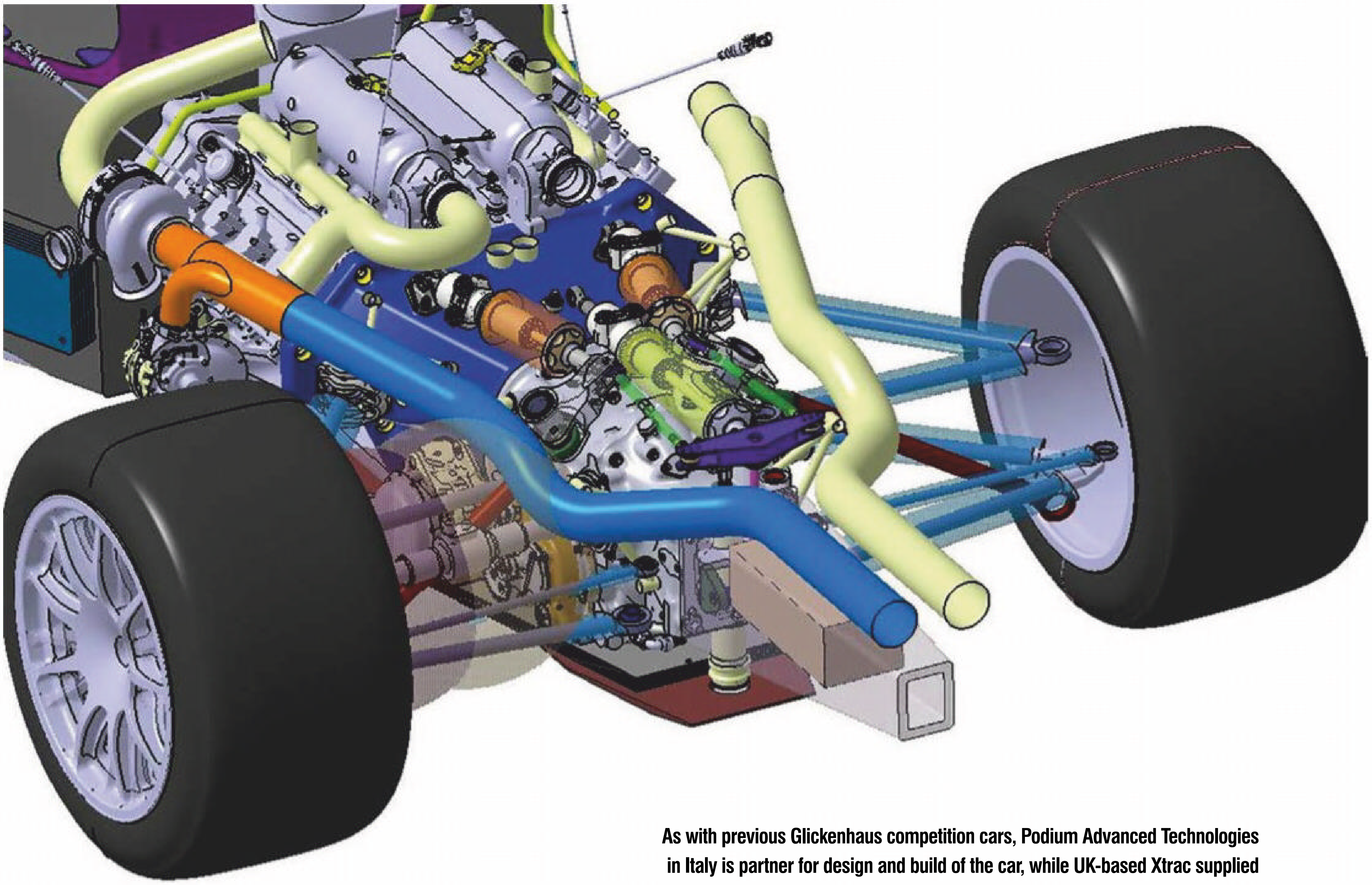

As with previous Glickenhaus competition cars, Podium Advanced Technologies in Italy is partner for design and build of the car, while UK-based Xtrac supplied the gearbox and the engine is being developed by Pipo Moteurs in France

mind – to compete for endurance racing's biggest prize, and has a plan that will not break the bank.

'The first price quoted to do a Le Mans Hypercar, and I don't know where it came from, was going to be 30 million euros,' says Glickenhaus. 'We are going to build, design, engineer and race for about $12 million. That's our real budget.

'When the guys in IMSA claim their cost is going to be 15m dollars to design and race, well, that number is higher than 12. One of those numbers is real because we are building the car. And we have sold a second car to a customer who is now joining us for the racing so we would have a two-car team, and we are seriously talking to a third customer. We may have a three-car team.

'If we have a two or three-car team, our costs go down because we will share those costs equally. We don't look at this as a profit centre, that's a joke. We race because we love racing, and our fans and the people who buy our cars love the fact that we race, so it also serves as our advertising.'

