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F1 returned to Imola after last year's race was cancelled and the RB squad took its fourth points finish to continue a solid start in the championship's tight midfield scrap

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Slow burn

Why patience is needed to enjoy the innovation in Formula 1

I'm not yet ready to admit how long it had been since attending my last Formula 1 race, but my visit to the Emilia Romagna Grand Prix in May was the first in a while. My background is in sportscars, so I'm more used to multi-class racing over six hours than a two-hour blast around Imola on a one-stop strategy.

The F1 race I chose to return to was not a classic. Once Red Bull's Max Verstappen fended off McLaren's Lando Norris into Tamburello, the finishing order was set (cueing resigned reactions of, 'Well, that's it then' from some experienced press room colleagues).

Only Norris' inroads on the world champion in the closing stages injected some life into the contest, giving shades of Michael Schumacher's desperate and unsuccessful pursuit of Fernando Alonso at Imola in 2005.

Wider view

Although this year's race was otherwise a dull affair, if you take a wider view, Norris coming to within a second of Verstappen was emblematic of what also makes F1 so interesting.

On F1's last visit to the same track in 2022, Verstappen cleared off into the sunset, finishing 16 seconds ahead of his teammate and 34 seconds beyond Norris in third. McLaren's development path since has enabled it to eat into that deficit and finally make Red Bull at least feel uncomfortable.

The Woking team rolled out a suite of upgrades in Miami, including a new front wing and engine cover, new front suspension geometry, a heavily revised floor, updated sidepod inlet and modified front brake duct. After Norris won his first GP in Florida, McLaren took that upgrade package to Imola where it also worked well.

The point is, in Formula 1, teams have the freedom to control their own destiny through technical upgrades, more so than many other motorsport categories.

Before reaching Imola, I visited RB's headquarters in nearby Faenza, where Red Bull's sister team is working on an updated front wing and a floor concept it switched to late last year. It is also using AI to accelerate its decision making, helping to get parts out of the factory door quicker.

The floor change especially was a significant development that has played a big part in RB making its best start to a season under the current regulations, which began in 2022.

I like the concept of there being two interlinked races in F1. There is the visible one at the track, and another in the background where teams strive to make their processes more efficient and bring upgrades out quicker than their rivals. That just doesn't happen to the same extent in other forms of motor racing where parts are tightly controlled, and Balance of Performance is there to keep the large number of manufacturers invested.

In the LMH and LMDh sportscar platforms, the main area where teams can make significant gains on each other is software, which has emerged as a key battleground at Le Mans. This is because the regulations have specified performance windows into which all car designs must fit, and the BoP then does the rest to keep the racing close on track.

The way things are at the moment, if a Red Bull is in the lead, the race is almost invariably decided, but keen observers are hoping for a more exciting conclusion in 2025, the final year of the current rule set

Except for 'Evo' joker performance upgrades, of which five are permitted in a car's homologation lifespan, there isn't much technological movement.

Cynically, my favourite part of the LMH / LMDh regulations was when the platforms were in gestation and manufacturers were trying out design concepts, at times having ideas thwarted by rule changes. Things were moving all the time.

Now, the races are great but, technologically, it feels inert compared to F1. There is some innovation occurring in the background, but translating the sportscar software battle into something spectators notice in the track action is extremely difficult. Whereas with F1, it's clear to see how backroom developments influence the trends that play out in the races.

The main drawback of F1 is that it takes a long time for its regulations to produce the kind of exhilarating on-track product that is readily available in categories with less technological freedom, such as IndyCar, NASCAR and LMDh.

Endurance sport

Oddly, F1 has become more of an endurance spectacle than endurance racing. The last regulation set saw one manufacturer dominate from the outset. Then, as the rules evolved and other teams found solutions to their fundamental problems, they closed the gap.

What resulted was seven years of Mercedes dominance that ended with a fantastic, season-long challenge from Red Bull in 2021. Everyone is now hopeful something similar will occur next year in the final season of the current regs. McLaren's recent strides seem to suggest that could happen.

Even if some individual races fail to inspire, there is an enjoyable purity about F1 teams being given time to advance their car designs and climb through the order. Patience is required to appreciate it.

The main drawback of F1 is it takes a long time for its regulations to produce the kind of exhilarating on-track product that is readily available in [other] categories

Track changes

The FIA WEC has held three races so far this year on very different tracks. We look at how the performance has been balanced heading towards Le Mans

By PAUL TRUSWELL and ANDREW COTTON

There have been major changes this year in the FIA World Endurance Championship. Not all of them have been obvious, but each has been significant.

Series organisers the FIA and ACO have introduced a new Balance of Performance (BoP) system, in which they use their own analysis to create a table and then share that information with the manufacturers.

The fact they now don't tell the manufacturers the criteria they are using has caused some consternation among the teams, and increased pressure on the governing bodies to get it right.

One of the key talking points is the so-called two-stage BoP, which separates the top speed performance balancing from the low-speed measures.

The paddock was collectively worried about the Ferrari 499P, a car that seems to have good top speed. The homologation wind tunnel at Windshear can only measure up to 240km/h, due to the limitations of its rolling road, and Ferrari's top speed appears to improve disproportionally over 260km/h.

Despite that, the FIA and ACO have not used their two-stage BoP this season, and at Spa stated they were not even considering it for the next race at Le Mans. Instead, they will use last year's 24 Hours of Le Mans data to formulate a BoP table that will take into consideration the Ferrari's top speed.

Meanwhile, personnel changes have been taking place up and down the paddock. Engineers have moved from team to team, but the headline switch was Toyota's experienced technical director, Pascal Vasselon, leaving the Japanese team in January of this year and being replaced by Frenchman, David Floury.

One of the key talking points is the so-called two-stage BoP, which separates the top speed performance balancing from the low-speed measures

At the start of the 2024 WEC season, the talk of the paddock was the Ferrari 499P, which appeared to have very high top speed in races. This was taken into account by the FIA and ACO when formulating this year's Le Mans BoP table, using data from last year's edition

Vasselon is a gifted engineer, but also a strong politician. The team is now having to adapt to a new way of working under Floury, who was previously a chief designer for ORECA, but also worked with Toyota as a race engineer under Vasselon, with the clear message that he would one day replace his countryman. Few expected it to be this year, much less the sudden and dramatic exit before the season had even started.

Toyota

The Toyota GR010 Hybrid has taken several hits this year. In 2023 at Le Mans, the car's minimum weight was increased to the maximum 1040kg allowed by the FIA's crash testing regulations. The top brass in the company were livid. Fast forward to the first race of 2024, and the minimum weight was upped further, to 1090kg, though fortunately without the need to re-test the chassis for the higher weight.

That put a particular penalty on the car on full tanks at the opening race in Qatar. Qualifying was strong on empty tanks, but the cars did not demonstrate their usual pace during the race and appear to have lost their advantage of being able to nurse the tyres, particularly during the second stint.

Toyota has been trying all sorts during the year to reduce the impact of the weight, including starting one car in Qatar on a set of tyres that had already completed 18 laps in practice, the other on a set that had done 34 laps. Even Michelin was surprised but, as tyre management is key to success this year, Toyota chose to roll the dice.

Testing so far has focused on endurance, which has meant the team has not tested at the circuits on which it has raced so far this year. That bodes well for Le Mans, but it has hurt the car's set-up work in the opening rounds, two of which were on tracks new to the championship (Qatar and Imola).

Though it looks good on paper, Toyota's win at Imola was more a case of snatching victory after a tyre choice error from Ferrari. 'They were stronger everywhere, except strategy,' admitted Floury after the Italian race.

Cadillac

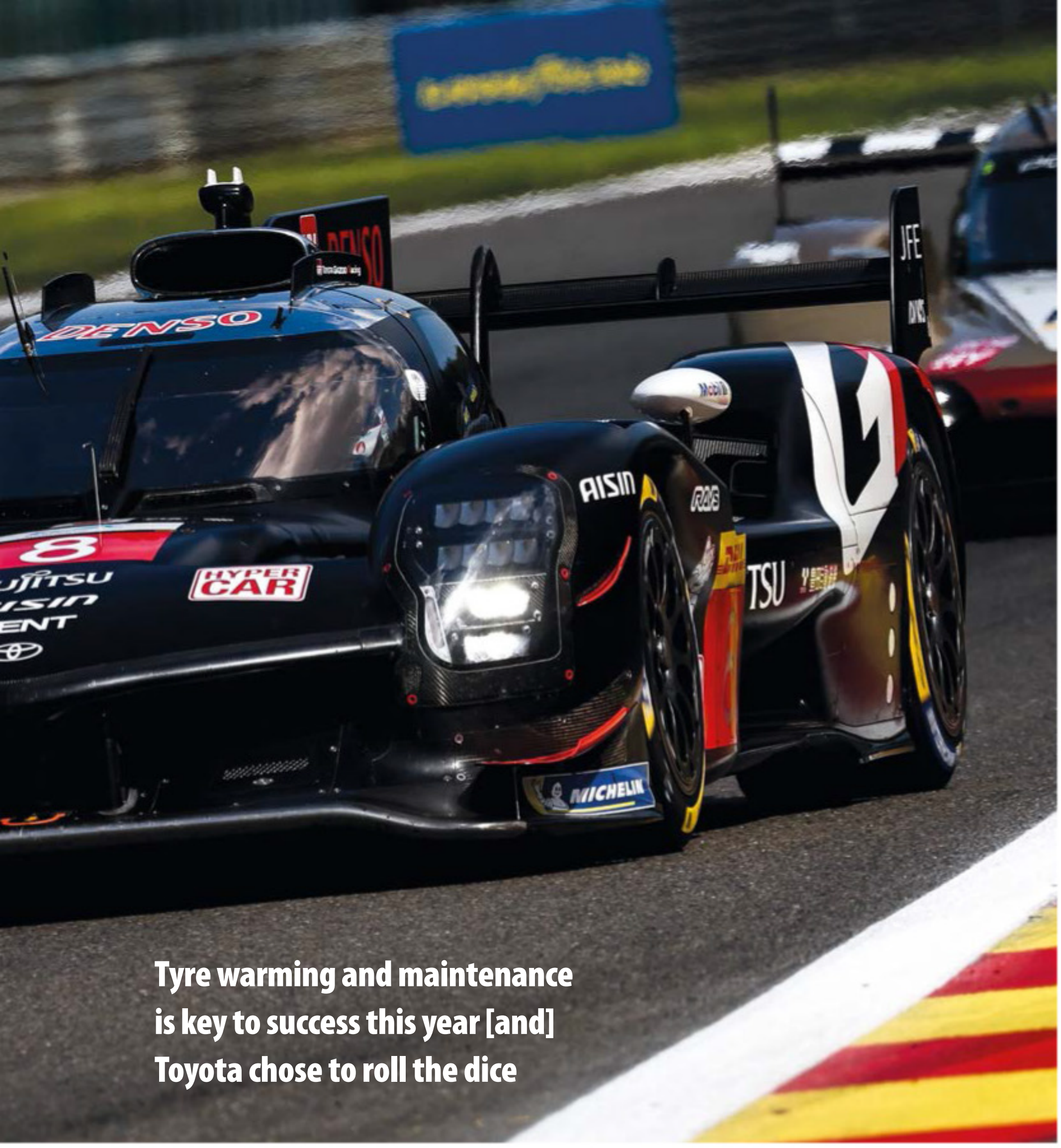
Chip Ganassi Racing and Cadillac announced in March that they will part ways after this season, and since then the rumour mill has been in overdrive trying to figure out who will work with Cadillac next season. Tests have been cancelled this year, and the car that raced in the first three events was the same chassis that crashed heavily at Spa in 2023. The bodywork was also the same as last year.

Rival teams have been watching the Cadillac performances closely, strongly believing the team is deliberately keeping its powder dry for the big race.

The team, meanwhile, believed it raced at Imola with a broken chassis, and wondered if

Hampered by the Le Mans BoP last year, Toyota came out all guns blazing in 2024 but its GR010 struggled to find its pace in the race, while the team experimented with unusual tyre strategies

After confirming its upcoming split with Chip Ganassi Racing, Cadillac has been running its 2023 car this season, though rivals think this approach could be a competitive ruse ahead of Le Mans



there had been an issue with the car during transport from the Qatar race. After a first-lap incident, the car was quick throughout the rest of the race, but then struggled to ride the bumps at Imola and handled horribly.

The team said at Spa that it set the car up to reduce the symptoms, but then in Belgium, Earl Bamber ensured there would have to be a new car for Le Mans anyway when he crashed heavily on the Kemmel Straight.

Peugeot

Peugeot brought its new, rear-winged, 9X8 Evo to the track for the first time at Imola in April. The aerodynamic addition endows the car with a totally different way of generating downforce, with a greater percentage of airflow over the body rather than under it and through the floor tunnels. The team says the set-up options are far wider than with the old car and increases its chance of getting it right… but also for getting it wrong.

The original, wingless 9X8 fitted into the performance balancing window in Qatar, and ran strongly. It clearly liked the smooth and low-degradation track surface and was on course for second place, only to run out of fuel on the penultimate lap.

The team and drivers have so far been hesitant to describe the new car, and have been upset by the BoP. After a weak showing in terms of pace at Imola, the car was given more weight and less power for Spa.

Peugeot's 9X8 Evo made its debut at Imola in April, but was off the pace and was then further upset by BoP penalties imposed for Spa. Nevertheless, the team remains confident it is a better car

New entrant, Lamborghini, is the only manufacturer in the series to choose the Ligier chassis and the team's engineers are on a steep learning curve with the SC63, but improving at every round

How much of the performance loss is down to team, car or BoP is impossible to tell, though we would expect it to perform better on the low-grip, low-degradation surface at Le Mans, where it was strong last year. It should be able to ride the bumps better but reliability is sure to be a concern.

New teams

More new manufacturers came into the WEC this year. Alpine brought its A424, an ORECA chassis with a 3.4-litre V6 Mecachrome engine developed from the Formula 2 unit. The car has shown early flashes of competitiveness, notably at Spa in May, where one of the cars made it through to 'Hyperpole', a sprint qualifying session in which teams receive a new set of soft tyres that are compulsory to use at the WEC races outside of Le Mans.

Lamborghini's SC63 is the only LMDh manufacturer to use the Ligier chassis, coupled with a new engine developed from an Autotecnica unit that the company had hoped would be used in F2. Lamborghini clearly has a lot to learn, notably around car set-up, and its engineers are working to develop a competitive baseline at every track.

One of the key areas of development for the SC63 is moving closer to the maximum allowed power curve allocated by the BoP. Clearly, teams want to operate as close to it as possible, but riding bumps, kerbs or even wheelspin can easily cause the power to exceed the curve. Getting the ride right is therefore a crucial step in the process, and the Iron Lynx team's engineers are learning more about what the car needs at every track, and then trying to turn that into performance.

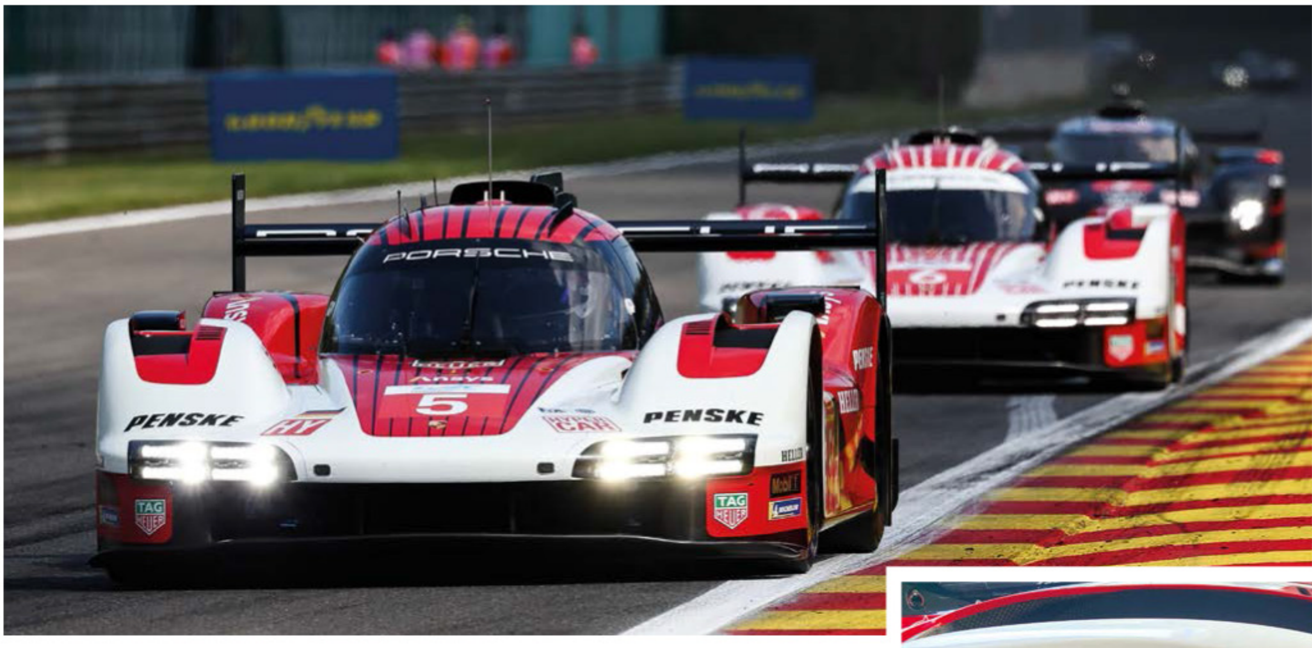
BMW has also joined the WEC party with the Belgian WRT team. Despite having a year of IMSA racing under its belt, BMW has faced a steep learning curve, and so far, its LMDh machines have not been competitive.

Learning how to manage the tyres to generate heat and then maintain them over a double stint and run close to the power curve, all the while learning the electronics, including power delivery and regeneration, is proving a major undertaking. Throwing a spanner in the works, as many as eight of WRT's test sessions were affected by rain.

Giant steps

Of the rest, Porsche Penske Motorsport and Ferrari AF Corse have both taken giant steps forward in terms of competitiveness. One of the main areas of improvement has come

The Alpine A424 uses the ORECA base chassis and a development of the F2 Mecachrome engine for endurance. The car had its most competitive outing at Spa and could spring a surprise this year



Porsche Penske Motorsport has made great gains this year, finding a seemingly novel way of introducing heat into its tyres from cold. The team says it is by not running a shield round the brakes (inset pic), but rivals remain sceptical

with tyre warm up out of the pits, which is key as the WEC doesn't allow tyre warmers. After particularly strong laps in Qatar and Imola, Porsche explained that it didn't have shielding around the brakes, and that heat from the pads and discs were the reason for their rapid warm up, but others have similar equipment yet don't have the same ability.

At the colder races, or on low-grip circuits, Porsche and Ferrari have both made huge gains in this area, despite tyre allocations being so low they have to double stint. Despite the quick warm up they don't seem to suffer the expected high degradation.

Porsche's customer teams have also been performing brilliantly, notably at Spa. There, the Proton Competition team put together a weekend of clean running, able to make the most of the practice sessions for the first time this season, and the result was a quick racecar. However, they were not able to turn that into a win. That came courtesy of JOTA, which received a leg up in the order when the red flag was shown, and duly capitalised on it.

Running low

The LMDh cars seem particularly sensitive to ride height changes; the lower the better, and this has been a major focus for Porsche on both sides of the Atlantic. While the customer teams have worked with chassis builder Multimatic to perfect their damping and ride control, Penske has done its development in-house.

Running low is not new, but the LMDh cars appear to be more sensitive than others. Bumpy circuits are their nemesis, compared to the LMH cars, but there is also a huge gain for cars running in clear air. Anyone at the front of the pack is able to control the traffic, and their tyres, better than those chasing.

Ferrari has spent the season so far working on tyre management, but also the electronics of its 499P. There is a big performance gain to be had by operating close to the torque curve, but also in having the electronic systems talk to each other cleanly and efficiently.

There is a maximum power limit, achieved either through the internal combustion engine alone, or supplemented by electronic power over a certain speed, which is dictated by the BoP table. The power from the ICE is cut proportionally to the electrical energy generated and getting these systems to work in sympatico is key to lap time.

However, even with the fastest car at Imola, Ferrari made mistakes on its strategy and turned a 1-2-3 in qualifying to fourth, seventh and eighth. The team has changed its decision-making processes since and doesn't expect to make the same mistakes, but that showed a clear vulnerability, which may remain for Le Mans.

One of the most significant cars on the grid is the Isotta Fraschini. The Italian LMH machine, built by Michelotto and run with a HWA engine, has a four-wheel-drive hybrid system and is privately funded. The team, which receives operational support from the experienced Duqueine LMP2 squad, admits its driving crew is not the strongest, but it is running steadily and learning every race.