Moving target

The development phase of the SCG 007C Hypercar has not been cheap. Like Toyota, Glickenhaus has had to change his plans multiple times as the ACO and FIA have failed to finalise its regulations. His original target horsepower of around 650bhp was based on the first set of regulations and involved Alfa Romeo's six-cylinder development of the Ferrari 488 engine. But when Aston Martin insisted on a huge increase in power to more than 800bhp, that plan was abandoned and a new engine partner sought.

At the end of April this year, the Scuderia announced it had partnered with French engine specialist, Pipo Moteurs, and would create a twin-turbo V8 out of two straight-four engines, each capable of producing more than 600bhp. The 840bhp target looked plausible, but then new regulations that will be confirmed by the ACO in September point to a lower target driven by the IMSA manufacturers of less than 650bhp.

'Under the original regulations, we could use that engine and a hybrid and get to a level that the rules allowed, so we went down that road,' says Glickenhaus. 'Then Aston Martin frankly screwed the pitch. They said they wanted to race the Valkyrie, which is not set up to be a Le Mans Hypercar, but they could have made a version that was. Their engine was a V12, and they could not get down to a low weight. They said to the ACO they would only show up if they raised the weight, and to do that they also had to raise the total horsepower. Both Toyota and us said tough, we have spent this money to go down this road and you now want us to change? But the ACO wanted Aston Martin so we reluctantly agreed and were forced to go look for a more powerful race-bred engine.

'Then Aston Martin announced they were pulling out. And what really pissed me off was they half-assed blamed it on IMSA, saying they had a less expensive way of going. Once again the rules flipped. We were now on the Aston Martin rules, which Toyota was not happy about because they had started with a durable four-cylinder motor and a beautiful hybrid. Reaching that 840bhp combined was a stretch with that combination, but they sucked it up and said they would do it.'

Aston Martin frankly screwed the pitch

Powered by passion

Glickenhaus had an approach from British company AER, which currently develops the four-cylinder, 2.0-litre engine for Mazda's DPi car, and had its best ever finish at Le Mans in 2019 with third place overall with the Russian SMP team powering a Dallara chassis.


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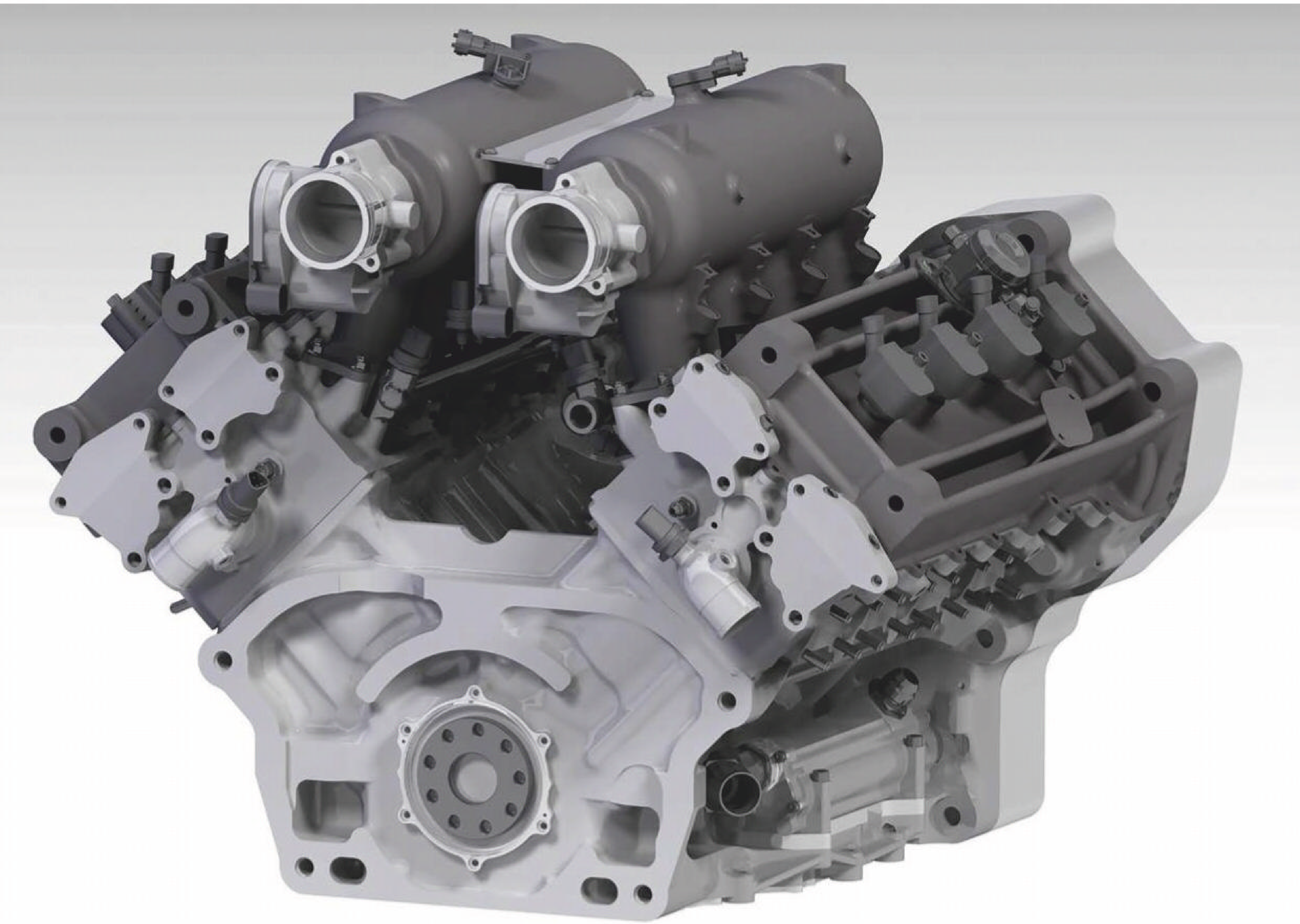


Pipo Moteurs-developed 3.8-litre V8 is two straight four engines, each capable of over 600bhp, on a common block. Target was 840bhp, but that changed post agreement

'AER made a proposal to us, and then we were contacted by Fred Pipo, who said he loved what we were doing and that his dream was to go to Le Mans and try to win,' says Glickenhaus. 'The AER proposal was good, but it was more expensive and, quite honestly, I personally felt Fred had the same passion I did. A V8, which is still incredibly compact, is probably a safer bet at very high horsepower.

'A twin-turbo V6 that can put out 840bhp for 30 hours in endurance is a real stretch,' continues the American. 'Fred's idea was to take two straight-line fours and a common block. He was already running his fours at over 600bhp on the dyno, so two of them could probably do 840bhp for the 30 hours needed. More importantly, we reduced the displacement slightly to a 3.8-litre engine, with approximately 6,000rpm.'

Glickenhaus has partnered with Xtrac for the gearbox assembly, and with Podium Advanced Technologies for the design and build of the car. This is the Italian company with which he developed the 003C and 004C. There are a lot of people out there thinking Glickenhaus is making a Hypercar and it will be a joke. Toyota is laughing, but we will see,' says the indomitable American. 'We can win Le Mans. With a one-car or two-car team it is hard – you can get hit and you can have a failure – but if we have any luck, we can win Le Mans. I am not saying we will, but we can. Our car is not a joke.'

A V8, which is still incredibly compact, is probably a safer bet at very high horsepower

The likelihood is the LMDh cars will dominate grid numbers in IMSA and the WEC, with manufacturer budgets far lower than the FIA's Hypercar dream, but Glickenhaus wants to race his Hypercar in IMSA's high-profile races, including Daytona, Sebring, the Petit Le Mans and at Watkins Glen, as well as the WEC's Le Mans 24 Hours. The only thing I find amusing is when they try to BoP our car to an LMDh. Good luck to them! The LMP2 cars are faster than the LMDh. That hybrid unit will be a total joke. You cannot use it in the rain, you cannot use it below 120km/h!'

The car will now make its competition debut at Sebring in March 2021. The 007C has a scheduled roll-out date of January 1 2021 and, despite delays in production brought about by recent factory shut downs in the midst of the pandemic, Glickenhaus still believes that to be possible.

Whether or not this fascinating team can take the fight to Toyota will be seen on the tracks next year.

The Mezger effect

Porsche's legendary engine designer died in June at the age of 90, but leaves behind a wonderful legacy both on the road and track

By ANDREW COTTON

Hans Mezger (1929-2020) dedicated his life to Porsche, and the company owes much of its renown to the engines designed by him

Shortly before the 50th anniversary of Porsche's first win at Le Mans, the German company reported the death of Hans Mezger, the man who designed the engine for that Porsche 917, and who was instrumental in the development of many significant Porsche racing and road car engines. Mezger was also responsible for the engine that powers what's commonly known as the Porsche 911, and was so highly regarded that those are known today as the Mezger engines.

Hans Mezger was born on November 18, 1929 in Ottmarsheim, a small village near Ludwigsburg on the outskirts of Stuttgart. At the age of 15, just three weeks before the end of the war, he escaped being enlisted into the German army by a stroke of luck and a faked medical certificate from a German commander. A year later, while continuing his grammar school studies, he attended his first race at Hockenheim.

Having taken his A-levels in Ludwigsburg, Mezger decided to study mechanical engineering at the Technical University, now the University of Stuttgart. However, at this time the German universities were very crowded because the young men who had returned from the war were given preferential treatment for admission.

'I wanted to join Porsche because the Type 356 sports car inspired me'

When he reached the required age, he used the university requirement for a 12-month internship to gain valuable experience in machining, welding and model making, and spent a few weeks in the grey cast iron and aluminium foundry.

'At that time I was riding a motor scooter, an NSU Lambretta,' he recalled in an interview. 'I rode the Lambretta until 1960, when I bought my first car, an old and quite worn out [Porsche] 356… It was not until years later that I came into contact with motorised two-wheelers again, when in the late 1970s it became necessary to develop new motorcycle engines for Harley-Davidson.'