A final important ingredient this year has been the tyre allocation from Michelin. The company is looking to reduce the number of tyres it provides per race to promote double stinting, but also makes the decision which

It has been a careful start for newcomer Isotta Fraschini, a relative minnow in Hypercar that has two silver-rated drivers in its lineup

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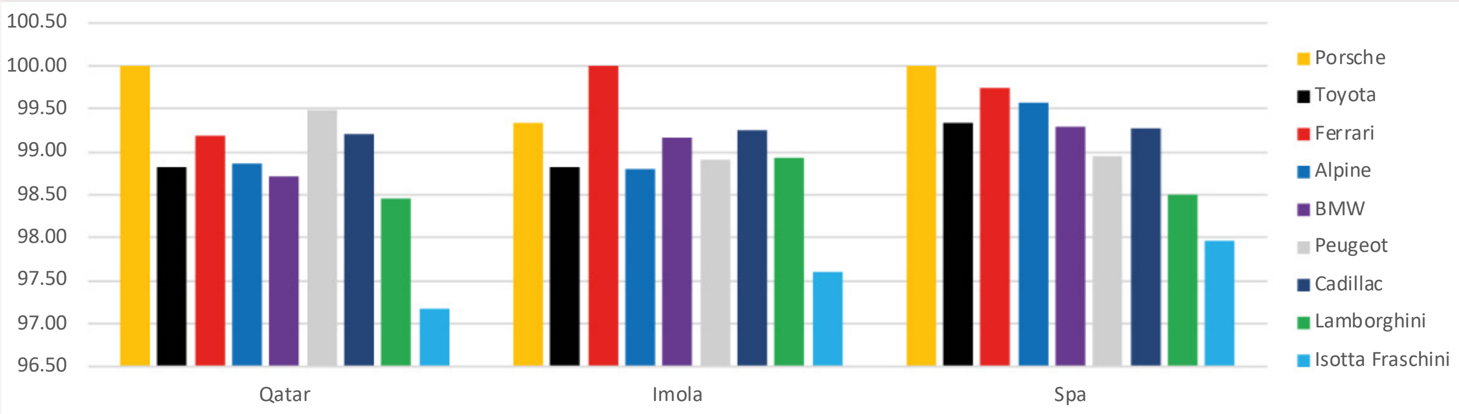


Performance tables of the opening three rounds of the 2024 WEC season show how dramatically the BoP can affect race outcomes, though obviously there are multiple other factors at play, too

Peugeot has had some reliability issues with the old and the new car in races this year, and has a habit of being involved in first corner crashes. The team is hoping for better at Le Mans

two of its three compounds it brings to the track. At Imola, it chose the medium and hard, expecting high temperatures, but needed the medium and the soft due to the changeable weather conditions. At Spa, then, it chose the medium and soft, but unexpectedly high temperatures meant it needed the hard.

The medium has enough range to suit most weather conditions, but bringing the wrong alternative tyre has reduced strategy options for the teams. Both Imola and Spa, for example, were run mainly on the medium tyre. All three compounds will be at Le Mans.

Balancing act

Using data from the first three rounds of the 2024 WEC to try to draw conclusions about forthcoming races, in particular Le Mans, is especially perilous. The FIA / ACO BoP procedure this year means each race is, in effect, run to a different formula.

Before each race, a new BoP table is issued, affecting various parameters of the Hypercar specification. Specifically, weight, power output, maximum energy deployed during a stint and refuelling docking time can all be altered between races. And they have been, depending on a certain set of measurements taken during the races.

The aim of this philosophy is to prevent teams from sandbagging and gaining an advantage in an upcoming race by making sacrifices in a previous one.

Perhaps the most affected car so far this year has been the Ferrari 499P, which had a big 34kg weight reduction for the second round, its home race at Imola, 12kg of which was added back on for the next race at Spa.

Alpine, Cadillac, Lamborghini and Peugeot have also all had sizeable modifications made to their energy deployment allowances as the season has progressed.

For the leading Hypercar manufacturers, this has been the second year of racing, and certainly the evidence of the three races held so far this year has shown the cars to be closely matched (although whether the FIA / ACO objectives with the new BoP have been achieved remains open to debate).

The LMDh cars, which seemed to be at a disadvantage throughout the 2023 season, have been encouraged by a boost in performance, and all except the Alpine and Lamborghini had the additional benefit of a 24-hour IMSA race at Daytona before the WEC campaign got under way in early March.

Performance tables

The performance tables shown above enable a comparison to be made of the cars at each event they have raced at so far this year. In Qatar, Porsche hit the ground running, achieving a lock-out of the podium positions.

	Best Result		Relative Average Lap Performance		
	Pos.	Round	Qatar	Imola	Spa
Porsche	1	Qatar	100.00	99.34	100.00
Toyota	1	Imola	98.81	98.81	99.34
Ferrari	3	Spa	99.18	100.00	99.75
Alpine	7	Qatar	98.86	98.79	99.57
BMW	6	Imola	98.71	99.16	99.30
Peugeot	9	Imola	99.48	98.91	98.95
Cadillac	10	Imola	99.20	99.24	99.28
Lamborghini	12	Imola	98.46	98.92	98.50
Isotta Fraschini	15	Spa	97.17	97.59	97.96

Relative average lap performances over the first three rounds show the front runners are still Porsche, Toyota and Ferrari

A final important ingredient for the races so far this year has been the tyre allocation from Michelin

Analysis of both the theoretical best lap time (calculated by adding together the three best sector times) and the average lap time of the best 20 per cent of laps shows they were undoubtedly the most potent cars on track in the opening round.

Surprisingly, perhaps, the 10-hour (or 335-lap) race was run mostly under green flag conditions, with only two short full course yellow (FCY) periods amounting to 6m 09s.

It is also interesting to compare the longest stints, although the tactical benefits of pitting when either track position or tyre wear can be optimised may have as much to do with this as actual fuel consumption. That said, the Cadillac demonstrated a little better frugality than the rest, though whether this will be of benefit over a long lap like Le Mans remains to be seen.

What is interesting (and not shown in the table), is that when the FCY was in effect, Mike Conway, in the no.7 Toyota, managed an extra lap, even though the FCY only lasted a little over four minutes. Such fine margins are hard to factor, but can have a significant impact in a race situation.

As already mentioned, Ferrari received a boost for the 6 Hours of Imola and used it to good effect, as can clearly be seen. Even though the race was won by Toyota (with Porsches second and third) the 499P was the fastest car, with Toyota half a percentage point behind, and Porsche further behind still.

The race had seven FCY periods and two safety car interventions. Altogether, nearly 39 minutes of racing time was lost, interrupting much of the flow. In analysing the data, these differences need to be taken into account, but a performance advantage is enough to enable a gap to be established while out on track and Toyota's advantage in that race seems to come in its ability to make best use of the FCY periods and be quicker in the pit stops.

A BoP adjustment before the 6 Hours of Spa was therefore inevitable, and saw the Ferrari's pace pegged back again. However, it was not the factory Penske Porsches that had the better performance in Belgium, but rather the 963s from race winner, JOTA, and, surprisingly perhaps, Proton Competition.

Even more so than at Imola, it was a messy race, headlined by a lengthy red flag. On top of that, an earlier safety car intervention and four FCYs affected a further hour and 16 minutes' racing. The performance table shows only the actual racing periods, so is the best guide to outright potential.

Bedding in

What is perhaps most reassuring when comparing average lap times at Spa is that the competition at the top is much closer than in the first two rounds. Seven cars are within half a per cent of each other, compared with just three in Qatar and at Imola. Perhaps the BoP is taking time to bed in? One hopes so. However, after its success at Imola, Toyota slipped back at Spa, so we can expect the team to be given a boost before Le Mans.

The season so far has seen the usual suspects at the top, with the exception of Peugeot at Losail. It has been a story of Porsche, Toyota and Ferrari battling for podiums. So what of Alpine, BMW, Cadillac and Lamborghini? Is a pecking order among these manufacturers emerging? Is a podium likely for any of them?

Alpine, with its new A424, is in ascendancy and so far looks the most likely to spring a surprise, unless the car is handicapped by the BoP for Le Mans. Remember the BoP change after qualifying last year? Similarly, BMW is becoming stronger with each event, while the evolution of Peugeot seems to be going in the opposite direction.

Cadillac has shown consistency, and has performed better than Peugeot at both Imola and Spa, while Lamborghini and Isotta Fraschini are both clearly struggling, not only with performance, but also reliability.

Driver effort

The WEC perhaps rewards manufacturer image more than driver skill but, nevertheless, it is interesting to compare individual efforts. Identifying a standout driver, though, based purely on lap times proves very difficult.

The driver summary overleaf shows the best 10 drivers in each race so far, using the average of the best 15 per cent of recorded lap times as a measure. The only driver to appear in the top 10 at all three of the races is Laurens Vanthoor. Fellow Porsche drivers, Kévin Estre, Fréd Makowiecki and Callum Ilott, appear twice, and Ferrari's Nicklas Nielsen is the only non-Porsche driver to make more than a single top 10 appearance. Of course, the timing of the stint is crucial,

Though the BMW M Hybrid V8 has so far failed to show any outstanding performance in the WEC, it has steadily improved at each round, so may well be one to watch as its first season progresses

and drawing any firm conclusions in this way is an exercise not to be recommended.

What is notable, however, is how close the top 10 are together at this point. In each case, the difference between first and 10th is considerably less than one per cent, and at Spa-Francorchamps it was just 0.45 per cent.

Summary

Looking ahead to Le Mans, and trying to predict a winner is to enter a minefield wearing a blindfold. Based on the championship positions, Porsche should start as favourite – apart from anything else, the brand has won more times at Le Mans than anyone else. Cynics might suggest the LMDh platform is due a first win as well. Even so, the question of *which* Porsche has to be answered. JOTA is clearly on a roll, and Proton demonstrated pace at Spa. Penske, on the other hand, will not have things as easy as it did at Daytona. As far as the numbers game is concerned, it is definitely advantage Weissach, with six 963s on the entry list.

Defending winner, Ferrari, currently lies third in the championship table, behind Porsche and Toyota, and cannot expect such a favourable BoP as it had at Imola (or at Le Mans in 2023). Many still say Toyota was robbed last year, and certainly the Japanese manufacturer will be eager to right any perceived past wrongs. Considering it has not followed Ferrari by adding a third, semi-works car, the reliability of the two Toyotas will need to be absolutely bulletproof.

For the rest of the contenders, even a place on the podium would be a surprise, given performances so far in 2024. Home teams, Peugeot and Alpine, will no doubt be embroiled in their own private battle for the honour of the *gloire de France*.

Having won at Sebring, and having a decently quick car, Cadillac was able to finish on the podium at Le Mans last year, even with an engine that dropped a cylinder early doors

GT category takes new direction

The biggest change to the FIA World Endurance Championship this season has been the replacement of the GTE-Am class with the LMGT3 category, which now runs on Goodyear tyres rather than Michelins. The decision came due to the rising costs of GTE, yet the GT3 cars are not significantly cheaper, particularly as they now employ torque sensors, which has changed the way they are set up and run.

There are new cars to GT3 from Ford and Corvette, but so far neither has scored a race win. Two of the three wins have gone to the Manthey Porsche squad, while BMW M Team WRT rolled the dice at Imola, left its cars out on a wet track on slick tyres, and took first and second in the race. Teams have had to adapt to the Goodyear tyres, which require a slightly softer set-up to work, but they largely appear to have done so.

One of the key differentiators in the class is the driver. Due to the cancellation of the LMP2 class in the WEC other than Le Mans, LMGT3 is now the place for the customer driver. This has led to some disparity, notably at Spa, where Sarah Bovy opened out a lead of almost 40 seconds on her bronze-rated competitors during her first two hours in the Iron Dames Lamborghini. The Dames are expected to be quick at Le Mans, and maybe their luck will change as they have not had the best reliability to date.

The introduction of GT3 has dramatically increased the variety of manufacturers on this part of the WEC grid, from four in the final season of GTE-Am to 10 today. One of the newcomers is McLaren with a pair of 720S GT3 Evos run by title-winning LMP2 team United Autosports.

One of the big adaptations that needs to be made to all GT3 cars in the WEC and GT World Challenge this year is to run on the WEC's TotalEnergies renewable fuel. As other series eye the switch to greener fuel, teams have had to mitigate the phenomenon of the fuel mixing with the oil.

'It's a heavier fuel, so it doesn't burn off,' says Malcolm Gerrish, chief engineer of McLaren's GT race programme. 'What we have had to do is adapt the breather system within the engine, the oil temperature, oil grade and calibration. It is all pieced together and now works, but it was a huge challenge to achieve that. We did track running, dyno sessions and so on to derive a robust solution that wasn't taking performance away.

'Obviously, you are getting fuel into the oil, and you can't stop that. We just have to get the fuel out of the oil as quickly as possible. Clearly, fuel dilution grows the volume of the oil, but if it's left in there a long time it will impact the lubricity of the oil for the engine.

'We did it by raising the global oil temperature vs water temperature. That, and a different grade of oil, and oil manufacturer, more towards a road car type of evaporator and breather system and it works. We literally separate the fuel from the oil due to the different weights of them.'

Adapting to the series-mandated torque sensors has also required some adjutments, but not the major change others have found.

'We ran a boost curve with the SRO,' Gerrish continues, 'but that boost curve led to a torque map to control the engine. Now we are running to a torque at the driveshaft, it's not really a big problem for us.'

Top ten driver summary

				Average of best 15% laps	Laps driven	Driving Time (H:MM:SS)
Qatar						
	5	Matt CAMPBELL	Porsche 963	1:41.587	170	4:55:23
	6	Laurens VANTHOOR	Porsche 963	1:41.639	130	3:46:33
	6	Kévin ESTRE	Porsche 963	1:41.688	141	4:03:16
	12	Norman NATO	Porsche 963	1:41.898	94	2:46:10
	93	Mikkel JENSEN	Peugeot 9X8	1:41.953	96	2:46:18
	5	Frédéric MAKOWIECKI	Porsche 963	1:41.999	62	1:48:04
	12	Will STEVENS	Porsche 963	1:42.124	124	3:35:39
	93	Jean-Eric VERGNE	Peugeot 9X8	1:42.257	110	3:14:13
	12	Callum ILOTT	Porsche 963	1:42.269	117	3:21:36
	50	Nicklas NIELSEN	Ferrari 499P	1:42.272	153	4:25:10
Imola						
	50	Antonio FUOCO	Ferrari 499P	1:32.295	66	1:54:23
	50	Nicklas NIELSEN	Ferrari 499P	1:32.691	102	2:46:04
	51	Antonio GIOVINAZZI	Ferrari 499P	1:32.776	103	2:47:20
	7	Mike CONWAY	Toyota GR010-Hybrid	1:32.887	69	1:53:44
	7	Nyck DE VRIES	Toyota GR010-Hybrid	1:32.931	61	1:41:29
	51	Alessandro PIER GUIDI	Ferrari 499P	1:32.950	39	1:03:56
	83	Robert KUBICA	Ferrari 499P	1:32.994	101	2:45:00
	6	Laurens VANTHOOR	Porsche 963	1:33.009	70	1:56:15
	8	Ryo HIRAKAWA	Toyota GR010-Hybrid	1:33.029	59	1:37:10
	99	Harry TINCKNELL	Porsche 963	1:33.060	62	1:41:23
Spa						
	36	Matthieu VAXIVIERE	Alpine A424	2:07.653	27	1:05:40
	12	Callum ILOTT	Porsche 963	2:07.724	69	2:35:23
	6	Kévin ESTRE	Porsche 963	2:07.761	47	1:46:36
	5	Frédéric MAKOWIECKI	Porsche 963	2:07.889	39	1:32:25
	99	Julien ANDLAUER	Porsche 963	2:07.951	81	3:05:27
	83	Robert SHWARTZMAN	Ferrari 499P	2:08.190	41	1:28:43
	5	Michael CHRISTENSEN	Porsche 963	2:08.209	25	1:20:16
	2	Alex LYNN	Cadillac V-Series.R	2:08.214	39	1:33:52
	6	Laurens VANTHOOR	Porsche 963	2:08.226	39	1:33:06
	51	James CALADO	Ferrari 499P	2:08.233	32	1:38:18

The difference between first and 10th is considerably less than one per cent, and at Spa-Francorchamps it was just 0.45 per cent

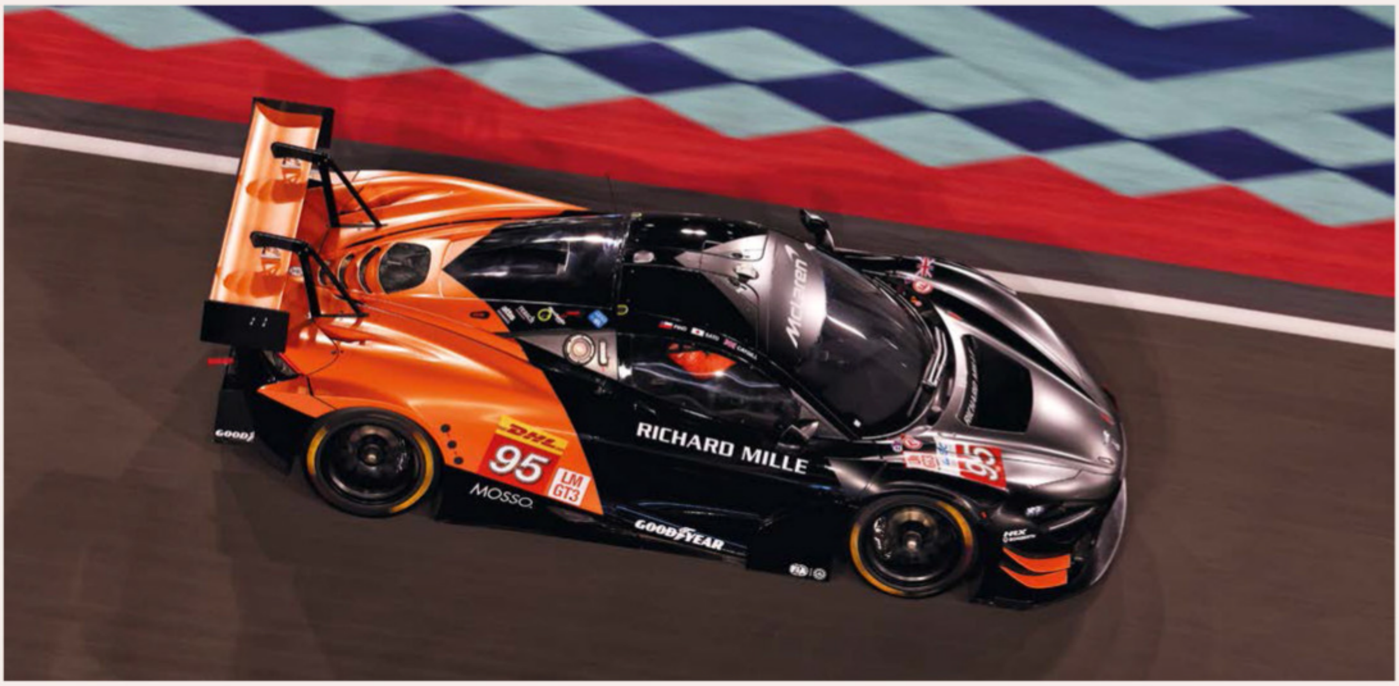
[note: Cadillac denied this, but the team did add some 60l of oil to the car during the race].

If the WEC Cadillac was indeed damaged in Qatar, and the bodywork not the most up to date in terms of manufacture, the team could have played a blinding game for BoP purposes. All will be revealed in due course.

BMW, meanwhile, has been steadily improving as the season has evolved, though it is still early days. However, rather than that dogged determination being echoed in a good result at Le Mans, it may well be greeted by an unfavourable BoP adjustment instead.

That just leaves Lamborghini and Isotta Fraschini, neither of which have had particularly successful seasons so far. Both teams are clearly at the beginning of their respective learning curves, but surprises can, and do, happen at Le Mans.

With such a strong entry of Hypercars, it should be remembered that the cream of the drivers, engineers, team managers and strategists have already been mopped up by those at the sharp end of the grid, making life even more difficult for the minnows battling to gain traction in their wake.



McLaren, making its first Le Mans appearance in 26 years, is one of three GT3 manufacturers without a Hypercar stablemate, along with Ford and Aston Martin. The latter has an LMH coming

ICE station zero

The ACO is still pursuing the hydrogen agenda for its top class, but it's far from an easy route. Racecar sat down with its H2 consultant, Bernard Niclot, to discuss the current state of play

By ANDREW COTTON

Toyota launched its hydrogen prototype concept at Le Mans in 2023, and has been closely investigating the fuel for competition. It has already raced with a liquid hydrogen-powered car in Japan

It has now been seven years since the ACO confirmed it wants to introduce hydrogen to its top class and compete for the overall win at the 24 Hours of Le Mans. Since then, the technology has advanced so quickly that the final choice of what to use has still to be made, and the timeline is being pushed further away because of it.

As *Racecar* reported last year, the original plan was to introduce fuel cell hydrogen cars, but refuelling them led to a fear of dramatic temperature changes from empty to full as pressure increases when the tanks are filled.

Research into hydrogen ICE technology has advanced since then and using hydrogen as a combustion fuel is now a real possibility. There, the temperature of stored hydrogen is low, and engine builders have to cope with a pressure change from 700bar to 40bar at the combustion chamber. Despite this, work on ICE engines running on hydrogen is progressing faster than the fuel cell concept.

However, fuel cell technology is fighting back, with new materials and processes coming online rapidly.