After graduating in 1956 at the time of the German economic miracle, there was a veritable flood of job offers. 'There were 28, but Porsche was not among them,' he said. 'I wanted to join Porsche because the Type 356 sports car inspired me. So I applied, got an interview, and the company offered me a job in diesel engine development. Until then, I didn't even know Porsche had such a thing.

'But I envisioned working on sports cars. They showed understanding and that's how I went on to start in the calculations department at Porsche.'

Mezger remained committed to Porsche for his entire working life and, in the latter stages of his distinguished career with the manufacturer, was working for technical director Hans Tomala, and Ferdinand Piëch.

Coming on cam

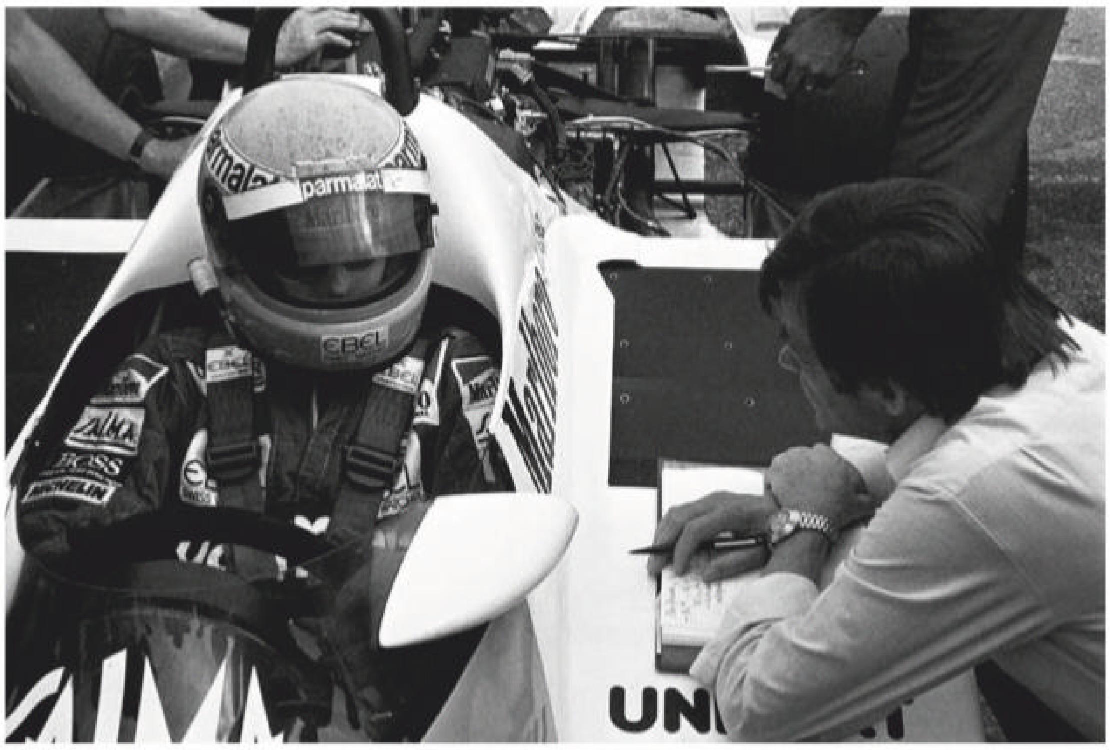
In those early days, though, Mezger was put to work honing the Type 547 four-cam engine, developing a programme for calculating cam profiles. He was involved with the development of the 1.5-litre, eight-cylinder 753 Formula 1 engine that debuted at the Dutch Grand Prix in 1962, and was then switched to the 901 engine, designed by Franz Reimspeiss. This was an engine which needed work. Mezger adapted it to dry sump lubrication, which lowered its overall height, and chose chain drive for the dual overhead camshafts, believing that the toothed belts might not be sufficiently robust.

'On this Formula 1 project I learned a lot about the design of combustion chambers,' he said. 'This also directly benefited the design of the six-cylinder boxer engine for the later 901 / 911.'

The Porsche 901 was announced in 1963 with a 2.0-litre, air-cooled engine developing 130bhp, and eventually evolved into arguably the ultimate road car, the 4.0-litre Type 997 GT3 RS, which develops just shy of 500bhp, an almost unimaginable 125 bhp per litre from a naturally aspirated engine.

Mezger's work continued on the racing side of the company, too. Together with his colleague, Valentin Schaeffer, he worked hard on the turbocharging system and, following the successes of the Can-Am cars, Porsche introduced the 911 Turbo (Type 930) model in 1975, which opened a new chapter for 911 enthusiasts. Of course, turbocharging went on to become the norm for all major classic race winners.