Consequently, what the rule makers are currently trying to do is understand where hydrogen technology is today, and then estimate where it will be by the time the cars eventually run on track, thereby ensuring their regulations remain cutting edge.

'[When we started] nobody was speaking about internal combustion technology, there was not really any such technology'

Bernard Niclot, hydrogen consultant to the ACO

Understandably, this is proving to be a difficult challenge as the regulators cannot risk slipping on banana skins.

The regulations have therefore still not been finalised, and the likelihood is now that they will be pushed back to 2028, at least.

Racecar sat down with Bernard Niclot, who has been consulting the ACO on how to implement hydrogen technology at Le Mans, to discuss where things stand in terms of being able to set the regulations in stone.

'It's quite clear that [when we started] nobody was speaking about internal combustion technology, there was not really any such technology,' says Niclot. '[Now] we have seen the development of the ICE technology, and development of the components, and so it [has] become technology that we have to consider.

'So, we took the decision to integrate the ICE into the regulations. However, the problem is that H_2 ICE is very recent, but ICE itself is older technology with a lot of development and a lot of optimisation [behind it], so they can ramp up quickly and can achieve some good levels of performance quite quickly.

'With the fuel cell, it's a different story. [The technology] came from space and only recently has been adapted to automotive. There are not the same curves of development. We have to understand the current potential of both technologies and also the future potential.

'The fuel cell is heavier and more demanding in terms of cooling, but is more purely zero emission, even if zero does not exist in physics. ICEs are very good in terms of very low emissions, but especially in terms of NO_X. It's not exactly the same story as fuel cells.'

Material development

Using new material technologies, it now seems very possible that around 100kg can be trimmed from the weight of a fuel cell, while other developments mean hydrogen can be stored in a wider temperature range, which further reduces the cooling demands.

'Now what I can see is that there are some membranes developed by chemical industries that run like a current fuel cell. They work at 140degC and this changes the game,' continues Niclot. 'You have no more water in the fuel cell, and then you can work 40 degrees hotter and so you have less of a problem. If you combine such technologies with lighter fuel cells, it changes the game completely.

'This is what we see today. What we see tomorrow, we don't know.'

The technical working group that is formulating the regulations was once broad, with around 10 manufacturers seated at the table, though the ACO has since pared that down to four. These are manufacturers that are more actively investigating hydrogen, both in fuel cell and ICE environments. Working with a smaller, more focused group has increased the depth, and speed, of investigation. The results are then shared with the wider interested community.

All in the timing

However, while different manufacturers are actively pursuing different technologies, timing is now becoming an issue. The regulations were supposed to be in place by the early 2020s, but were delayed by Covid and now the rapidly changing landscape of the new technologies. The deadline subsequently moved to 2026, but now it looks as though that will be pushed back again, to at least 2028.

While the LMDh regulations are in place and running in IMSA until beyond the turn of the decade, LMH might need to have its lifespan extended as endurance racing waits for these regulations.

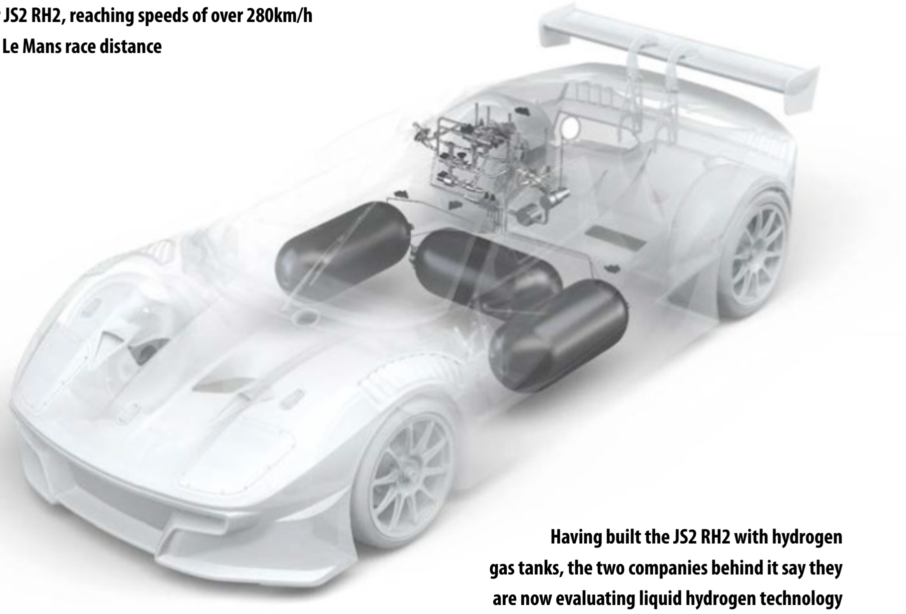
With no regulations currently out there, it is estimated that it will take 18-24 months to confirm them with the working group, ratify them through the FIA, and for the manufacturers to build, test and have their cars ready to race.

There was a rumour that, in order to drive the regulations through quicker, there could be an interim solution of combining hydrogen with petrol. That would certainly help the manufacturers to produce the power and achieve the fuel economy required to complete 10 laps at Le Mans at a competitive speed. However, while this would significantly reduce CO_2 emissions at the tailpipe, the engines would not achieve the zero emission target.

'Motorsport has to be a bit more ambitious,' reckons Niclot. 'Zero emission is an ambition. I don't believe the future can be only efuels, and biofuels is a question of how you produce a big enough quantity without damaging agriculture. You need also to feed human beings, and you can never conflict with this.

DPPI

Bosch and Ligier Automotive have completed high-speed testing with their JS2 RH2, reaching speeds of over 280km/h and completing a Le Mans race distance



Having built the JS2 RH2 with hydrogen gas tanks, the two companies behind it say they are now evaluating liquid hydrogen technology

'Some people could find ways to massively produce biofuels, and I hope that would be the case, but at the moment it is not, and to develop real zero emission vehicles is still a very important target.'

Road relevance

While Niclot is well aware of the time constraints, he says he prefers to do the homework properly, rather than make a decision now and then have to make a costly, or disastrous, amendment.

'We want to think to the future. When [ACO president] Pierre Fillon announced at the beginning that we were going hydrogen, we were very alone. There were not so many people around, but now you see that the manufacturers are interested, and you see the momentum can switch. It's nice to see. I think that motor racing has to show an example.

'Then, if we speak about road relevancy, we cannot only consider passenger cars, but also trucks, trains and so on. It's clear hydrogen will play a role in this type of mobility.

'When Pierre Fillon announced at the beginning that we were going hydrogen, we were very alone… now you see that the manufacturers are interested'

Manufacturers form part of a technical working group to develop regulations for the new hydrogen class in endurance racing

‘ACO, Le Mans and WEC are worldwide championships, and we welcome manufacturers from outside Europe, so we cannot just take on the European regulations’

‘For road cars, perhaps not 2027, but I think even though hydrogen is not the music you can hear at the moment, because people say it’s for professional mobility, I’m not so sure. I hope that hydrogen can be developed also for passenger cars.’

For that to happen, the manufacturers have to be guided by the regulations that are being proposed in Europe and around the rest of the world. These, too, are changing rapidly. From the ban on the sale of internal combustion cars by 2030, that has now been pushed back to 2035 in Europe, and there are few who believe it will happen at all.

Manufacturers have been pouring money into electric, but are now starting to pivot back towards ICE as electric car sales are not as buoyant as many had hoped.

Meanwhile, the development of sustainable, low-carbon fuels is increasing at pace, and there is a realistic chance that a zero-emission vehicle could still feature an internal combustion engine.

Global concern

‘First of all, ACO, Le Mans and WEC are worldwide championships, and we welcome manufacturers from outside Europe, so we cannot just take on the European regulations,’ concludes Niclot. ‘There are parts of the world where ICEs will have some life and personally, as an engineer, I consider a hydrogen ICE basically to produce water, so it is not like a gasoline one.

‘Even if ICE is banned for the moment by the European authorities, the chances are it will continue because we are also speaking about efuels, so the situation is a bit confusing at this level, and this timeframe.

‘It is clear that we have to address zero-emission technologies, but climate change is not a European problem, it is a global problem, and we have to address it with this picture and this vision.’

So, the race is still on to introduce hydrogen as a power source to endurance racing, but with the right technology and performance levels, and to bring the manufacturers along with it to genuinely improve our mobility demands on the environment. It’s a tough ask.

’Glow in the dark

The 440bhp Alpenglow HY4 is a rolling laboratory on a Ligier LMP3 chassis that allows engineers to learn about hydrogen as a combustion fuel. It has a four-cylinder engine, but Alpine will build a bespoke six-cylinder unit that will run on liquid hydrogen

At Spa in May, French manufacturer, Alpine, presented its Alpenglow HY4. The hydrogen gas-fuelled car was originally launched at the Paris Motor Show in 2022 but at Spa was scheduled to complete laps of the circuit ahead of the six-hour race. Unfortunately, electrical difficulties prevented it from doing so on that occasion, but it will soon.

The car currently features an adapted version of ORECA’s four-cylinder engine, but Alpine plans to develop its own six-cylinder unit for the Alpenglow HY6 that will use liquid hydrogen fuel.

At time of writing, the V6 engine is being dyno tested, with a proposed launch date of 2027.

Meanwhile, the HY4 features three 55-litre tanks with gas stored at 700bar, which reduces to 40bar injection pressure. Engineers have needed to manage the temperature change during this process, while also stabilising the combustion process due to hydrogen’s volatile nature.

Although Alpine has confirmed the hydrogen-powered car will be capable of WEC Hypercar performance, there is no plan to race it yet.

‘It is working well on the dyno, and then it is about adapting the car, and I think that can be done quite quickly,’ said Bruno Famin, vice president of Alpine Racing.

In terms of meeting Hypercar regulations, though, Famin was less optimistic.

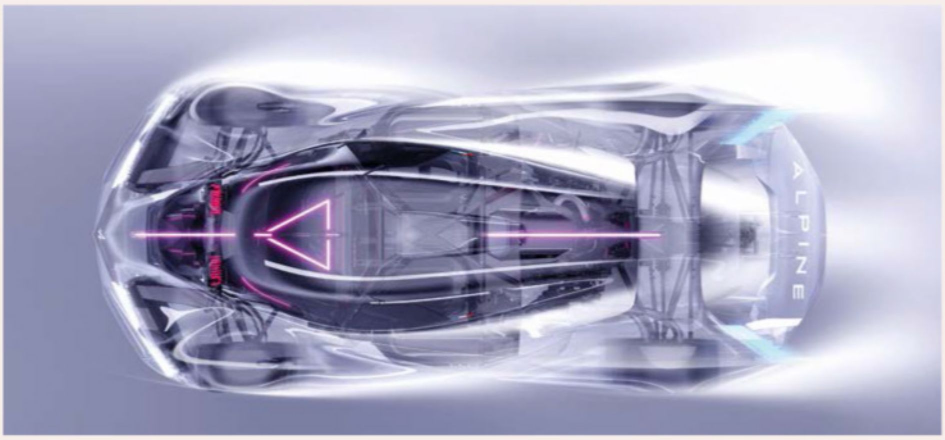
‘It might be different in terms of needing more downforce, or aero devices, but it won’t be a Hypercar in the way that we know. For the time being, with the Alpenglow HY4 and HY6, we just want to develop the technology. Then we can go both ways, road car or Hypercar.

‘We pushed for changing to liquid storage and are happy that the FIA and ACO have followed that. To us, that is key in terms of packaging and performance. If you want a 10-lap stint at Le Mans, you must have it.

‘The date the ACO has given is 2027, and we will see what it will be, but everything needs to be sure for regulations and suppliers.

‘The cycle of the current Hypercar goes until 2027, inclusive, and then let’s see when we will be able to race with a hydrogen car.’

While the Le Mans regulations for hydrogen-fuelled cars are slowly coming into focus, Famin is aware that the Formula 1 regulations will be revised in 2031, and that hydrogen could offer a solution for that formula, too. There have been no public discussions about that yet, but learnings from Alpine’s HY4 / HY6 project will certainly not disadvantage the Renault brand.



Packaging for cooling is easier with a combustion engine than for a fuel cell, although the technology for both solutions is changing rapidly and becoming more efficient. The hard job for the regulators now is making a decision that is future proof

Faenza files

How RB is rising up the F1 grid and why AI could be a subtle, yet effective weapon in its arsenal

By DANIEL LLOYD

There hasn't been too much to shout about for Red Bull's second Formula 1 team since the current regulations cycle started in 2022, but that could all be about to change.

RB, which started life as Toro Rosso, emerging from the ashes of Minardi in 2006, finished ninth and eighth in the last two editions of the 10-team Constructors' Championship, notching up sporadic points finishes and only a single top five, courtesy of Pierre Gasly at Baku in 2022.

The team, which is primarily based in Faenza, Italy, but has aerodynamic and R&D resources in the UK, enjoyed a strong ending to the previous rule set when it amassed 142 points and finished sixth in the table.

After a languid start to the current ground-effect era, its management is eager to replicate that upward trajectory as the car platform continues to mature.

The early part of the regulations' penultimate season this year has offered some evidence to support that: Yuki Tsunoda, now in his fourth campaign with RB, scored points in four of the first seven races, while Daniel Ricciardo finished fourth in the Miami sprint. Heading into the European leg of the calendar, RB was already only six points shy of its 2023 total, and well on the way to eclipsing it. Winning the so-called 'midfield' battle between the bottom five teams is top of its priorities and, at time of writing, looks to be within reach.

Fast starter

Although RB has undergone yet another re-naming exercise after the end of a four-year title partnership with the AlphaTauri clothing brand, the current VCARB 01 Honda builds on learnings from the previous AT-badged, Honda-powered cars.

Big changes for 2023 finale included reduced floor edge wing camber, repositioned floor fences and extensively modified mid-floor

'We believed in the baseline concept of last year's car, evolved it for this year, and just carried that aerodynamic goodness forwards'

Jody Egginton, technical director at RB

Having struggled in the first two seasons of the current regulations cycle, RB is now starting to find its form

Red Bull Content Pool

Egginton says RB understands the VCARB 01 base car 'resonably well', and admits it didn't with the early AT04

RB applied upgrades to the AT04 up until the final race of last season as it was trying out aerodynamic solutions that it could carry through to the VCARB 01.

According to RB technical director, Jody Egginton, there were 'some breakthroughs' late last year that put the team in a position to spring out from the blocks quicker in 2024.

'The [2023] car ended the season reasonably competitive in the midfield,' he says. 'We thought that gave us a better opportunity to start reasonably competitive. We had quite a productive winter as well.

'Because we developed the car late, and there was a lot of learning that translated aerodynamically, we found we could cover some more ground. We believed in the baseline concept of last year's car, evolved it for this year, and just carried that aerodynamic goodness forwards. We had no significant mechanical concerns.'

Operating window

One of the AT04's main weaknesses was rear instability on corner entry, but those troubles appeared to have been dispelled with eight races to go. As the team made progress in that area, adjusting some of its wind tunnel processes and gradually adding load to help calm the rear, it could increase the car's operating window.

With the drivers able to brake later and take more speed into the apex, they could lap faster, and with more confidence.

Significant updates were brought to the Singapore and Austin (shown) rounds in 2023 but the team ended up choosing an alternate aerodynamic path

'Over the winter, we retained – we hope – our low-speed goodness,' continues Egginton. 'We still worked on it, but focused on some other areas of development.

'This year has been slightly different as we've overcome the worst of that problem.'

Encouraged by the validation of the Abu Dhabi race, RB switched permanently to its concept floor design for the VCARB 01

Floor focus

That drew RB into a major focus on enhancing performance from the floor, which generates downforce through ground effect. Last year, the team developed a concept floor that was fitted at the Abu Dhabi finale. This ran in the background to its regular in-season floor programme that culminated with significant updates for Singapore and Austin. It resulted in a substantial workload for the team's engineers as RB chased two aero directions simultaneously.

'At the start of 2023, we were uncomfortable with where we were with it, as a group,' admits Egginton. 'One of the positives of the group is we're quite honest with ourselves. So we put more resource onto it because it's a key aero component.

'We were doing [concept floor] development in the background that started about race six. It was a very different look at how the floor worked, and what we wanted from the floor in terms of operating window and sensitivity. That delivered, so we put it on the car last thing.'

Encouraged by the validation of the Abu Dhabi race, RB switched permanently to its concept floor design for the VCARB 01. This explains why the team has been aggressive in rolling out floor updates in the early part of 2024. It did so at round four in Japan and round six in Miami, although Egginton hints that the latter floor was 'a lot more new' than the former.

For Miami, the height and shape of the floor's forward section was re-worked, along with the floor fences. The target was to modify load distribution of the forward floor, generating more load in that area whilst at the same time minimising any negative effects on rearward airflow quality.

At the same time, RB rolled out a revised diffuser inlet to improve airflow quality to the diffuser. At time of writing, a further floor update is planned for round 10 at Barcelona.

'If you imagine that [Abu Dhabi] was the first of a new development direction, we were very keen to get floor updates early into the season because we'd learnt a lot during the winter,' offers Egginton.

'When we're talking about floor updates, we're also by definition talking about bodywork updates. [With] the structure of the car underneath the wetted surfaces, we've had no concerns last year and this year that we've needed to do major updates to facilitate the aero development. So we've been able to focus on aero, which is good.'

Wing side view

'Now our focus continues [on] floor, bodywork, and there is quite a big front wing programme gobbling away in the background. I wouldn't call it a concept front wing, but we are taking a different view of it.'

At time of writing, the updated wing was undergoing wind tunnel testing. Optimising the front wing design is crucial because it dictates much of the airflow to rearward parts of the car, including the front of the floor. Additionally, as the car navigates a track, it encounters variations in ride height that change the wing's proximity to the ground, altering the downforce it generates.

The latest evolution of the new floor concept arrived in Miami, but was intended for the next race at Imola

Front wing changes are coming as RB looks to manage characteristics such as tyre squirt and load distribution off the flaps

'The thing the wing does in this regulation [is] you're setting up your flow structures in order that the floor can take benefit from them,' explains Egginton. 'Although the headline numbers from the wing itself are not exciting, teams will be focused on making sure that you're setting them up as you want. We certainly are.

'The wing is a facilitator, as are our suspension, wishbone shrouds and brake ducts, to some extent.'

Suspension switch

A notable design change for the VCARB 01 was a switch to pull rod front suspension, like Sauber, as covered previously in *RE* V434N6. Whilst Sauber's new layout diverged from that of its power unit supplier, Ferrari, RB has moved closer to its own supplier, Red Bull, and now uses the title-winning team's pull rod front / pushrod rear combination, which has been used to great effect by the title-winning team in terms of ride control.

However, the team could have taken that approach from the start of the rules cycle in 2022, so why didn't it?

'We made a decision on pushrod,' recalls Egginton, 'but reviewing those decisions, looking back on what our beliefs were at that time, and where we were in floor development and other things, we could have easily gone pull rod.

'We were so immature on some other aspects of the car's aerodynamic design, and we stopped development of the 2022 car quite early. I don't think we had all our ducks in a row then, so we stayed where we were.

'One of the things we learned in the second half of 2023, though, when our development really gained a lot of momentum, was that we could see some goodness, aerodynamically, in the pull rod.'

The pull rod configuration, where the rod arm connects at the bottom of the chassis rather than the top, is more aerodynamically efficient than a pushrod, but has several drawbacks, such as inferior compliance, and weight. It is hard to quantify how much heavier the pull rod option is because weight saving measures in other parts of the car obscure the calculation. However, Egginton estimates it contributed to around 1-1.5kg on the VCARB 01.

'On balance, the aero benefits outweighed any mechanical, packaging or mass-associated penalties,' he adds. 'At the end of the day, you want your car to be underweight. The car is underweight. You also want to have sufficient ballast to move the weight distribution around in the way you want.

'You've [also] got to make sure that, as you develop the car through the year, you don't get involved in some massive lightweighting programme. If the car gets heavier due to aero development, you don't want to put yourself in a corner.

'Once you've ticked all those boxes, aero is key. We were fortunate that, thanks to the hard work of the designers, we were in that situation. We had that freedom to push aero.'

Emergent battleground

RB's gradual on-track improvement has been supported in the background by its exploration of artificial intelligence (AI) to accelerate production capabilities and other processes. This, the team hopes, will help to give it an edge over its closely matched rivals in one of F1's emergent battlegrounds.

For example, the VCARB 01's new floor for Miami was delivered early; the plan was for it to arrive one race later at Imola. That is the sort of tangible result RB hopes its adoption of AI software can produce.

Most F1 teams now have an ERP (enterprise resource planning) partner and RB is no different, having inked a deal with American technology firm, Epicor, in 2021. Others include Oracle with Red Bull and SAP with Mercedes. How teams use these companies' software is fuelling a quiet development race. This year, RB started using Epicor Prism, a generative AI suite based on large language models (LLMs).

'With the cost cap, it has made a field that has never been [so] close,' says RB team principal, Laurent Mekies.

RB has started using Epicor's Prism, an AI program designed to speed up its parts production and purchasing capabilities

'Can AI help us to reduce the gap? We believe it can. Which is why, as a company, we are in a position where we feel we need to take risks to close that gap. Some of these risks are perhaps in our bias towards innovation and trying to see if we can get a competitive advantage.'

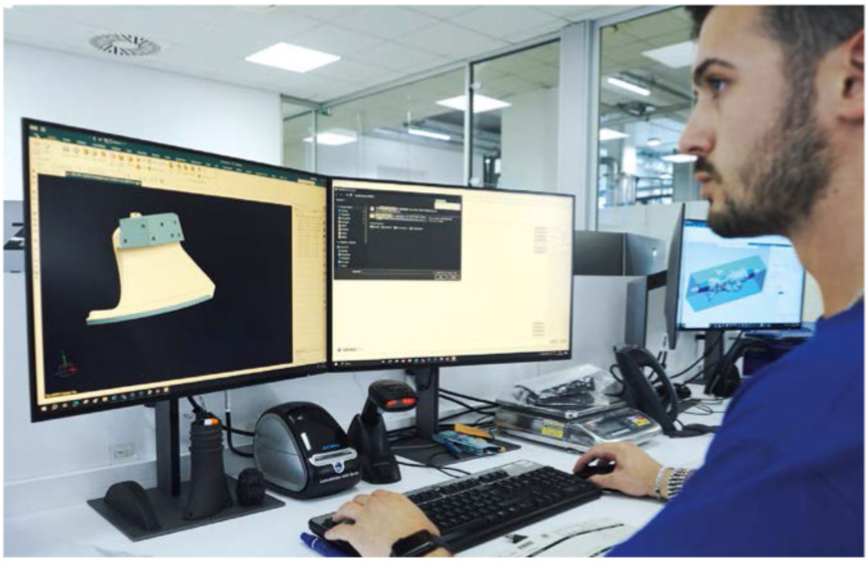
At the factory, the Prism software streamlines parts production and completes tasks that are either mundane or require lots of data interpretation. All stages of the parts production timeline – design, manufacture, treatment and assembly – have screens that track the progress of each component and who worked on it. Any problems can therefore be easily traced back, allowing the team to establish the root cause of any recurring issues quicker. The idea is to give everyone immediate clarity on status updates and timelines, increasing overall efficiency.

'We have 14,000 parts on the car, and you need to make a call on each of these parts,' continues Mekies. 'Do you produce it yourself? Do you get a supplier to make it? What is the best way for your company, in terms of cost and speed?

'That's a practical example of where Epicor is leading the way in integrating AI, and opening doors we didn't think of.'

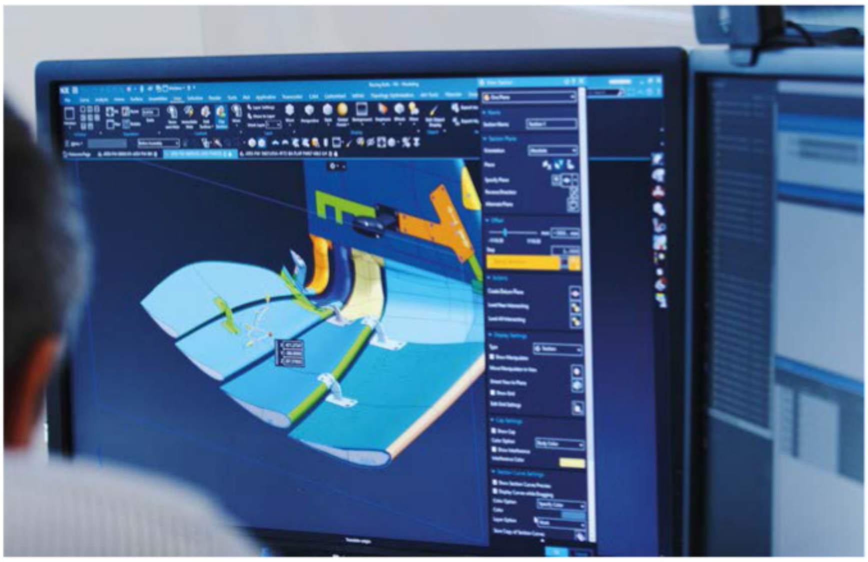
Trackside benefits

Streamlining the production process means upgrades, like the new floor, come to the track quicker. It also helps to extrapolate the masses of in-race data to rapidly narrow down strategy or mechanical adjustment options.



Epicor VCARB

RB has started using enterprise resource planning and AI as a time-saving device. Now, an engineer wanting to see a part's production record can ask the system directly, rather than waiting for an IT colleague to dig out the data



Epicor VCARB

The 'time to race' battle for producing new parts as quickly as possible is a major focus of all the current F1 teams, especially now with the field so closely matched. A gain here can equate to a competitive advantage on track

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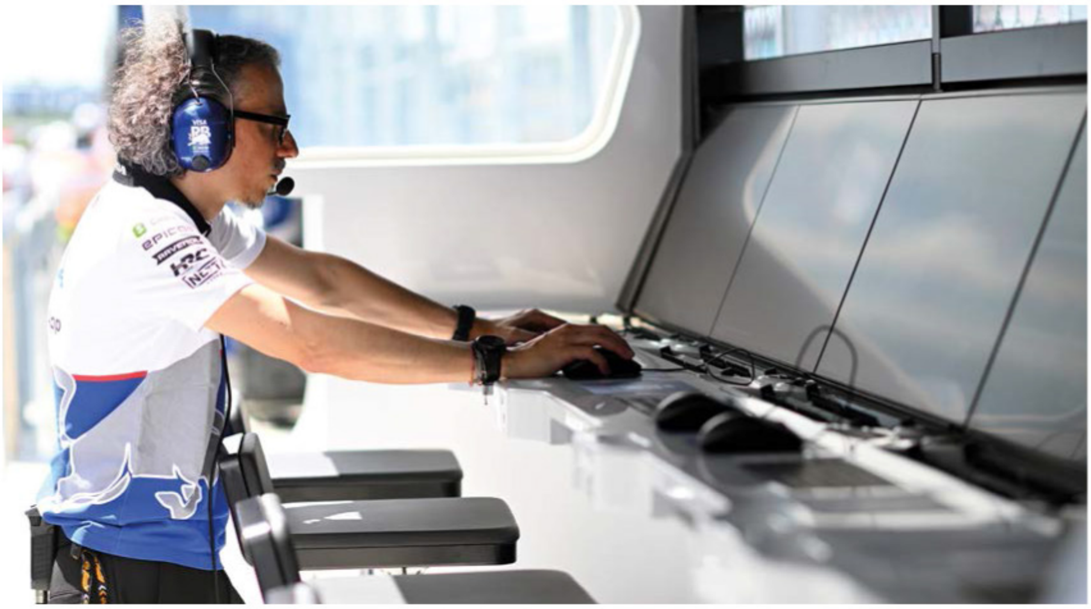

'With the cost cap, it has made a field that has never been [so] close. Can AI help us to reduce the gap? We believe it can'

Laurent Mekies, team principal at RB

Laurent Mekies started as RB team principal this year, replacing long-time leader, Franz Tost. He previously worked for Ferrari, Toro Rosso and the FIA

'The biggest advantage is the time to market,' says RB head of performance engineering, Guillaume Dezoteux. 'We look at the car data, talk with the drivers and see an opportunity for improving the car. We test it in the simulator and, when we find a valuable upgrade, the rest is very fast.

'For example, since the start of the season, Daniel [Ricciardo] was struggling a little bit with the steering feeling, which is a key parameter for the driver to gauge front tyre performance and car balance. We have tried different options to make the steering heavier or lighter and changing the power steering parameters. Once we have defined a new target, then we drop it and the time to market is incredibly fast.'

AI is also being used to speed up simulation processing. The software can explore terabytes of data each day, picking out relevant trends for the engineers to consider. They may decide to discard some of them, but being given options and ideas in the first place is a huge time saver.

That also extends to CFD aerodynamic simulations, which are regulated to a certain number per team, depending on their position in the standings.

'Before, you would have gone and run another 10 simulations, and [now] suddenly you have patterns that say you don't want to do that,' says Mekies. 'It's making us scratch our heads every day. Even if you run just lap time simulations, and you run 80,000 [of them], how do you then filter them? You have the lap time output, but there are more articulated key performance indicators that come out of it. You say, can I really run the car that way? And then you explore.'

Mekies' suggestion that AI can be used to save valuable CFD runs is an interesting one. With the worst-performing teams allocated more CFD simulations, there is an added incentive for those teams further up the grid to be savvy with the tools they use to handle such data.

More to come

Of course, RB is not alone in using AI to enhance its background processes. However, the full extent of AI's role in benefitting performance is yet to be realised.

Mercedes F1 chief technical officer, James Allison, says AI-integrated ERP systems are 'starting to deliver' in purchasing and production, although he acknowledges that understanding the full extent of how to maximise the efficiency gains – and what they cost – is 'a bit ahead' at present.

'The areas where it's already kicking around the place are in aerodynamics and race strategy,' explains Allison. 'It's recently being used to create surrogate models, to create a filter of ideas so that you can hopefully run [them] through a trained machine learning cluster that will give you an idea whether it was better than your last idea. Or give you a higher percentage chance that your idea might be slightly better than the baseline.

'If you can make that work effectively, then gradually your rate of finding lap time gain will be steeper. It's already in all the teams, and will gather pace in the seasons to come.'

This feeds into a warning from RB's CEO, Peter Bayer, that, whilst teams are currently seeing what they can achieve with AI, there will be a need for the organisers to step in.

'These things, ultimately, need to be regulated,' Bayer suggests. 'Bigger teams might have more funding. Mercedes, for example, might be able to use one of the big AI centres they use for road car development. We would obviously want to have that well regulated in the future.'

Red Bull Content Pool

Aside from track updates, RB is using generative AI to speed up processes at the factory and on the pit wall, too

Alongside software, RB is upgrading its bricks and mortar in the UK. Since its Toro Rosso days, the team has used an R&D facility in the depths of a Bicester industrial estate to conduct its aerodynamic work. However, it is no longer big enough for the needs of today's F1 team.

Expansion chamber

In 2021, RB started utilising Red Bull Racing's wind tunnel in Bedford, switching away from its own station in Bicester. Its new aerodynamic and future car concept offices in Milton Keynes will be closer to the Bedford site and will have more space for the team's visiting Italian staff. The remote operations room for race events will also be upscaled and the overall size of the base will be larger.

RB plans to move into the Milton Keynes site in December this year.

'We have filled Bicester,' says Egginton. 'Milton Keynes gives us the opportunity to grow. But also, very importantly, it gives us a chance to move people between sites. Right now, we have to be careful with how many people we move to Bicester for a meeting, or a couple of days, because we're desk limited. The freedom will be great.

'As a company, especially on the technical side, we've really embraced this flexible working across sites. Now we've got a facility that enables us to do that comfortably and people feel they have a place in both factories. More meeting rooms, more space to talk about what we're here to do.'

'We've really embraced flexible working across sites. Now we've got a facility that enables us to do that comfortably and people feel they have a place in both factories'

Jody Egginton

The key word surrounding the factory move is flexibility. Egginton notes that the team is trying to 'gel everyone together' by streamlining the interaction (ie the flow of people) between Italy and the UK. Getting that right creates a more coherent team.

'We like to have designers who have experience over multiple areas and disciplines, so we're really flexible on what we can do,' he adds. 'If we're pushing hard on aero, we will have mechanical guys who will jump on board and do some metallic work associated with aero.

'One way to get that flexibility is to give people exposure to different areas of the business. When you've got more desk space, you can do that.'

In addition to the switch of British base, RB has continued to improve its Faenza facility. Alongside its ongoing software developments, the team is continuing to invest in hardware. RB installed its first in-house simulator at Faenza last month, having previously relied on Red Bull's rig in the UK.

'We still use the Red Bull simulator as well, we've just increased our capacity,' explains Egginton. 'We're a little bit late to the party with that. Having our own simulator on site is a fantastic engineering tool and our young, clever engineers really embrace it. We're using it for a whole range of activities. It's another clear sign of growth and development.'

Eyes forward

RB is now showing its best on-track form since the current regulations began but, like all teams, it has one set of eyes firmly on the 2026 refresh. The question now is whether it shifts more attention to its studies for 2026 (bearing in mind aero work is banned until January) or continues developing its solid baseline car for a serious crack at podiums in 2025. The history books may hold the answer.

'We were pretty strong in 2021 and we also changed wind tunnels,' recalls Egginton. 'In hindsight, we probably should have turned the 2021 car off a bit earlier, because we weren't where we wanted to be with the 2022 car out of the box. So [we will] take that learning, see where we are now and what we've extracted out of this year's car, and what learning that will take into 2025.

'It's the last year of the regulation, and [there is] a very big regulation change coming for 2026. It's very much, in my mind, about getting that transition right, and putting the resource where it's needed.'

RB's team principal, Laurent Mekies, believes there are 'no back markers' in F1's tight midfield battle, so every little bit of growth and development counts in the run up to the 2026 regulations

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15/06/2024 19:40:39	#123	LE MANS	69.4 kg	30.8 s	92.5 L	20.1 C	29.5 C	100 %	31.4 s
15/06/2024 18:53:59	#123	LE MANS	69.1 kg	30.7 s	92.2 L	21.4 C	33.5 C	100 %	31.2 s
15/06/2024 18:13:09	#123	LE MANS	69.6 kg	30.9 s	92.8 L	21.2 C	32.1 C	100 %	31.4 s
15/06/2024 17:28:22	#123	LE MANS	69.3 kg	30.8 s	92.4 L	21.8 C	32.4 C	100 %	31.3 s
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Contact patch

There was a Formula 1 race on the first weekend of April this year. It featured more passing manoeuvres than you could count, cars sliding broadside through turns and drivers punting other cars out of the way without a murmur from the stewards. This was not the Japanese Grand Prix at Suzuka, but a Formula 1 Stockcar race at King's Lynn in Norfolk, UK, and just one bit of an action-packed evening.

BriSCA Formula 1 Stock Car is the pinnacle of the UK short oval racing scene and, while very different to its NASCAR namesake, there are also some similarities.

British stock cars began in 1954, so this year marks the sport's 70th anniversary, with cars based on roadgoing machines, but has evolved since into highly specialised devices now more akin to American Sprint Cars.

These cars are often built by racers, who will also sell cars on the back of reputations made on track. There are no marques, as there are in circuit racing; they're all just stock cars. As current frontrunner and car builder, Matt Newson, puts it, 'You can tell a Matt Newson car from a Tom Harris or a Stuart Smith car, because it's my shape, my style and look, but it's not actually called by a specific name.'

The most obvious way stock car racing differs from circuit racing is that full contact is an integral part and, while cars are designed for speed, this can never be forgotten.

'You're always pushing the boundaries of everything,' says former world champion, BSCDA (British Stock Car Drivers Association) vice chairman and car builder, Frankie Wainman jnr. 'Pushing car set-up, car design, car layouts… everything to get performance.

'But our job is unique, because it's a full contact sport. It's alright having the car as fast as you can get it, but if you get run into the fence and it doesn't come out of the fence because it's bent, it's no good whatsoever.'

Heavy metal

With the above in mind, it's no surprise to learn there's a lot of steel in a stock car, but not of a typical British racecar construction.

'It's actually a flat chassis,' explains reigning world champion and car builder, Tom Harris. 'You can't use a spaceframe in Formula 1. They are very similar to a spaceframe, but you must have two main chassis rails, which are 70 x 70mm box section with 5mm wall thickness, and they have to run from the front of the car to the back, with no cuts in them.'

A variety of steels are used on the chassis, usually high tensile for the front runners.

'We mainly use T45 on the tarmac cars,' confirms Harris. 'One, to get the strength, but two, because you can use a lot thinner wall and keep the strength, so you take a lot of weight out of the car.

'Then you can better balance the car up, putting the weight where you want it.'

The mention of 'tarmac cars' above points to something that may surprise some of you reading this, and that is that at the top level there are bespoke cars built for the two different kinds of surfaces that F1 stock cars race on – loose shale and tarmac.

'With a tarmac car, you want the weight as low down as possible, and the chassis as wide as possible to keep it stable. Whereas on dirt, you want the weight up a little higher so it rolls about more and gets grip that way'

Tom Harris, F1 stock car world champion and car builder

With around 700bhp on tap, crash bars and full contact, Formula 1 stock cars are brutes, but also impressive pieces of race engineering

By MIKE BRESLIN

With powerful V8s and extremely close, full contact racing, F1 stock cars are the most popular category on the UK short oval racing scene

Pictures: Paul Tully Photography; Dave Bastock Motorsport Photography; Colin Casserley Photos; Bresmedia

'There's a specific car for dirt, and another one for tarmac,' says Harris. 'With a tarmac car, you want the weight as low down as possible, and the chassis as wide as possible to keep it stable. Whereas on dirt, you want the weight up a little higher so it rolls about more and gets grip that way [through weight transfer].'

Surface treatment

Stuart Smith, a former world champion who now builds cars, says one of the motives for the two different variations is to cut down on the amount of work involved in changing between the two set-ups, though there are also more fundamental reasons.

'To be right at the top, where you're looking for half a tenth per lap, you really need two cars if you want to compete on both surfaces,' Smith says. 'The biggest reason for this is engine positioning. On shale, you naturally want more rear-end weight because it's quite a slippery surface. The more weight you have on your drive wheels, the more grip you're going to get. It's just simple physics.

'Tarmac is different though. If you have too much rear-end weight, your car will overheat the rear tyres quicker. So, what everybody does with a tarmac car is put their engines as far forward as they possibly can, but then there are rules for this.'

The regulations state that the racecars, which are not especially light, with a minimum weight of 1350kg, must be no more than 55 per cent weight biased to the rear, and only 52.9 per cent biased to the left (in the UK, Stockcars race anti-clockwise on oval tracks).

'That said, we still want people to be able to race on both surfaces with the same car,' continues Smith, 'so we've tried to keep the difference as small as possible. That's why we introduced a rear weight rule on tarmac.

'The biggest difference [between a shale and tarmac car] is still engine positioning, you're probably talking a 10-inch difference.'

'If I take the wing off on tarmac, you don't notice a difference, but if you take it off on a shale car and then go into that corner, you'll spin around in a circle'

Frankie Wainman jnr, BSCDA vice chairman and car builder

Tarmac wings are mounted flat and are regular downforce-producing main planes with large end plates. Opinions are split on how effective these aero devices are at the speeds these cars reach

Shale wings, on the other hand, are huge devices angled to lever downforce onto the inside left rear wheel. They help produce grip, while also aiding stability in a slide

Chassis also tend to be asymmetric, as is common in short oval racing, with a slightly shorter wheelbase on the inside, the left.

Other steel parts of great importance are the imposing bumpers and side rails.

'We need something to give in an impact, so they're interchangeable,' explains Smith. 'You do three meetings and then you cut them off and weld new ones on. It's simply part of the upkeep of a stock car.'

Perhaps unsurprisingly, carbon fibre is not allowed, and the cladding that makes up the vestigial bodywork is lovingly worked by hand in hard aluminium.

'We fold it, we shape it, we bend it,' says Smith. 'It's a very long process doing that, as everything is bespoke.'

Aero or advert?

One place where this metalwork artistry is displayed to the full is with the wings.

'When I first started making wings, we would use a steel frame and then skin it with aluminium,' says Harris. 'Now, the whole thing is aluminium and there's so much more work involved in TIG [tungsten inert gas] welding it. It's a very time-consuming job. But then the weight of the wing is up high, so keeping them light is important.'

High wings are a distinctive feature of F1 stock cars, as is the different approaches between a wing used on the shale and one used for tarmac. The former is very big and set at an acute angle, while the latter is flat and more similar to a circuit car approach.

Amongst racers and car builders, there are widely differing views on the aerodynamic value of wings, with some people quite dismissive about their effectiveness.

'I don't believe it works,' states Newson. 'For me, personally, it's just an advertisement board… We don't go quick enough for them.'

This is not an isolated opinion, though others feel differently. Harris, who also races in Midgets and Sprint Cars in the States, says: 'Racing in America has changed my perspective of the air and the wings enormously. Let's face it, if you hold your hand out of a car window at 50mph you have a job to hold it forward. So, a 4ft x 4ft spoiler at 70mph has to be doing something.'

A Stuart Smith rolling chassis. There are two regulation 70 x 70mm, thick wall, box section main rails running from front to back and a spaceframe-type rollcage construction on top. Bodywork is individually hand formed in hard aluminium

Most do agree that on shale, at least, the wings aid stability in a slide.

'If I take the wing off on tarmac, you don't notice a difference,' says Wainman jnr, 'but if you take it off on a shale car and then go into that corner, you'll spin around in a circle.'

Smith concurs: 'On shale, we enter the corner sideways, and the cars are so heavy that the inertia just makes them want to spin out. The wings stop that happening.

'[With a wing] you can enter the corner faster and, in the apex, they hold the car in. It really does have quite an effect. I once damaged a wing during a race, and then it came off the car, and I noticed an instant difference in the handling.'

Shale wings are not the most subtle of aero approaches, more akin to a sail on a boat.

'If you look at the car from side on, from the offside, the top of the wing is formed so the wind can catch it,' explains Smith. 'It's the height of the wing off the car that does the work. That has sufficient leverage to force the downforce onto the nearside rear of the car, so the wing, with the aid of the wind – obviously – holds the weight on the left rear.'