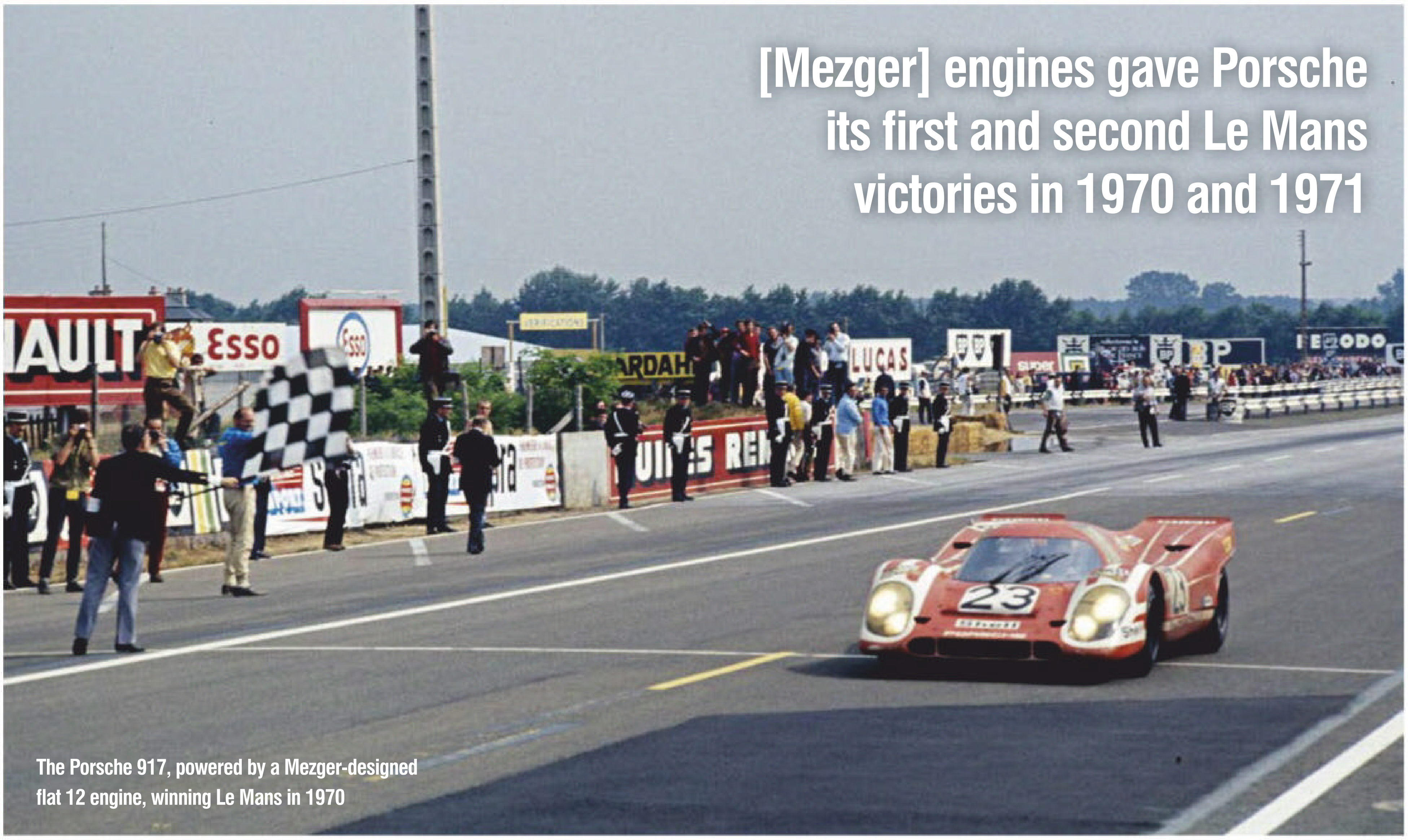
Versions of this engine powering the 935 and 936 race cars won the Le Mans 24 hours four times, and further developments with water-cooled heads and four valves per cylinder powered the 956 and 962 Group C cars that won Le Mans six times in succession, 1982-1987, and again in 1994.



Niki Lauda won two World Championship drivers' titles in 1984 and 1985 powered by Mezger-designed Porsche engines. Team-mate Alain Prost followed in 1986. McLaren won two Constructors' titles

The engine drawing room: Mezger (left) and Valentin Schaeffer (right)