Nevertheless, it should be noted that the aero approach on the cars Smith builds now is somewhat unusual in stock cars, in that he uses a smaller shale wing that's more like a tarmac version, although still angled, with a downforce-producing profile.

Sideways is best on shale and the brakes are set up for this, with a bias to the rear and front left. Fangio-style four-wheel drifting is the most effective way to race

Shale cars run with a vast amount of stagger on the rear wheels, which can be up to four inches wider on the outside wheel. Chunky rubber is supplied by American Racer, with gravel-spec rally tyres also used on the inside for loose track surfaces

'One [rear] tyre is considerably bigger than the other, which makes it go round a left-hand corner. It won't go around a right, and they're hard to keep in a straight line, but they are *very* good at turning left'

Matt Newson, current F1 stock car front runner and car builder

There is no restriction on the height of the wing, although the overall size is regulated.

Front wings, on the other hand, which are used sometimes and sit on the body of the car, are tightly controlled. Most seem to agree that they are not particularly effective, and Harris, for example, eschews them completely, believing they hinder airflow to the main wing.

With tarmac cars or set-ups, people are even more dubious about the efficacy of the aero, but believe it has its place, even if any performance benefit is marginal.

With cars this heavy, and speeds relatively low (peaking at around 70-80mph), mechanical grip is where the real focus is.

Staggering home

You might reasonably assume that one reason for using a front wing would be to combat understeer. After all, these cars run with a locked differential so a certain amount of push is expected, especially on shale. This is in part countered by the sideways driving style but also, more importantly, a quite 'staggering' difference in the width of the rear wheels and tyres.

'We don't really get understeer,' says Newson. 'We do have a locked diff', but we run tyre stagger. So one tyre is considerably bigger than the other, which makes it go round a left-hand corner. It won't go around a right, and they're hard to keep in a straight line – you have to hold it right – but they are *very* good at turning left.'

The rubber is American Racer control tyres all round on tarmac, but more open on shale.

'The left is open, so you run a [gravel] rally tyre,' says Peter Falding, ex-world champion, BSCDA chairman and car builder. 'The maximum wheel width you can go on the left rear is 10in, while on the right rear it's 14in.'

Axles are often from, of all things, Ford Transit vans. That's not as odd as it sounds. Van and truck parts were once commonplace in the sport, chosen simply because they're beefier, though there's been a move to more specialised equipment recently.

'The latest thing now for the tarmac car is a Ford 9-inch,' says Harris. 'There's not much difference in weight between the axles, but the diffs are a lot stronger in a 9-inch. After all, a Transit never made 700bhp.'

The gearboxes are generally Doug Nash units, or variations on that theme.

'It's a gearbox designed in the US,' says Smith. 'It's a two speed, and we started running them in the '80s. That style of gearbox has been continued by other companies who've [made their own versions of] it.'

The cars actually use one gear for the race, the other being a 'crawler' ratio for driving through the paddock at low speed.

Some have also used the Raptor 'box, although that doesn't have the same flexibility in terms of ratio changes – something that is done surprisingly often. For even though they might look similar, all short ovals have their own characteristics.

'The Doug Nash [gearbox] has a rear end that unbolts and you have two drive gears,' explains Smith. 'You can literally pull them off


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Control Gaz dampers with limited adjustability are used, but most of the suspension set-up is done through spring changes, with softer units preferred on the shale

Ford Transit axles were traditionally used at the back, but are now largely replaced by the venerable Ford 9-inch. Independent rear suspension is not allowed and Panhard rods are a popular locating solution. The differential is locked and all cars use a two-speed gearbox, though only one gear is used during a race

The small block Chevrolet V8 in Matt Newson's car measures 6.5-litres (396ci) and produces 700bhp. Engines are limited to 7500rpm and must run on regular pump fuel

with your hand and swap them to change ratios. We do that for different tracks.

'At the same track, you might have to change gears too, depending on conditions. We do change gear [ratios] quite often.'

Stock control

The rear axle is kept in place with the help of either a robust Panhard rod, a Watt's linkage or a z-bar. Independent suspension is not allowed at the rear, but it is at the front.

Dampers are a control item from UK supplier, Gaz Shocks. These are adjustable, but not high-spec to keep costs down and because of the need for regular replacement after the inevitable damage.

With minimal scope for tuning with the dampers, the springs are where much of the suspension tweaking takes place. These can be anywhere between 250lb and 650lb, depending on the surface and track, but as a general rule of thumb a soft set-up is preferred for shale, and the left front is usually the softest spring.

'On tarmac, you'll run fairly stiff on the front to stop the car rolling,' says Falding, 'but then you also want the grip, so your back will be a bit softer.'

Generally, though, when it comes to suspension, as with most things on a stock car, the need to handle knocks is uppermost in a car builder's mind.

'Because the cars are so heavy and clumsy, if you moved a bracket half an inch you wouldn't notice it like you might on a [circuit] racing car,' says Wainman jnr, 'and you've got to remember you're hitting that wall as well, so it has to be strong.

'There's always a balance between getting the speed and being able to carry on when you're getting whacked into the walls.'

Different requirements for shale and tarmac also show up with the way the steering is set up, being very quick on the loose, for lightning-fast corrections, and slower on the tarmac.

The steering system itself is quite low-tech, again because it needs to be strong.

'We don't use a rack,' says Smith. 'We use steering boxes off vans and commercial vehicles. I think the most commonly used box is off a Chevrolet truck from the '80s and '90s.'

Similarly basic are the brakes, which originated on a 1980s Transit van, while the pads are spec fast road items.

The brakes also need to be set up in an unconventional way for the sideways driving style required on shale.

To keep costs down, iron blocks and a single four-barrel carburettor are used. You're also only allowed a single cam, and two valves per cylinder. Otherwise, people are free to do what they like

'Your brakes are balanced to actually induce a spin into the car, so we have more braking on the front inside and on the rear axle,' confirms Smith. 'We have valves to shut off the front outside on shale so, if you go in a straight line and stamp on the brakes, the car will turn left and spin out.'

The driver can adjust the bias during a race, as the conditions change, but with what are basically road pads and a 1350kg car the engine also needs to be used to help with slowing down.

Stock cubes

It's because of a relentless search for more engine braking that a rev limit of 7500rpm, which is monitored by a control MST ECU, was introduced.

'We put a rev limit on the engines because people were revving them to 9500rpm, which does give you more engine braking,' says Wainman jnr. 'We've also got to use pump fuel [which can be boosted to 101 octane with additives], which then limits your compression ratio to 10.5 [or] 11, tops.

'With pump fuel you can't run a lot of compression, and that is a big factor with our engines, because it keeps everybody a little bit grounded. If they could run race fuel, you'd be up to 850-900bhp'

To keep costs down, iron blocks and a single four-barrel carburettor are used. You're also only allowed a single cam, and two valves per cylinder. Otherwise, people are free to do what they like inside the engine. All of this means that policing the power units is vastly simplified.

'You can check if it's a steel block with a magnet,' says Falding. 'You can tell by the rocker covers whether it's a quad cam, or whatever. So it's all visual checks. It's not like we need to strip an engine down to see what's in it. There are guidelines, but it's all around the outside of the engine.'

There is no restriction on engine choice in F1 stock cars, but all are American V8s, with small block Chevrolets being the preferred option for most. These engines can produce up to 750bhp, but most are in the 600-700bhp range, with roughly matching torque figures in ft.lbs.

'Some people still have big block Chevys,' says Newson, who also builds engines. 'Mine are all small block. Basically, a big block is cheaper and easier to get horsepower out of but, if you can tune a small block to the same horsepower, you've immediately got a 50kg weight advantage.

Bore and stroke

'However, to tune a small block to that level of performance costs a lot of money. Mine is 6.5-litre, but you can do anything, from a standard 5.7 (350ci) small block right up to a 7.0-litre (427ci) small block. All the parts to do that are readily available and you can bore and stroke them to whatever size and combination you wish.'

Power isn't everything in stock cars, though, as there are other limiting factors.

'My engine has 700bhp,' says Newson, 'but some of that is probably wasted, in terms of what I can actually use on track. Some of the other cars have 550, but the tyres will only take so much. Some people think if you've got more horsepower you will be quicker, but it doesn't work like that in stock cars.'

Because of these smart engine regulations, it's quite easy for someone on a budget to compete in stock cars, though maybe not at the highest BriSCA F1 level, where the annual spend can be as steep as the shale-spec wings.

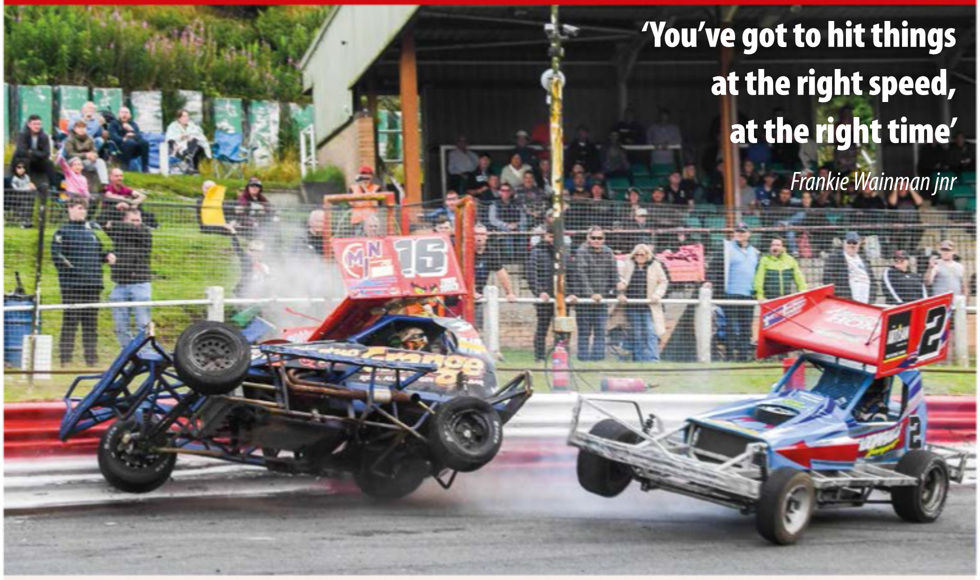
Stock market

It has proved difficult to nail down actual racing budgets, but the cost of a car can be anywhere from £20,000 (approx. US$25,125) to £80,000 (approx. $100,500), with £50,000 (approx. $62,825) seemingly an average price for a brand new one. Second hand, they cost considerably less, but that depends on spec.

There are also plenty of opportunities to race, with a meeting somewhere in the UK pretty much every weekend from March to November, most attracting around 40 entries, with up to 70 turning up for the bigger events, which draw large crowds.

However, if you were looking to switch from engineering a circuit car to running a stock car, Newson has a word of warning: 'I don't care what motorsport you're into, it will not immediately come right with a Formula 1 [stock car]. You can talk to people who are very motorsport mechanically minded, and they'll turn around and say, "You must do this, you must do that." With a stock car, it's not like that. They've got their own set-up. It just won't be the same.'

Bump steer



'You've got to hit things at the right speed, at the right time'

Frankie Wainman jnr

Matt Newson is punted into the fence – a regular occurrence for competitors in BriSCA F1 Stock Car races. However, a more subtle approach from the vehicle behind is generally thought to be more productive when 'pushing to pass'

Contrary to popular opinion, there is a real skill to hitting another car in F1 stock car racing. Basically, it's about trying to induce understeer in the car in front, but to do so correctly you need an almost delicate touch.

'You want to be tapping that car wide enough to get past it, but you want it to come back in behind you without letting other cars through, too,' says Wainman jnr. 'Otherwise, you're just clearing a way for others to follow.

'You've got to hit things at the right speed, at the right time. If you get them coming into a corner, just as you're braking, you're using him to take your speed off, too. So your lap time hasn't altered, but you've moved a car.

If you start going into cars heavy and hard, though, you're just going to slow yourself down.'

With reverse grids based on grades (shown by the colour of the wings), nailing down this aspect of stock car race craft is crucial.

'People think it's easy just to run into someone and overtake them, but it's not,' adds Newson. 'If you hit someone and don't know how you're doing it, you just help them around the corner.

'There's quite a skill in hitting them wide and passing them. You're trying to knock them off the line, but not interrupt your own line. There's an art in what you're doing with the brake, throttle and steering whilst you're hitting them.

'Nine times out of 10, they'll never hit the fence. You will just hit them, they go off the line and you go through underneath them. That's what you're trying to do. But obviously the guy behind you is trying to do the same thing to you…'

Top cars like Frankie Wainman jnr's machine (no.515), seen here mixing it up with another stock car on the shale, cost between £50,000 and £80,000 to buy, though second hand ones are available for much less. Regular repairs are an accepted part of the sport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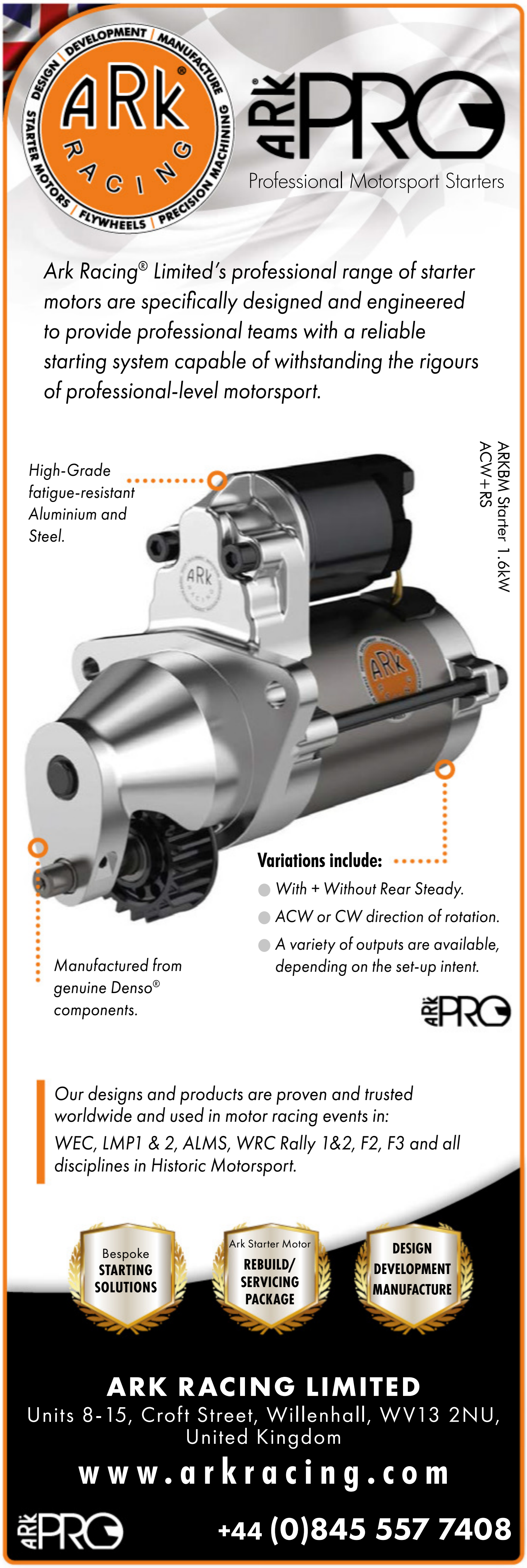
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Cutting edge

From the back of a Chinese takeaway to a 500-employee business, UK transmission specialist, Xtrac, has come a long way in 40 years

By DANIEL LLOYD

The company's factory site at Thatcham, UK, puts Xtrac right amongst the British motorsport industry's key players

Xtrac

Each day, employees entering Xtrac's design office pass a wall-mounted layout drawing for the company's first racecar transmission. The G4 gearbox was developed by former Hewland engineer, Mike Endean, for rallycross star, Martin Schanche's four-wheel-drive Ford Escort. The plan serves as a reminder of where Xtrac started, and how much it has grown in the 40 years since.

Now entering its fifth decade, the British transmission manufacturer has an increasing staff count of almost 500 employees, two regional outposts in the United States and several long-term supply deals for major series. It currently builds the transmissions for IndyCar, NASCAR, Supercars, RX1e rallycross, all LMDh cars, most LMH cars, several in Formula E and more.

In recent years, the company has diversified into the high-performance automotive sector with several electrification projects and boasts an impressive factory in the UK. And it all started with that hand-drafted design for the G4, which enabled the spectacular Schanche to win multiple European Rallycross rounds in the 1980s.

The first Xtrac headquarters were a small workshop around the back of a Chinese takeaway in Wokingham, a town outside London. Its first gear-making equipment came from a company called MEH in nearby Staines, which was closing down and selling off assets after one of its directors died.

That machinery enabled Endean to build components in small quantities, mostly for off-road motorsport.

The name Xtrac only emerged after the G4 gearbox had started racing in 1983. The story goes that Endean lightheartedly told the revered British motorsport commentator, Murray Walker, that his as-yet-unnamed firm was called 'Mr X's Traction Company'.

Walker then ran with it, going onto the broadcast and spurting out 'Xtrac' for short. The impromptu, catchy moniker stuck and Endean, together with his wife, Shirley, established Xtrac Ltd on June 15, 1984.

Early doors

One of the company's earliest employees was Peter Digby, who became its managing director and is now its president. At the time, Digby was factory manager with Williams and assistant managing director at Haas Lola. Both teams ran Hewland gearboxes, giving Endean and Digby a connection. When Carl Haas shuttered his short-lived F1 operation in 1986, Endean reached out to Digby with an offer.

'Mike called me,' Digby recalls. 'He said, "I know you've been running a factory with 100 people. How do you fancy working in a factory with four?"

'I came and joined Mike behind the Chinese takeaway. By then, he already had this amazing vision and had found a site near Finchampstead [Hogwood Lane] where he had reserved a plot of land and started looking at building work to put up our first factory, which was about 9000ft.sq.'

That was quite large premises for such a small company, so Xtrac initially rented out a quarter of the floor space to a sub-contractor to help with cashflow. But then, as it adopted more projects, it steadily filled the new facility, leaving the workshop behind the Chinese takeaway for good in 1987 and officially moving to Hogwood Lane.

Off-road racing gave Xtrac most of its early business, and the popular Group A rally category of the 1980s was an important source of income. According to Digby, road car gearboxes at that time were totally unsuitable for rallying applications.

So, building on the international success of the G4, Xtrac entered partnerships with the likes of Mazda, Toyota, Opel and Mitsubishi, with which it also collaborated for the Dakar Rally. As manufacturers noticed the reliability gains from a specialist racing product, Xtrac found itself with plenty of welcome work.

'We were bringing in one new person every two to three weeks,' recalls Digby. 'We couldn't afford to buy machines because we were so small, so we would go to these [car manufacturer] customers and say, if you want to have that gearbox, we need this much up front for design, tooling etc.

'We would then take that money and go to a machine tool supplier, quite often having to wait until they brought out the right CNC machine for the job.'

Gearboxes were coming out of the Hogwood Lane site left, right and centre. However, one limiting factor was the lack of in-house heat treatment capabilities.

So, in 1988, Xtrac purchased a heat treatment plant, cutting out an area in which it relied on sub-contractors and increasing its production efficiency.

As the company grew, it branched out from rallying and set its sights on Formula 1. It had made a few F1and IndyCar parts in the early days, for the likes of Haas and Penske, but not an entire transmission. That changed in 1989 when Onyx contracted Xtrac to develop a transverse gearbox for its F1 car. The connection was designer, Alan Jenkins, who switched to Onyx from Penske where he had liaised with Xtrac on producing parts in the mid-1980s.

'Then we were approached, almost at the same time, by McLaren,' remembers Digby. 'Pete Weismann had designed them a new, revolutionary gearbox and they were making gears, but having some issues. McLaren decided to do a back-to-back test. Allegedly, ours lasted longer.

'So, overnight, we had a massive order in from McLaren, which was a real challenge. Then, within a couple of years, we had six Formula 1 teams that came to us.

Karl Zemlin / IndyCar

IndyCar is Xtrac's longest single-supply customer. This year, the P1359 gearbox will replace the outgoing P1011 to coincide with the arrival of hybrid power

Xtrac supplies components to most of the Le Mans grid, including all Hypercar transmissions, except Peugeot

The last Xtrac F1 gearbox was the P1044, a seven-speed sequential with 340Nm of maximum continuous input torque capacity used by Lotus, Hispania and Marussia

'Overnight, we had to build 100 [IndyCar] gearboxes very quickly with all our own money, before we sold one. We were bursting at the seams'

Peter Digby, president

'Nearly all of the work was bespoke at that point. We had Benetton, McLaren, Tyrrell, BAR, Williams and Jordan on the books. That was probably our peak of Formula 1.'

Xtrac is still involved in F1 today, supplying torque-carrying steel internal gearbox components to 'a number of successful teams.'

The company pushed in the past for F1 to adopt a single gearbox supplier, as other series have done, but that didn't materialise.

'We've spent big, six-figure sums trying to convince the teams of the benefits,' admits Digby. 'Outside of F1, the whole one-make gearbox has grasped most of the motorsport industry. Why wouldn't you do it? It just benefits so many areas.'

Sole supplier

Nevertheless, single-supply contracts are where Xtrac really accelerated its growth heading into the 21st century. In 1999, IndyCar enquired about a standardised gearbox to try and prevent development wars and reduce costs for teams.

'Gearboxes in those times coming from Lola and Reynard were about US$150,000 for a spare,' says Digby. 'If you bought it with a car, it was a bit cheaper, but the organisers wanted to get on top of this.

'We basically put together a package that said, if you allow us to have a five-year contract, overhauling the gearboxes and supplying them exclusively, we can do it for under $50,000 [per unit].'

Xtrac built some test parts and convinced IndyCar to start the contract. This was a huge scoop for the British company and helped further its worldwide reputation in motorsport.

'Overnight, we had to go and build 100 gearboxes very quickly with all our own money, before we sold one,' Digby recalls. 'We were bursting at the seams.'

The huge increase in workload that came with the IndyCar deal had Digby out every Sunday morning on his motorbike looking for a potential new factory location.

He eventually came across a 13-acre industrial site in Thatcham, Berkshire, and decided it was suitable for the next stage of the company's expansion. Ridge & Partners, the architect for most F1 team headquarters in the UK, put the 88,000ft.sq factory in place for staff to move in by the summer of 2000.

Three years later, Xtrac opened its first American outpost in Indianapolis to service the IndyCar transmissions. However, this rapid expansion came with a financial cost.

'We needed to finance all these IndyCar gearboxes,' says Digby. 'We also needed the machinery that was going to come into this factory… so we took on board our first private equity partner, which was HSBC Private Equity [later called Montagu]. They came on board and took a 25 per cent shareholding and helped us finance the growth and obtain the security we needed.'

The IndyCar deal came after Xtrac had already expanded into other areas of motorsport. The company made its first complete 24 Hours of Le Mans transmission for the Peugeot 905, developing a six-speed sequential manual for the first time.

It also went on to supply the GT1-class McLaren F1 GTR, and then many LMP entries towards the end of the 1990s, including ones from BMW and Toyota.

In parallel, Xtrac was building front and rear sequential transmissions for several BTCC cars, and eventually moved to a single-supply contract for the series that it still holds today.

'We then decided to take sequential to rallying,' says Digby. 'Most of the drivers said they didn't want that, but we built a gearbox mock-up to show them that you could go from sixth to second as quickly as you could on an H-pattern, but without blipping the engine. It was transformational at that point. Nobody looked back after that.'

Covering various categories and adapting the gearbox technology to suit different vehicles' demands helped increase Xtrac's reputation across motorsport. Its products were often not the cheapest option, but its selling point has always been reliability, which makes it cost effective in the long run.

Automotive expansion

Despite hailing from motorsport, Xtrac has ramped up its high-performance automotive (HPA) business in the last two decades. According to company CEO, Adrian Moore, years of working on hard and fast motorsport deadlines enabled Xtrac to be agile in reacting to road car projects which tend to be more fluid from a timing perspective.

'The core of the business is still motorsport,' he says. 'It gives us the customer focus, the reaction time and the ethos.'

However, the automotive side is growing.

'Today, we're about 60 per cent motorsport and 40 per cent HPA,' adds Moore. 'That HPA percentage is growing, but not at the expense of motorsport shrinking. It will be more like 50 / 50 in a couple of years.'

Since its first electrified powertrain project for a Tesla prototype in 2006, Xtrac has also increased its EV and hybrid workload, and this will soon overtake internal combustion.

'As legislation changes, we're still small and agile enough to react... We're ambivalent as to which way regulations go, it just depends what the customer wants'

Adrian Moore, CEO

According to Moore, the split last year was about 65 / 35 in favour of IC, but now they are on equal terms. Top-level motorsport series adopting hybrids, such as LMDh for IMSA and Le Mans, has been a big part of that swing.

Hydrogen has also recently emerged as an option and Xtrac has started developing transmissions for hydrogen combustion engine prototypes, such as the Alpine Alpenglow HY4 that is covered in this issue.

'As legislation changes, we're still small and agile enough to react to that,' says Moore. 'As well as IC, our capability is transmissions for those three [hybrid, electric and hydrogen propulsion systems]. We're ambivalent as to which way the regulations go, it just depends on what the customers want.'

Mechatronic age

Nowadays, Xtrac doesn't just sell transmissions. Last year, it formalised a dedicated mechatronics department for its automotive customers, who were increasingly requesting turnkey solutions such as control systems, gearshift mechanisms and clutch actuators.

'HPM [high-performance mechatronics] has two focuses: one is motorsport, which is really actuators, and the other is automotive, which is the turnkey package,' Moore explains. 'That moves towards a gearbox having an electric machine that's part of the supply.

'On our HPA gearboxes, for example, one of the products we build has a hydraulic gear change system. That leaves here with the clutch in place, the clutch bite point set, and every parameter set on the gearbox. Our end-of-line testing sets all of those, and we just plug it in the road car, and it works.

'That's a different requirement compared to motorsport and is where a lot of our development has gone, in terms of bringing capability in-house. We have software engineers, electronic designers and control system engineers. In the last couple of years, that has been quite a big growth for us.'

Currently, Xtrac produces a quarter of a million components annually – that's almost 5000 weekly, or 685 daily.

Before any part is manufactured, it is conceptualised in the design office. There are 90 engineers working in this department,

Xtrac

This Kapp Niles VX-series, 90-degree profile grinding machine allows for sequential roughing and finishing tool use

Xtrac

Heat treatment of parts is all done in-house, and is gradually moving towards the low pressure carburising solution

with about a third of them on motorsport projects and the rest on high-performance automotive. The gear design engineers, R&D, system engineers and analysts float between the two, depending on the project.

Downstairs from the design office sits the production office, where manufacturing plans and quality control are directed. Since each project contains sensitive customer information, Xtrac has high security data systems in place such as multi-layer authentication and encryption.

Unsurprisingly, the manufacturing area utilises the most space at Thatcham. It is constantly evolving, with new machines regularly being introduced or re-positioned for efficiency. A wide walkway runs along the length of the factory floor and serves as a gateway between the offices and machinery on the other side. Along the walkway, project timelines are laid out on whiteboards. With so many projects on the go, it's important that schedules are communicated clearly so they are executed with minimal delay.

'They give a day-by-day rundown of what is going on in the factory,' explains principal engineer, Nick Upjohn. 'It's all trackable, and constantly monitored, and that feeds back to the operation control centre (OCC) office so, if there are any issues, we can solve them immediately, trying to cut down on time lost.'

Factory landscape

Xtrac has high-grade steel supplied to its own specifications, and holds stock of about 200 tonnes at any one time, ensuring it has enough to ride out any supply chain dramas.

On the manufacturing floor, gear-cutting machines stand like towers above a network of narrow walkways, through which technicians and engineers commute between the different stages of manufacture – turning, milling, gear cutting and heat treatment.

Once a part is designed in CAD, its first step towards manufacture takes place in the turning department. This consists of nine Okuma CNC lathe machines, which receive inputs from a turning program.

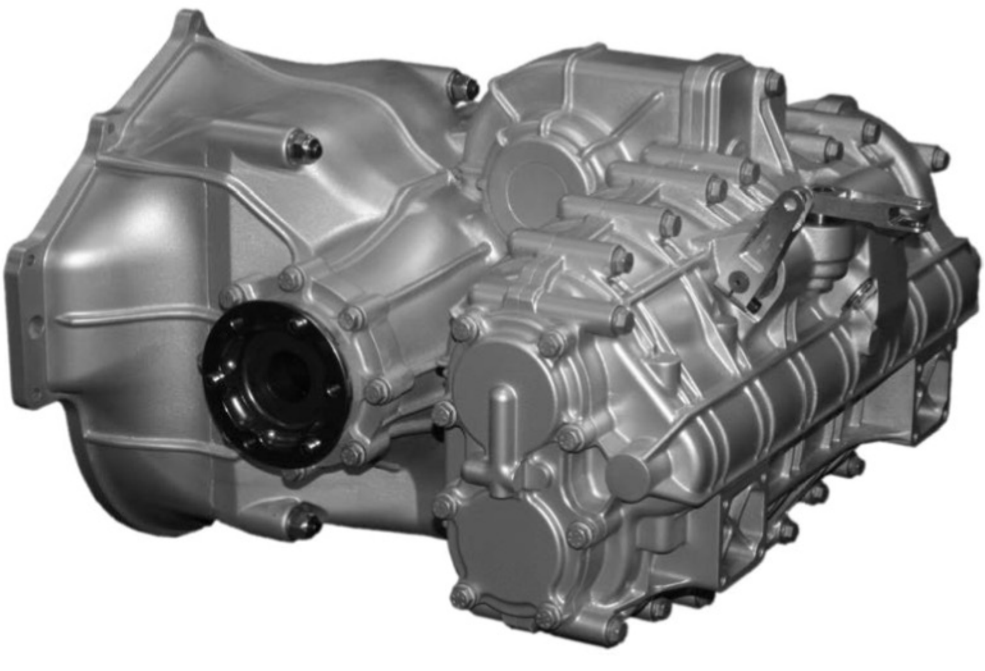
Xtrac

The cityscape of towering gear cutting and grinding machines dominates the factory floor at Xtrac's Thatcham manufacturing base

Xtrac

Mechatronics and control systems solutions mean Xtrac's business today is not only about supplying gearbox parts

Xtrac



High-performance road car work has increased in recent years. Xtrac announced its 6012 transverse transaxle in 2006

'We've got multiple coordinate measuring machines, which are used to measure our parts,' says Upjohn. 'They validate that the program is machining the part how we want it. That way, if you've got an error in the program, you can correct it and account for any discrepancies in your next turning operation. It's a nice, closed-loop system. A lot of work will be done here before any issues present in our manufacturing support office.'

Next is the milling department, where over a dozen mills cut and remove material to define the part's shape, be it a bearing retainer or a gearbox casing.

'We have a huge array of mills,' says Upjohn. 'Anything from small, three-axis manual mills for simple parts, all the way up to five-axis machines that can accommodate a one metre cubed work piece.'

Cutting teeth

Once a blank part has been made, it is taken to the shaping, or hobbing, departments where teeth are cut into it by up and down movements. It takes about 15 minutes to produce a spline of 30mm diameter.
Some gears can have as many as 150 teeth, and there are different cutting methods employed, including broaching and hobbing machines, which use rotary cutting tools.

'One of our most exciting machines is our bevel grinder,' adds Upjohn. 'In the very early '90s we invested in the latest technology Klingelnberg bevel cutting machine that could cut the bevels soft, and then finish the teeth very accurately after heat treatment. That was a really key step in enabling us to bring in house every manufacturing process.

'Around 15 years ago we invested in a bevel grinding machine from Klingelnberg, and then a few years ago a second machine.'

That's not said lightly when you hear the bevel grinding machines cost in the region of a million pounds (approx. $1.267m) each.

'Our Klingelnberg G30 CNC spiral bevel gear grinding machine was the first in the UK,' says Upjohn. 'We dress the form of the tooth we would like onto the wheel, and it then form grinds the material away. It's an abrasive process, as opposed to a metal chipping one.

'We then take it to our inspection department and a probe will measure where it's incorrect vs the true perfect form. It will then send that information back to the first machine, which will administer corrections to make it the perfect shape. It's a closed-loop system, right back to the original design data, which enables our engineers to refine the design for optimum strength, wear, efficiency and, for automotive applications, low noise.'

Heat treatment

Once the gear has been produced, heat treatment is employed to realise the intended material properties of hardness, ductility and strength. Xtrac uses two types of heat treatment furnace technology, both of which use electrical elements to heat to the correct temperature: a seal quench furnace (of which the company has three) and a low-pressure carburising furnace.

The heat treatment process creates a reaction in a gaseous environment that produces carbon, which infuses into the gear's surface when the heat is raised up to around 1000degC. The latest technology, low-pressure carburising furnaces are newer to Xtrac, having only been introduced within the last six years, and can provide a more precise process than the older, but well proven, sealed quench furnaces through their gas quenching process, rather than the oil quench of the older equipment. There are currently two in operation, all feeding off a dedicated electricity substation.

Once heat treated, most parts, including gears, are processed through shot peening to improve their fatigue resistance and prolong their lifespan. This aerospace process involves firing tiny shot pellets at the gear surface and creating surface tension.

Off limits

Heading back out to the main walkway, greyed-out windows on the office side signify the R&D department. Of course, this most interesting of rooms is strictly off limits to outsiders, but we are told it contains testing apparatus, such as a four-square rig, a gimbal rig and a quasi-transient differential test rig (QT-DTR) that customers and Xtrac both use.

The factory also houses two fully loaded, transient powertrain test rigs, and multiple rigs used for end-of-line gearbox testing.

'Having the R&D facility here in-house brings people in,' indicates Upjohn. 'You get them in the door and show them around, then maybe – hopefully – bring them on board as a customer.'

Around 15 per cent of Xtrac's current employees started their careers on the company's apprenticeship and undergraduate schemes

Next door is the Xtrac Academy: a practical training area for level two and three apprentices with manual and CNC machines for making non-production parts, and computer-aided engineering (CAE) training areas. Xtrac takes on around 10 apprentices per year, and a high proportion go on to stay with the company. As an example, Xtrac's first apprentice from the 1990s, Simon Short, is now head of its Indianapolis build shop.

Upstairs from R&D and the academy is Xtrac's motorsport build area, where gearboxes are put together. Five years ago, it was the assembly shop for all the company's products, but the increased HPA workload has correlated with a significant investment into a dedicated automotive gearbox assembly line located in a different area.

At the time of our visit, sportscar gearboxes are being assembled for Le Mans. Also visible is a huge, 3D-printed casing built for the 932kW Czinger 21C electric hypercar (an industry first as most gearboxes use L169 aluminium). This makes a fitting bookend to the G4 layout encountered at the top of our tour. Gearbox technology has come a long way since Endean's first innovative product and Xtrac has been a key part of furthering reliability and performance in many categories during that time.

As motorsport looks to other powertrain and fuel solutions for the future, Xtrac is well positioned to remain at the forefront of transmission design.

The factory houses two fully loaded, transient powertrain test rigs, and multiple rigs used for end-of-line gearbox testing

Evolving business

Xtrac's growth has been stimulated through structural changes. The first major shift occurred in 1997 when Digby led a management buyout of the company whilst Endean stepped back. It involved Xtrac selling 49 per cent of its shares to the shop floor, while retaining 51 per cent for top management to maintain quick decision making.

'Mike pledged us that we wouldn't give ourselves any pay rises, and all the money would be spent on machinery,' Digby recalls. 'We needed his permission to buy a new machine. It set us on this path that is still going, and we are still taking on a new employee every two or three weeks.'

The employee share model continued after Montagu bought its 25 per cent stake in 2000. The private equity company was onboard for 13 years and, according to Digby, enabled Xtrac to 'grow up' and expand its manufacturing, commercial and financial departments. After Montagu's exit, Digby became company chairman and then president, and in 2015 appointed Moore, previously technical director, as managing director to lead another management buy out and further re-structuring. In 2017, Inflexion Private Equity invested in Xtrac, facilitating an expansion of the manufacturing plant and a tripling of revenue from electrified powertrains.

'We still were employee owned in that time, but we ended up wanting an investor in the business,' explains Moore, who became chief executive in 2018. 'The reason for that stems back to the early 2010s when we were still a motorsport business, but we could see the automotive and electrification leads coming at us and needed investment to fulfil those customer needs.'

Inflexion's influence lasted six years and was shortly followed by MiddleGround Capital purchasing a majority stake in 2023. These outside investors have enabled Xtrac to maintain its spread into automotive and electrification, which is set to continue.

Follow the leader

Racecar *investigates the dramatic effect Gen3 is having on Formula E race strategy*

By GEMMA HATTON

Formula E has always been a battle of energy management, but its latest evolution of racecar has transformed the racing into a chaotic peloton, with more on-track action than ever, throwing conventional race strategy out the window.

The regulations in Formula E have been written to force teams to utilise the energy from the battery as efficiently as possible. Before each race, the FIA dictates the number of laps and the amount of energy teams are allowed to use. Typically, this is around 25 per cent less than what is needed to complete the race, which is why they need to implement energy management techniques and also regenerate energy to ensure they reach the finish line.

In *RE* V34N6, we delved into this complicated world of energy management and walked through how teams calculate lap energy targets. Essentially, these are the kWh of energy the driver *should* consume per lap to use all the energy available in the battery in the fastest total race time.

However, these energy consumption targets vary according to the car's efficiency, as well as track evolution, tyre degradation and the slipstream effect of other cars. Consequently, teams spend much of their time trying to understand these influences.

These are then modelled via a frontier plot, which illustrates the relationship between energy and lap time. Engineers use this plot to identify the lap targets that allow the driver to save energy, for the least possible lap time penalty.

ISO metrics

In the Gen2 rule set, energy management strategy was relatively simple. The key to winning was to ensure the driver utilised every kWh of allocated energy in the most efficient way possible to achieve the fastest total race time. This typically led to so-called 'ISO' races where the lap energy target remained relatively constant throughout.

'To calculate the ISO lap energy targets, you basically take the amount of energy you have available – which is specified by the FIA for each race – and divide that by the number of laps,' explains Cristina Mañas, head of performance and simulation at Nissan Formula E Team.

'In Gen2 we had 45-minute, time-based races, so the number of laps also depended on the pace of the leader. However, in Gen3, the FIA define the number of race laps.

'This effectively gives an ISO target, which means the driver has to drive to the same amount of kWh every lap to run the most efficient race from start to finish.

'This leads to a standard energy profile. An energy profile is made up of three phases: accelerate, lift and regenerate. For an ISO race, this profile is the same lap after lap, so all the coast and braking points are the same.'

The majority of races in Gen2 were ISO races and so, although energy management was vital, the lap energy targets were a relatively easy calculation. Only if the pace of the leaders was significantly different to what was expected did teams have to adapt their lap counts, and therefore energy targets.

Different strategy

The introduction of Gen3, however, has turned this approach to strategy upside down. Races are no longer won by simply achieving the fastest total race time for the allocated energy. Instead, the winner is the first to cross the finish line, even if they have excess energy on board.

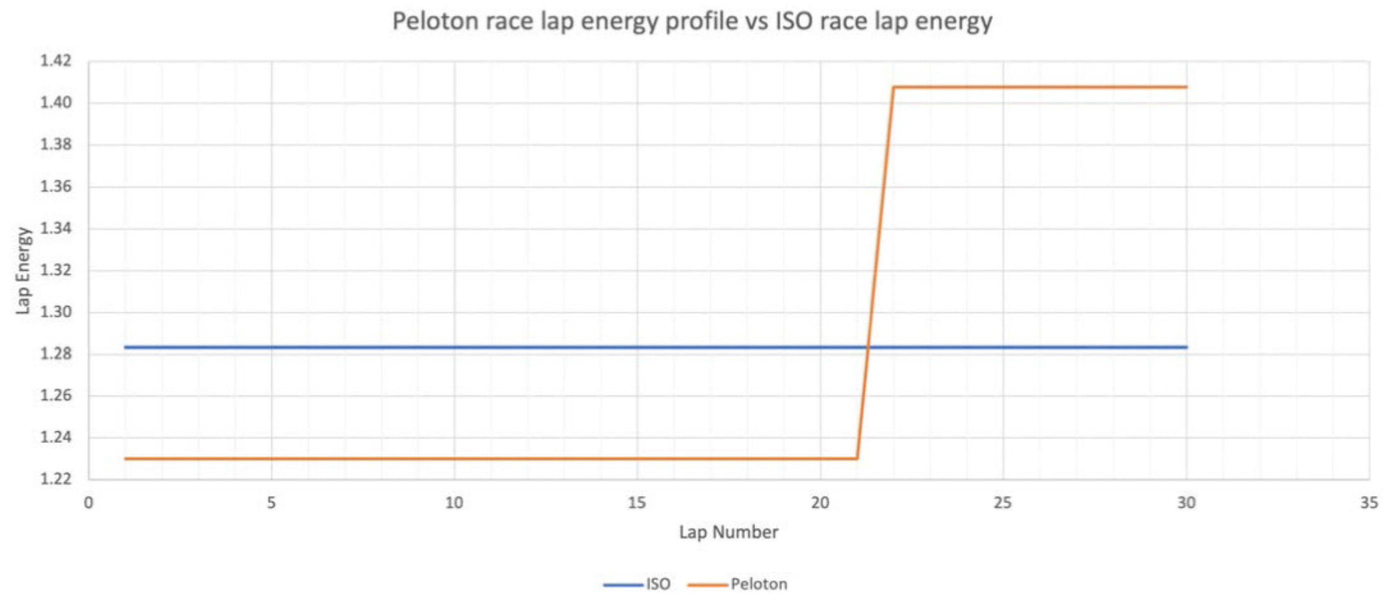
On the face of it, this sounds like a much easier strategic problem, but the reality is far more complex. Essentially, no driver wants to lead, so the pack bunches up as everyone jostles for position, navigating the tight street circuits three or more cars wide. Then, at a seemingly random lap, a driver will suddenly break away, triggering a near flat-out race and, if you haven't saved enough energy by that point, you come home last. Simple as that.