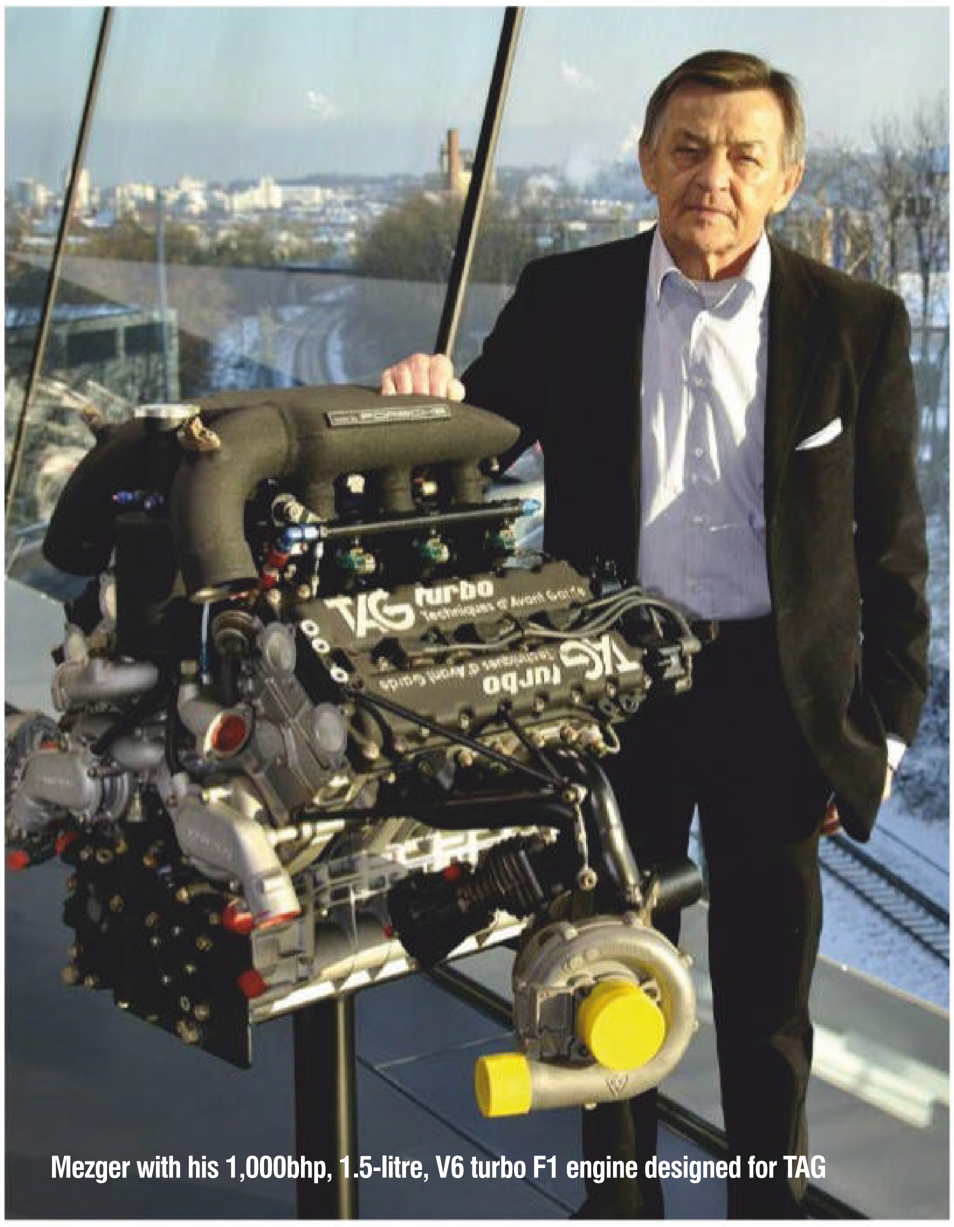
There were 28 [job offers], but Porsche was not among them



[Mezger] engines gave Porsche its first and second Le Mans victories in 1970 and 1971

The Porsche 917, powered by a Mezger-designed flat 12 engine, winning Le Mans in 1970

His most enduring legacy is the glorious engines that powered both road and race 911s from 1963 until the 991 GT3 ran a new design in 2016



Mezger with his 1,000bhp, 1.5-litre, V6 turbo F1 engine designed for TAG

The pinnacle of Mezger's creations, however, were his specialised race engines. First, the 12-cylinder 917 engine, essentially two flat sixes in tandem with the drive to the gearbox taken from the centre of the crankshaft, so eliminating the risk of whip from an over-long crank. These engines gave Porsche its first and second Le Mans victories in 1970 and 1971, followed by two triumphant years in the Can-Am series with turbocharged induction, where power output reached 1,200bhp in the 917/30 in qualifying trim.

Creative mastermind

And yet, Mezger said his favourite engine was that designed for TAG, the Arab backers of the McLaren F1 team. Ron Dennis and his McLaren racing team set out in search of a powerful turbo engine for Formula 1 in 1981. Porsche was chosen and the decision was made to design and build a completely new engine, as well as to provide on-site support during the races.

Mezger was the creative mastermind behind the resultant 1.5-litre V6, with an 80-degree bank angle, which would go on produce over 1,000bhp.

In 1984, Niki Lauda became World Champion with it, and did so again in 1985, followed in 1986 by Alain Prost. The TAG Turbo won a total of 25 races, plus two Constructors' World Championships in 1984 and 1985.

Mezger also designed the Type 2708 Indy engine for Porsche, and the Formula 1 engine that raced in 1990.

However, his most enduring legacy is the glorious engines that powered both road and race 911s from the model's inception until the 991 ran a new design in 2016. The new GT3 car, which debuted at Daytona that year, was homologated with a new engine design after the decision had finally been taken to drop the Mezger engines from the production line.

Hans Mezger 1929-2020

Advanced Engineering leads the industry charge into 2021

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The UK's largest annual gathering of engineering professionals will return to the NEC, Birmingham on November 4 and 5, 2020 for the Advanced Engineering Show. Here, the UK's talented and vast industry can come together again to begin generating business for the new year after a challenging start to 2020.

Bringing together thousands of attendees, Advanced Engineering incorporates all aspects of engineering from design, test and measurement to inspection, materials and production within the aerospace, automotive, marine, medical and many more industry sectors.

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Advanced Engineering offers a great opportunity to meet suppliers, partners and generate business leads for the first time in several months. It's clear that the engineering industry is keen to showcase its innovations before the year ends, with new exhibitors still registering at an impressive pace.

'With the current situation restricting how companies do business, we're looking forward to maximising our time at Advanced Engineering as our chance to set ourselves up for a successful 2021,' commented Jonathan Archer, General Manager, Renishaw UK Sales Ltd.

The show offers a diverse range of exhibitors the opportunity to showcase their expertise to a primed audience of motivated and ready-to-buy attendees, interested in sourcing products and solutions. It's more important than ever to hit the ground running in 2021. Advanced Engineering's exhibitors will have the opportunity to pre-load their business pipelines right from the start of the year. However, as valuable as it is to attend the show, it is not just during the show that exhibitors have the chance to increase their brand awareness.

Every exhibitor package includes access to Advanced Engineering's extensive marketing tools to increase exposure pre, during and post event. Especially now, it's important for exhibitors to feel confident that they can reach their target audience in the lead up to the event itself. For this reason, Advanced Engineering exhibitors will have access to additional marketing tools free of charge, from the moment they register, to the day of the show and beyond. This ranges from personalised postcard invites for exhibitors to send to clients or to attach to printed communications, to personalised banners and unique links to track who has registered to visit a specific stand at the show.

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In these unprecedented times, it's important for the engineering industry to look to the future and continue to market themselves to ensure success following the COVID-19 crisis. Whether you've exhibited at Advanced Engineering before, or if you think the show could be the perfect place for you to forge new relationships and build on existing ones, get in touch with our team to discuss our exhibition options.

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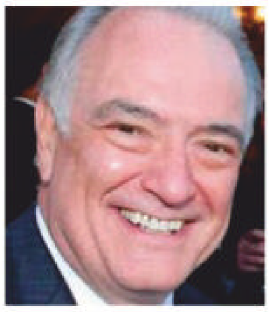

So, what's next?

There's light at the end of the tunnel for the business of motorsport

What's next is a good question, as every changing week feels like a lifetime at present. Plenty of challenges lie ahead, but at last light is emerging. Motorsport Valley's rate of recovery will follow decisions of UK government so, although I primarily focus on UK industry here, there are parallels across Europe.

While accepting their first priority must be the health of their population, national governments have never had such direct, immediate influence on demand and supply to all motorsport businesses.

Initially, the MIA's most urgent work was to lobby and influence government decisions affecting lockdown, as these will be pivotal to next year's business performance. We influenced the Job Retention Scheme becoming more flexible, and encouraged business loans.

Most UK companies severely cut activities, or even temporarily closed. There was some ongoing business in high-performance automotive brands, health and defence, but very little in motorsport.

After three months lockdown we, along with others, successfully lobbied for the return of motorsport as the UK moves into its 'restore and re-grow' phase. Fans will now enjoy eight F1 races in July and August, and 12 BTCC races in August alone. And it's good to see the UK hosting two F1 races this season, one being the 70th Anniversary Grand Prix at Silverstone, its birthplace.

By relying on TV income and contracts, other motorsport series will also re-start, but without live audiences. Teams may lose a few sponsors, but most will choose to remain.

Track Days have re-commenced with strong bookings, and amateur racing will return soon, but for all these activities venues have to meet the expense of constraints and regulations to keep everyone safe from the virus.

Act responsibly

When it comes to public gatherings and safety, the business of a motorsport event is similar to that of a shopping centre, where crowds move freely around. As I expect such centres to open soon by satisfying safety and social distancing rules, so motorsport venues prepare to do the same. They will cater for smaller audiences but, if people behave responsibly, motorsport will grow again and, crucially, industry revenues will rise.

All this on-track activity brings very welcome business for the motorsport supply chain during the remaining, much-compressed, half-year calendar of 2020. End-of-year revenues for the supply chain and most teams will probably fall by some 50 per cent or more overall in 2020. Most spending will be adjusted to focus on a full 2021 season instead, and the critical production cycle will start very soon this year.

Racing is back on track, with a hectic schedule ahead for series such as the British Touring Car Championship that returns to racing in July

Budgets for this season will be even more tightly controlled than normal, unfortunately just as suppliers face extremely difficult cash shortages as a result of lockdown. Cash availability has never been so vital, so all are doing everything possible to use this resource carefully. Meanwhile, government continues to cautiously control much of the demand and supply whilst the virus remains a threat.

Many companies will regrettably be forced to take on more debt, some through generous government schemes, but all of that borrowed money will have to be repaid sometime. A measure of how much UK government can influence businesses during these unprecedented times is the suspension of the UK's 'wrongful trading' law. This move aims to reduce insolvencies at a time when businesses can no longer control their revenues and outgoings in a satisfactory manner.