[Gen3] races are no longer won by simply achieving the fastest total race time for the allocated energy. Instead, the winner is the first to cross the finish line, even if they have excess energy on board

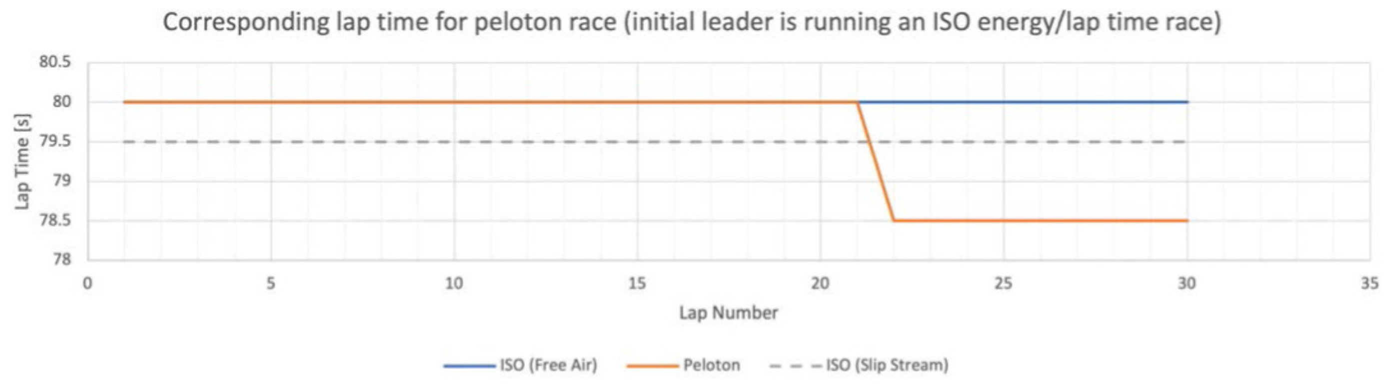
'It's difficult for us as engineers to define the perfect strategy, so it comes down to the drivers more to judge when they can make up positions efficiently, and when the pace of the race starts to change'

Cristina Mañas, head of performance and simulation at Nissan Formula E Team

The more power and higher drag of Gen3 is leading to peloton-style races where the pack bunches up as drivers save energy and wait to see who makes the jump for the line first



The graph above shows the lap energy profiles for a driver in free air running an ISO race (blue) and a driver in the slipstream running a peloton race (orange). It is clear that by sitting in the slipstream, the orange driver consumes less energy and has enough deficit to overtake on lap 21 and then use more energy to achieve faster lap times (shown below) for the rest of the race



'It is similar to criterium racing in cycling,' says Roger Griffiths, team principal of the Andretti Formula E team. 'The leader manages the pace to build up energy, so the lap energy targets increase. Then, at around 70 per cent through the race – although it varies from track to track – once you've saved enough energy, you can go flat out until the end.

'The difference in lap time between the first and last laps of the race can be as much as six seconds, so now a Formula E event really is a race of two halves.'

Behind the change

So, what is it about the Gen3 car that is causing this new style of Formula E racing?

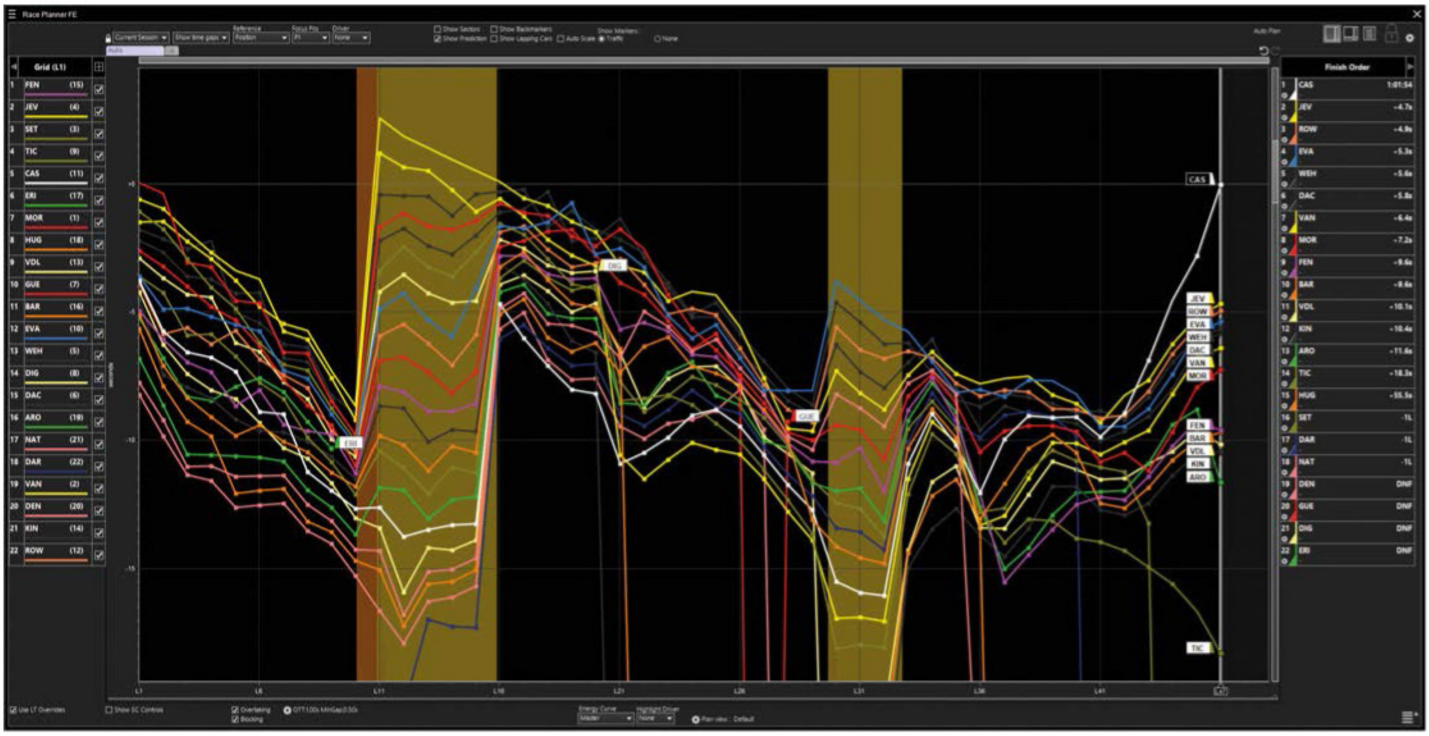
'The biggest difference between Gen2 and Gen3 is the power limits, which cascades into a higher drag effect on the cars,' explains Mañas. 'We can now regenerate more power – 600kW compared to 250kW – and maximum power output has increased from 250 to 350kW.

'So, for the same amount of braking torque demand, we can regenerate more power, which we can then discharge on the straights, allowing us to reach higher speeds over the same distance.'

Sitting in the slipstream of the cars ahead is now vital to saving enough energy to overtake and then hold position later in the race

According to data published by Formula E, the top speed of a Gen3 car is 322km/h (200mph), compared to 280km/h (174mph) for Gen2. Although some teams have commented that Gen3 cars are slightly slower than this quoted figure in reality, it is still significantly faster than Gen2.

As we know, drag force is proportional to the square of speed, so the faster a car travels, the higher the drag force resisting it. Consequently, the car needs to consume more energy to overcome this drag force to achieve the same speed. In practice, this means the leader in free air experiences more



This RaceWatch race planner illustrates how chaotic the peloton races can be, with Cassidy (the white trace) saving enough energy early on in the race to move from 21st position into the lead

drag and therefore consumes more energy relative to the drivers behind, while a driver sitting in the tow of a car experiences less drag and consumes less energy. This banked energy can later be used to overtake during the faster phase of the race.

Drag act

'The [Gen3] car is a different concept of car, and consequently is a little bit more draggy compared to Gen2,' says Griffiths. 'We now have exposed front wheels, we've got a bit of a parachute above the driver's head and several slats in the engine cover. All this reduces the aerodynamic efficiency of the car, which adds to the drag penalty of leading.'

The energy consequences for being at the front early on are so damaging that, in some cases, drivers have voluntarily moved aside to hand over the lead of the race.

'The sensitives are so large now that you really can save a substantial amount of energy by being in the tow,' explains Ash Willoughby, senior energy management engineer at ERT Formula E team.

'If you are the race leader, the most efficient way to run the race is to follow the ISO energy target, which is the optimum point on the lap frontier. However, drivers behind sitting in the tow can travel at the same pace without consuming as much energy, which gives them an advantage.

'Let's take some simple numbers and assume that the driver behind saves 0.05kWh of energy each lap. If they spend 20 laps behind the leader in a 30-lap race, they will save a total of 1kWh, which is a huge saving.

'Consider that the available race energy in Gen3 is now 38.5kWh, 1kWh is almost three per cent of the total race energy that they've banked, simply by sitting in the tow.'

This saved energy increases the lap energy targets for the remaining 10 laps, so the driver has much more energy available for the rest of the race compared to the leader.

'Everyone is now trying to save energy by following someone else until the point where they have stored enough energy to achieve sufficiently quick lap times that allow them to overtake and defend until the chequered flag,' continues Willoughby. 'It has now become a game of who can get to that point the fastest.'

The go point

Establishing the point at which a driver has enough energy to drive flat out towards the end of the race constantly changes, but is relatively simple for the teams to calculate for their own cars. There is no live telemetry in Formula E, so the driver updates the team with energy information each lap via coded messages, which the teams then use to adjust the lap energy targets.

The trick, however, is predicting the 'go point' of the rest of the field, and then using this knowledge to outpace them to the line.

'The [Gen3] car is a different concept of car, and consequently is a little bit more draggy compared to Gen2'

Roger Griffiths, team principal at Andretti Formula E

'We try to monitor the energy buffer our drivers build up throughout the race and then estimate when we can afford to spend energy on overtakes,' says Mañas.

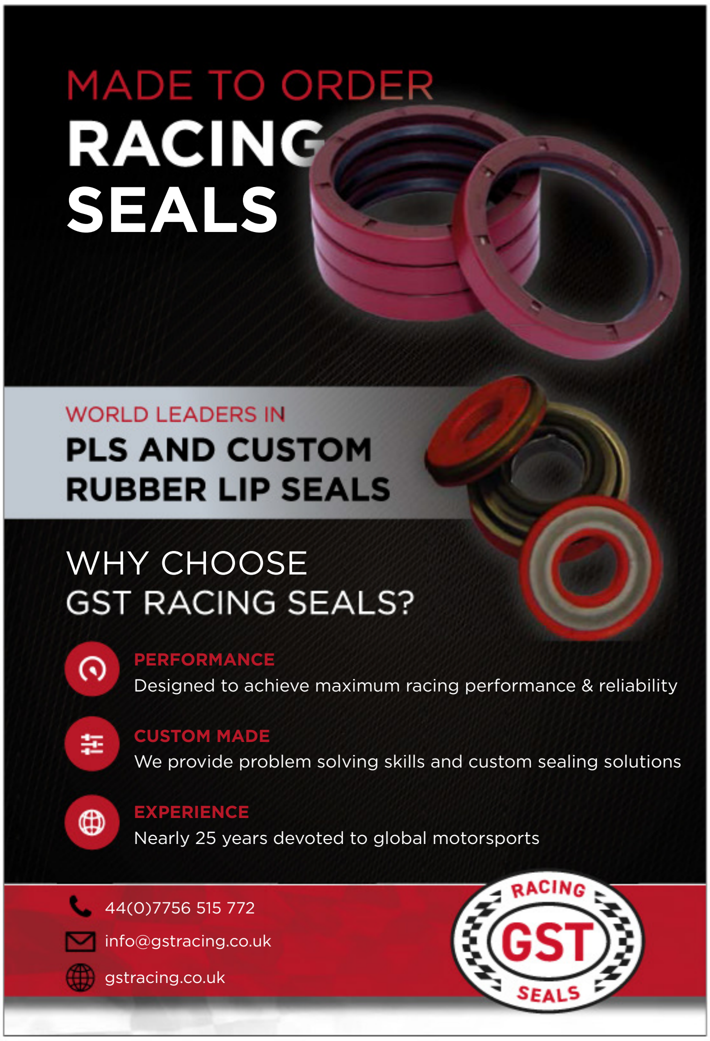
'You then have to factor in that to move through the field, the drivers need to overtake and, with the pack so bunched up, there is a high potential of crashing.

'It's difficult for us as engineers to define the perfect strategy, so it comes down to the drivers more to judge when they can make up positions efficiently, and when the pace of the race starts to change.'

'Another thing to consider is that it becomes increasingly harder to find those overtaking opportunities when the race enters its flat-out phase,' adds Griffiths. 'It is relatively easy to overtake when drivers are saving energy, because they coast into corners, or you can choose to deploy more energy relative to them when you want to overtake. But when you get to that faster part of the race, overtaking can be almost impossible so, if you're not near the front of the pack at the point it starts to break away, it can be game over.'

Strategic command

As teams have started to get their heads around this completely new style of racing, we have seen some blinding strategies come into play. At the first round of the Berlin double header, for example, Nick Cassidy for Jaguar TCS Racing qualified ninth on the grid and, by lap 21, had dropped down to 21st place. However, he had saved such a significant amount of energy that he then moved through the field to take the lead and win by a four-second margin.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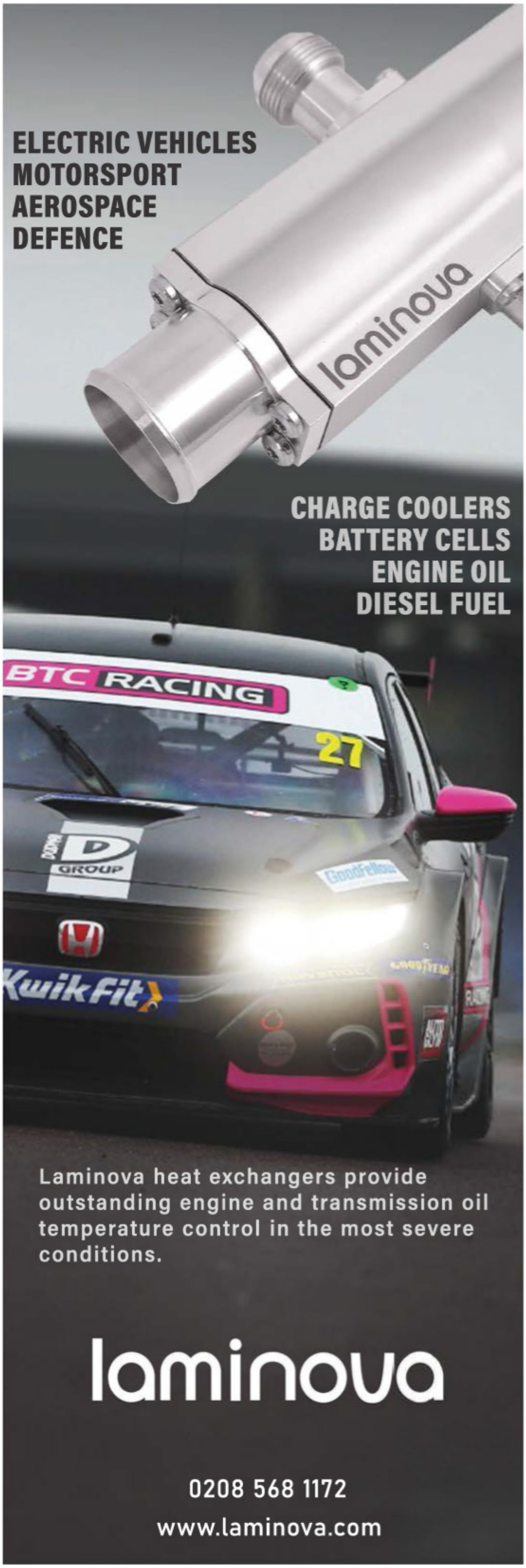
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ERT pulled a strategic masterclass in the first round of the 2024 championship at Misano, propelling their drivers from 16th and 21st to fourth and sixth as they crossed the line

Last year's driver champion, Jake Dennis, pulled a similar move for Andretti in the opening race at Misano this year. Starting in 18th position, Dennis banked energy early on and then navigated a thrilling 31 overtakes to finish on the second step of the podium.

During the same contest, the ERT squad mastered the go point, propelling its drivers, Dan Ticktum and Sérgio Sette Câmara, from 16th and 21st to fourth and sixth respectively. That gave the team its highest points haul for the since 2017 during the Gen1 era.

Team tactics

Another trend emerging from Gen3 racing is team tactics. To protect the leader from consuming too much energy, the team in the lead manoeuvres its second driver to the front. Once both drivers are running in first and second, the team then cycles between the drivers, giving each an opportunity to save energy in the other's tow, making up for the energy deficit of leading.

Other strategies involve defensive driving from the car behind, helping to protect their team mate ahead from an optimistic lunge, or rivals triggering the flat-out phase of the race. Team tactics are particularly influential when it comes to taking Attack Mode. This requires a driver to go off the racing line and drive through an activation zone containing three transponder loops. This triggers an extra 50kW of power the driver can then deploy over the next two, four or six minutes. Each driver must take a total of eight minutes of attack across two activations during a race.

'Depending on the sensitivity of the track, in some cases the time you lose going offline to activate Attack Mode is more of a detriment than the gain in power you get,' explains Mañas. 'At circuits where it is easy to overtake, you can afford to lose positions when taking attack because you know it's relatively easy to gain them back. But at tracks where the attack power isn't as effective, you want to try and build up a time buffer to the car behind so you can activate Attack [Mode] without sacrificing too many positions.

'We're seeing teammates now working together to hold up the rest of the field so the driver in front can take Attack Mode without losing places,' continues Mañas. 'We saw this with the Porsches in Monaco. [António Félix] da Costa climbed through the field up to protect [Pascal] Wehrlein when he took his Attack Modes. More and more teams are starting to understand this so, if teammates are running together, they now work together more to protect each other from overtakes.'

4D chess game

The limited amount of race energy drivers have at their disposal, combined with this now more powerful slipstream effect, is making Gen3 the most strategically challenging era of Formula E so far.

'Race strategy in Formula E now is like a game of four-dimensional chess,' concludes Albert Lau, chief engineer at NEOM McLaren Formula E team. 'You start with the basic energy targets defined by the frontier plot, which is the most efficient way to complete the race in free air. Then you add a second dimension that covers factors such as track evolution and tyre degradation. The third dimension is this 'Gen3 effect' of saving energy in the tow.

'Now, the drivers need to save energy, manage battery temperature and be aware of the race pace in case the leaders break away, all whilst battling for position around tight street circuits'

Albert Lau, chief engineer at NEOM McLaren Formula E team

'On top of all that, you also have to manage the temperature of the batteries as well, which is like the fourth dimension.

'This is where it gets super exciting as an engineer, because there are so many factors you have to consider to be successful, and nobody has got it completely right yet.

'In Gen2, races were temperature limited. That was the main thing we worried about. We didn't also have to consider driving in a peloton race. Now, the drivers need to save energy, manage battery temperature *and* be aware of the race pace in case the leaders break away, all whilst battling for position around tight street circuits. It's an interesting time to be in Formula E right now, for sure.'

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Built tough

How motorsport is leading the way in the dynamic and evolving field of structurally efficient design

By JAHEE CAMPBELL-BRENNAN

Design has been a pursuit of humanity since day one. The practice of taking materials from the world around us and shaping them to create a useful function is one of the fundamental processes to have delivered us to the world we live in today.

The initial motivations for our ancestors were driven by the desire to facilitate meeting needs for provision of food, water and shelter. These are the fundamental requirements of survival. Shaping a hammer to work a stone tool, or using plant materials to build a shelter, were some of humanity's earliest design enterprises.

With the perfection of concepts like the lever and pulley bolstering agricultural productivity, mechanisms such as the windmill soon emerged, enabling ever more complex functions to be considered and sparking an industrial revolution.

The evolutionary process of design flows such that innovations lead to innovations and, once basic needs are met, further experimentation is driven by some level of enjoyment gained from tapping into our innate desire and curiosity to keep exploring, optimising and doing better. What we know today as the pursuit of excellence.

Like all art forms, practicing creativity and imagination is deeply rewarding.

The imagination of the first wheel led to the innovation of the horse-drawn carriage, which, in relatively short time, led to the innovation of the motor car.

Sport from design

Following that glidepath, it's not difficult to see how humans, enjoying the comfort of plentiful food and warm houses, began to create sport out of design. This eventually led to the development of hugely complex mechanisms like Formula 1 cars, made of thousands of components, each one of them a specialised evolution of a basic function, acutely focused on a specific objective.

The addition of sport and competition to design activity is a significant point. With competition in the mix, the quality of a design is considered with a new scrutiny because an edge is gained by designing better than your competition. This leads to some unique specialisations.

In any high-performance design, each innovation and iteration is undertaken with a focus on improving the previous function by a certain metric. When the designs are intended to bear loads, the metrics are largely strength, stiffness and weight, although the business side of the sport would encourage us to keep cost amongst those, too!

And with this, we enter the world of structurally efficient design.

In motorsport, we need components to be strong enough to withstand their intended use without permanent, plastic deformation or damage. That's our primary constraint. As a secondary constraint, we also need parts to be stiff and not flex excessively during operation.

The catch is we also need them to be light, because every excess gramme of weight carries a performance penalty, primarily in the form of a lap time increase.