As a result, businesses can now access loans without directors being held liable for wrongful trading. An unusual, perhaps inevitable, decision of government as they need loans to be available to businesses to keep the economy moving. Whether this results in increases in 'bad debt' in the future, only time will tell.

Slowly, production is returning, contracts that have been temporarily halted will be re-instated and earlier business interest re-started.

Switching focus

The MIA will now switch focus to help direct members towards the increase in government R&D funding for development work, particularly for automotive, marine and alternative sector activity.

In six months the UK will leave the EU, with or without mutually reasonable trade arrangements – hopefully the former. In the meantime, the MIA has secured government funding to help motorsport businesses re-engage with their primary export markets, Europe and the USA.

Don't waste time trying to deliver a reliable forecast as these rely on specific figures as their baseline and a clear start and end date. However, it's the right time to focus on exploring and preparing a variety of options and possible scenarios covering all eventualities. Then be ready to move quickly in whichever direction when a particular option becomes, obviously, the right one to take.

Whichever route that is, all companies must preserve cash wherever possible, but be ready to move fast and with agility. Motorsport businesses know how to act fast, as was demonstrated by their response to help manufacture PPE equipment recently.

Looking forward, we can see business opportunities. Governments will press forward on their energy efficient, green agendas. The sport will face a re-alignment and reduction of OEM funding as they themselves focus on hybrid, electric or even hydrogen power sources. Learning from the success of Formula E, the sport will be asked to help OEMs promote their own versions of these green solutions, and more.

So guard your cash carefully, aim to start next year with some left in the bank and you'll already be ahead of many of your competitors. What a year so far. Who knows what's next?

Preserve cash wherever possible, but be ready to move fast and with agility

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Back to life

With motor racing taking its first steps back to normality, what will the 'new normal' bring?

Motor racing teams and suppliers are able to celebrate the return to motor racing in June and July as lockdown restrictions are eased and life starts to return to a new kind of normal. As large crowds are not permitted anywhere at present, organisations have been stretched to come up with new and innovative ways of maintaining social distancing, while fans and media are, at time of writing, not invited to watch the majority of races on site.

Right now, it's hard to imagine how any form of motorsport will get back to that stage. Yet motor racing is an innovative and fast-moving sport, one that can adapt to adversity and, as one industry leader put it, one that recovered quickly following the attacks on the World Trade Centre in 2001, and again from the financial crash of 2008. There is no reason to assume it will be any different recovering from this Covid-19 pandemic.

There have been challenges few would expect, and it is clear that understanding is still a long way from being perfect. The GT World Challenge gets underway in July in Italy, where they had an unusual obstacle to overcome. Between driver changes, the local authority wanted a complete clean of the cockpit to prevent transmission of the disease, leading to potentially 15-minute pit stops. Given the drivers probably share space on the truck to get changed, eat together in the same restaurant and likely share transport to and from the track, this was quickly dropped, but it highlights the caution even local government has to be seen to be taking.

We have now grown used to the new use of the term 'bubbles'

Controlled media

We have now grown used to the new use of the term 'bubbles', and understand the implication of them. F1 will create a larger bubble that, at time of writing, includes some select media, but who will be on the list?

It's a worrying time as other companies push hard for unpopular changes, using a crisis as an excuse, and I worry that some organisations will try and instigate controlled media. Long have manufacturers and organisations pushed for stories to be approved before publication, some already make it a condition of allowing an interview to proceed, but that's just another level of control.

Limiting the media on-event I hope is only a short-term solution to what will be a long-term problem.

More positively, the ability of motor racing companies to adapt to online working has been a success. As one put it, if they looked to introduce remote working it would have taken six months to plan and still would have been difficult. The pandemic pushed them to do it in three days and it works perfectly. How many times have races been decided on such short notice and decision making?

Critical time

It's encouraging that many manufacturers and suppliers report they are busy, too. Naturally, those with a more diverse portfolio stand a better chance of survival, but for those who rely on racing this is a critical time. No one is pretending the virus has gone never to return, but seeing at least some race series back on track is a welcome relief. So what will the future look like from here?

For national racing series, or international series based in one country, the task is easier. That explains NASCAR, IMSA and IndyCar able to return in short order. DTM has also started strongly.

But international races are more complex. No one is able to plan with certainty which borders can be crossed, where is best to leave trucks between races. No one can say when suppliers (and media) will have garage access. I suspect endurance racing teams will take this opportunity to push for a permanent reduction in people with access to their garage!

Virtual analysis of data is a given, and suppliers have been working hard to reduce the number of people travelling. Okay, so travel is a drop in the ocean in terms of a team's overall budget, but a reduced number of people in the paddock will be a plus for any team.

Well, any team other than those hiring out their mechanics. That business model is going to suffer if teams have to create, and stick to, individual bubbles.

As this is written, the British government has a 14-day quarantine policy in place for anyone coming into the UK, which makes international travel and racing challenging. F1 got around the regulations, and there are so many exemptions I wonder how effective this measure will be.

For now, I hope the number of cases continues to fall, restrictions continue to be lifted and that people continue to find new, more efficient and safer ways of working.

ANDREW COTTON Editor