Stiff little things

Stiffness is a consideration that attracts focus in motorsport for very particular reasons. Testament to this is the suspension system, where excess deformation in the control arms or steering rack caused by high *g* lateral and longitudinal loading will dynamically alter the wheel's camber and toe.

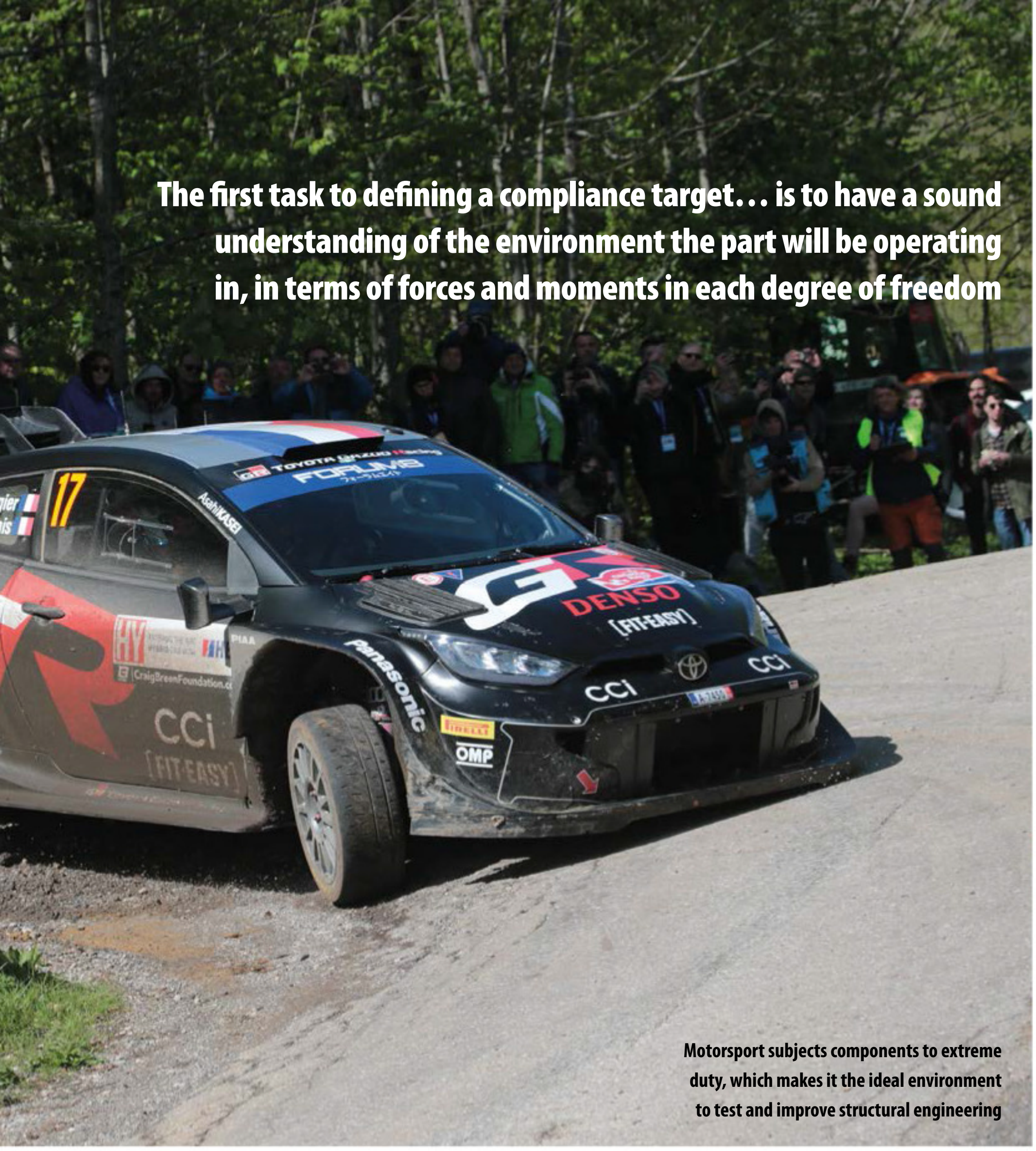
After spending many hours running countless simulations to dial in your kinematics, it would be tragic to have it ruined by an overly compliant suspension.

Similarly, taking an example from ICE engines, insufficient stiffness in the valvetrain can lead to gas exchange issues as valve sealing loses the precision we intended, while an excess of weight in reciprocating components inevitably means larger inertia and higher stresses.

As a general rule, if we design a part to be strong enough, it likely won't be stiff enough. Conversely, make a part stiff enough without care to the detail and it will be overly strong and score poorly on our weight metric. Consequently, two contrasting, but equally important requirements have emerged.

To begin to untangle this problem, we need targets. Most structural parts will carry some compliance constraint, defined by their respective attribute group. This gives us a starting point to approach the design process.

Landing from jumps can generate up to 11*g* of vertical load. That's a colossal amount of force that must suddenly be managed and dissipated



The first task to defining a compliance target… is to have a sound understanding of the environment the part will be operating in, in terms of forces and moments in each degree of freedom

Motorsport subjects components to extreme duty, which makes it the ideal environment to test and improve structural engineering

Damian Harty

Damian Harty, former CAE team leader at Prodrive and founder of Future Vehicle Systems, had the following thoughts to share on his approach: 'In our suspension target definition, I used to ask what's the smallest adjustment to the geometry we can make that the driver can measure? This was about one tenth of a degree for toe and a quarter, or half a degree for camber. So, that defined our compliance target under the maximal lateral loading we'd expect during a season.'

Compliance target

The first task to defining a compliance target into something useable is to have a sound understanding of the environment the part will be operating in, in terms of forces and moments in each degree of freedom. This is perhaps the most fundamental stage of the design process.

It's not an exact science, as the use cases of the component are never quite as clearly defined as we would like them to be. In motorsport, unexpected loading events are almost a given, so must be accounted for.

Defining nominal loading is straightforward enough, but in something like a suspension system or chassis structure we must also account for crashes, contact with another competitor, kerb strikes or other events that introduce abnormal loading into our components. The standard deviation of loading is therefore relatively high.

'In our WRC project, we used to design the cars to withstand a vertical load of 11*g*, but we also wanted to be clear on what would break if we exceeded that, and what would happen as a result,' recalls Harty. 'By the time we were at those loads, the tyres were contacting the inner wheel well, and the armoured belly was in contact with the ground. The car could survive that, but seeing as much as 11*g* generally means the driver has done something quite wrong.'

Defining these upper limits is still very much a human process, where judgement, experience and data are part of the decision making. The idea is to design such that we have a reasonable confidence that we won't see failure, even during abnormal events.

This is a sound philosophy, but can look quite different in its implementation across different component types.

Heavily loaded powertrain components, for example, such as connecting rods, crankshafts and, to a lesser extent, gearbox and driveshaft components, all must withstand very high peak loads. However, as the combustion process is reasonably repeatable, the standard deviation of these loads is way less than that of wheel loads.

Chasing efficiency

So, once stiffness has been defined, the objective is to achieve this while using the minimum amount of material possible. This is where the 'efficient' element of structural design comes into focus.

Structurally efficient design is an extremely interesting domain. It can be distilled into the following considerations: 1) robust material selection; 2) design that mitigates localised stress concentrations in the part with filleted edges and no abrupt section changes; 3) optimisation of the stress distribution through the part; 4) consideration of the section modulus to maximise bending stiffness relative to the volume of material used.

Clearly, then, the choice of material for a component is a meticulous process.

Stiffness at the material level is often evaluated through what is called the specific modulus. This relates the part's stiffness (Young's modulus) to its density. Interestingly, the most commonly used high-performance engineering materials – aluminium, steel and titanium alloys – all have a similar stiffness modulus.

This means for a given weight, they are all just about as stiff as each other. There are no advantages to be gained there, apparently. So, the appropriate material choice isn't immediately obvious without further consideration.

The loading experienced up to yield stress can be simplified as the linear strain region, where the relationship between stress and strain is approximately linear

Evaluating strength with respect to density is another way to filter the good from the bad. Here, specific strength is our metric. A higher specific strength means less material is needed for a given part strength, so initially we want to screen materials to have both high specific strength and specific modulus.

Material choice

Amongst the metals, the high specific strength of titanium alloys like Ti-6AL-4V is attractive, but it loses out to steel grades such as AISI 4340 in specific modulus. An aluminium alloy such as 7075-T6, on the other hand, performs well in stiffness and strength, comparable to both steel and titanium, but falls short in fatigue resistance, elongation and toughness. This means it bends less before failing and can withstand fewer loading cycles.

Carbon fibre stands out above metal alloys for some of these metrics, so can be a strong choice for applications where loading modes are well understood and relatively simple. However, unlike metal alloys, which are isotropic and exhibit the same strength in all directions, composites like carbon fibre are anisotropic, meaning their mechanical properties vary with loading direction.


Damian Harty

Implementing features to remove excess material where it's not required is the essence of structurally efficient design

This property makes a material challenging to apply in complex loading scenarios, and its low elongation and toughness means failure is often catastrophic when yield is exceeded.

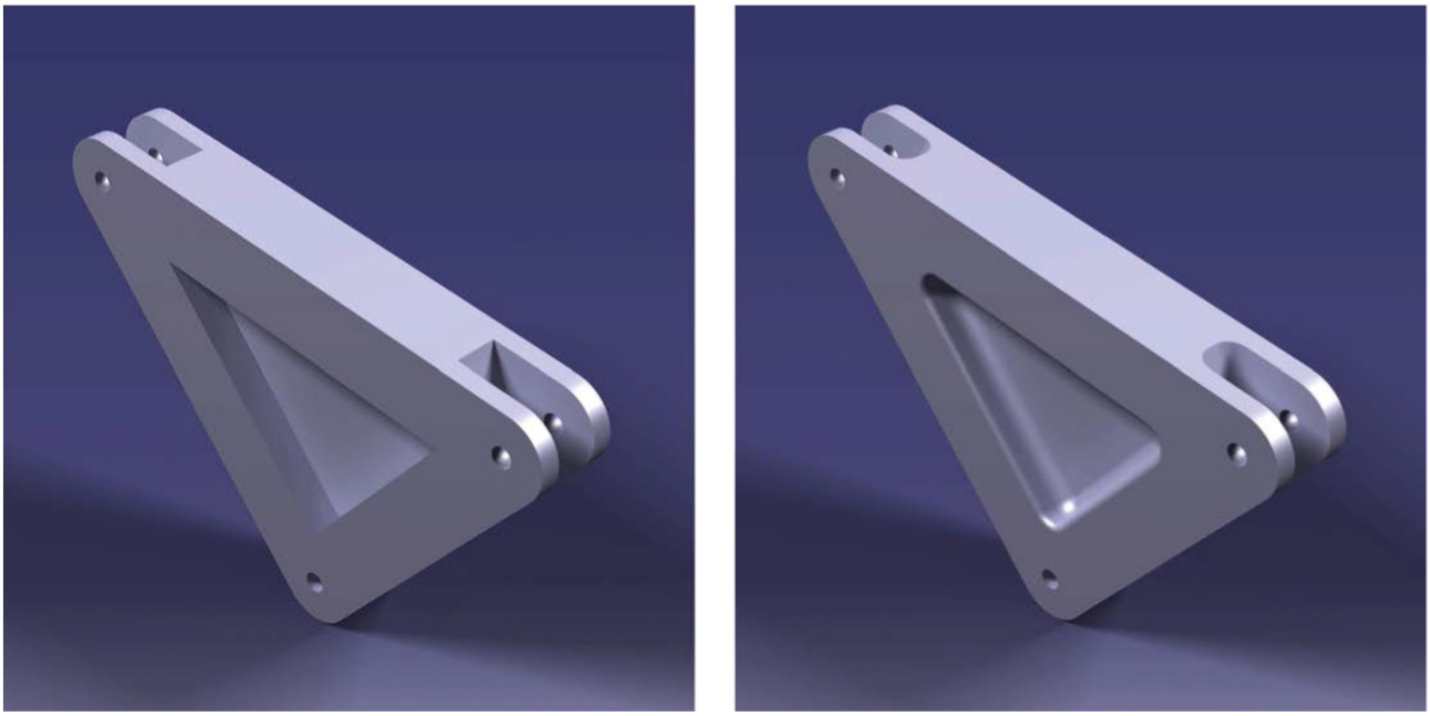
Special mention here should be given to some of the more exotic alloys, such as Al-Li (aluminium-lithium), Al-Be (aluminium-beryllium) and MMC (metal matrix composites), all of which offer some very attractive properties, but are generally tightly controlled by regulations due to their huge expense (or, in Al-Be's case, outright banned because of its toxic properties).

It's not hard to see how complex the matrix of considerations is to pick the right material for a job, especially as, in reality, many of the material options can be used somewhat comparably.

Stress and strain

The loading experienced up to yield stress can be simplified as the linear strain region, where the relationship between stress and strain is approximately linear. With continued strain, it enters the realm of plastic deformation, where the relationship between stress and strain becomes highly non-linear.

These distinct properties form a lineation in material behaviour, and we ideally want our upper design load to sit right at that transition of linear to nonlinear response.


Wavey Dynamics

Elementary design considerations such as rounded and / or blended transitions dramatically improve a component's strength and durability

The field of biomimetics recognises that nature has some truly spectacular engineering solutions

Materials and their stress / strain responses are fascinating in their own right, but component design is the realm where it all starts to become a little more tangible.

Joining our components together to form the structure is clearly the most pressing concern and, while packaging and kinematic constraints will certainly dictate some of the final form, there is a huge amount to be said for craftmanship, which is an art form in itself.

One wonders if the fact that pretty, aesthetically pleasing structural designs are often the most efficient load bearing shapes is purely a coincidence, or an innate feeling we all have for good and sound design.

Sharp edges give rise to sharp stress gradients, so fillets and smooth edges and transitions are a designer's best friend. That's elementary, but further refinement required a trained eye, and a particular inspiration.

Nature's gift

The field of biomimetics recognises that nature has some truly spectacular engineering solutions to this end. Bones of animals feature trabecular tissue, which is specifically present to increase the stiffness and strength of bones without largely impacting the mass.

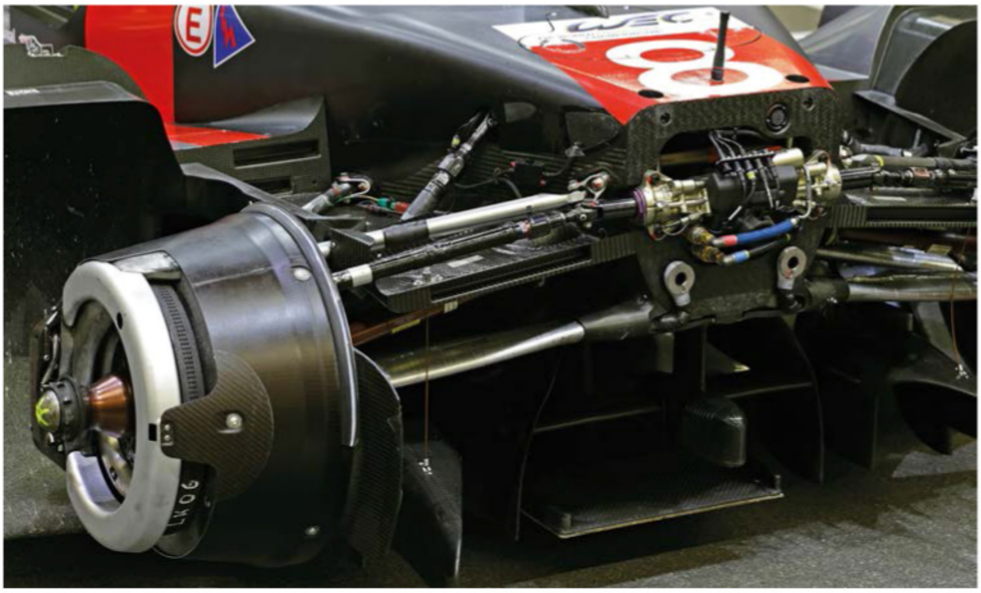
Soaring birds such as the red-tailed hawk are widely recognised for their strength-optimised skeletons, which feature hollow, yet strong bones filled with trabecular tissue helping to stay light, with the ability to cover vast distances, while expending minimal energy.

Bones also provide a brilliant observation of maximising a geometric property called the section modulus, which provides a metric of a form's ability to resist bending stress.

A high section modulus is achieved by placing material away from the neutral axis, where the bending stress is zero, raising the moment of inertia and, in turn, the stiffness for a given quantity of material.

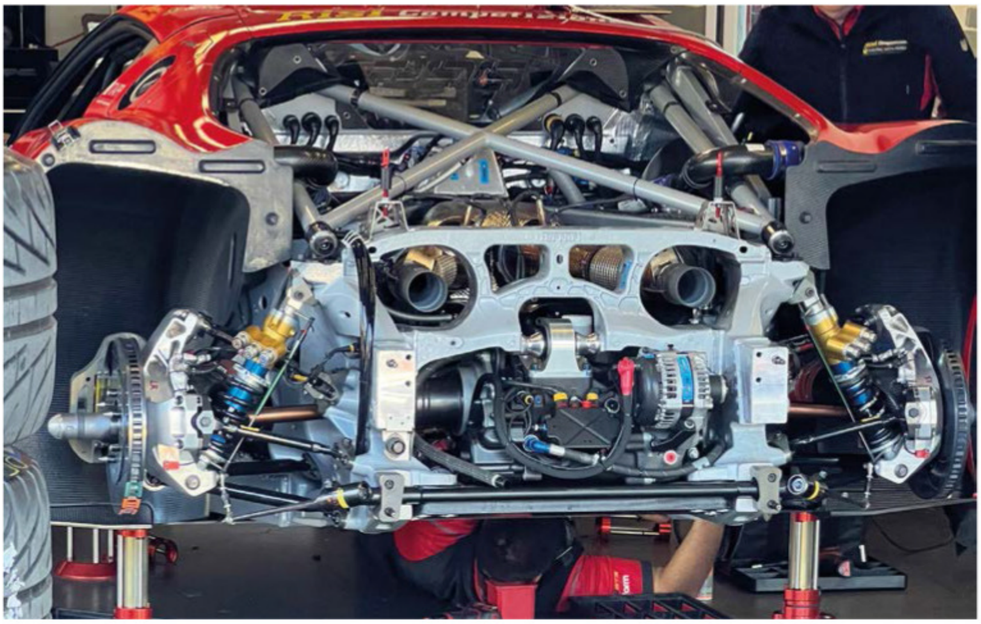
Applying this to motorsport engineering is the reason we have larger diameter tubes in rollcages, and why aluminium parts are generally larger section than an equivalent steel part. A great practical demonstration of the effect of an increased section modulus can be found in the steering rack.

A steering rack can be simplified as a bar inside a tube, supported in two places. The bar (rack) has teeth cut into it to allow the pinion gear to move it back and forth as the steering column rotates.



Audi Sport

Even something as simple as the orientation of a steering rack can have a huge influence on its section modulus



Wavey Dynamics

High-quality materials, efficient load paths and consideration of section moduli are the vital ingredients for lightweight design

'As the suspension articulates, there is an appreciable bending moment on it that makes the rack flex vertically, in a meaningful way,' explains Harty. 'When we were looking at compliance on the BMW Mini Countryman project [at Prodrive], we rotated the rack to give us the stiffer side of the bar working against the bending moment. It worked really well, and just seemed so obvious when we looked at the model.'

Validation time

With such time and focus on achieving efficient design, painstakingly selecting the correct alloys and designing elegant part geometries, we of course need methods of validating the resulting component.

In earlier times, performing structural analysis was a slow process and required relatively large teams. Today, this is another of the long list of engineering applications that have been revolutionised by the rapid advance of design and simulation tools and computing power.

Finite element analysis (FEA) tools, for example, have advanced leaps and bounds in both ease of use and integration into the design process. They use mathematical models of material behaviour and, in the linear strain range at least, provide quick, relatively simple and accurate predictions of how a material will behave.

As we discussed earlier, material behaviour becomes increasingly complex as it transitions into the non-linear strain range, requiring the model to accurately capture properties dictating stiffness and stress during plastic deformation.

'The material models we use to predict behaviour [in the industry] really aren't quite as good as we'd like them to be,' says Harty. 'Predicting loading in the linear range is

It can also be prudent to integrate features on a part to ensure it fails in a way that minimises the damage to mated components in the occasion of an abnormal loading

reasonably accurate but, as soon as you have high energy loading, or you're trying to calculate fatigue, it takes hours and hours, and we don't generally have high confidence we can trust the results.'

Beyond the elastic limit, stress / strain curves are affected by strain rate dependence, temperature effects and the effect of heat treatments or defects.

Time can also affect how the material behaves as micro-cracks, manufacturing defects and heat treatments evolve. It's not easy to model all this accurately.

Iterative approach

Here's where the modern day design iteration loop manifests. Whether linear or non-linear simulation, results from the FEA are fed back to the designer in very short time to allow modification of the design based on stress concentrations and overloaded areas.

This iterative approach to design has been in practice for decades and, while there have been efficiency improvements to workflows and methodologies, the basic principles have remained static.

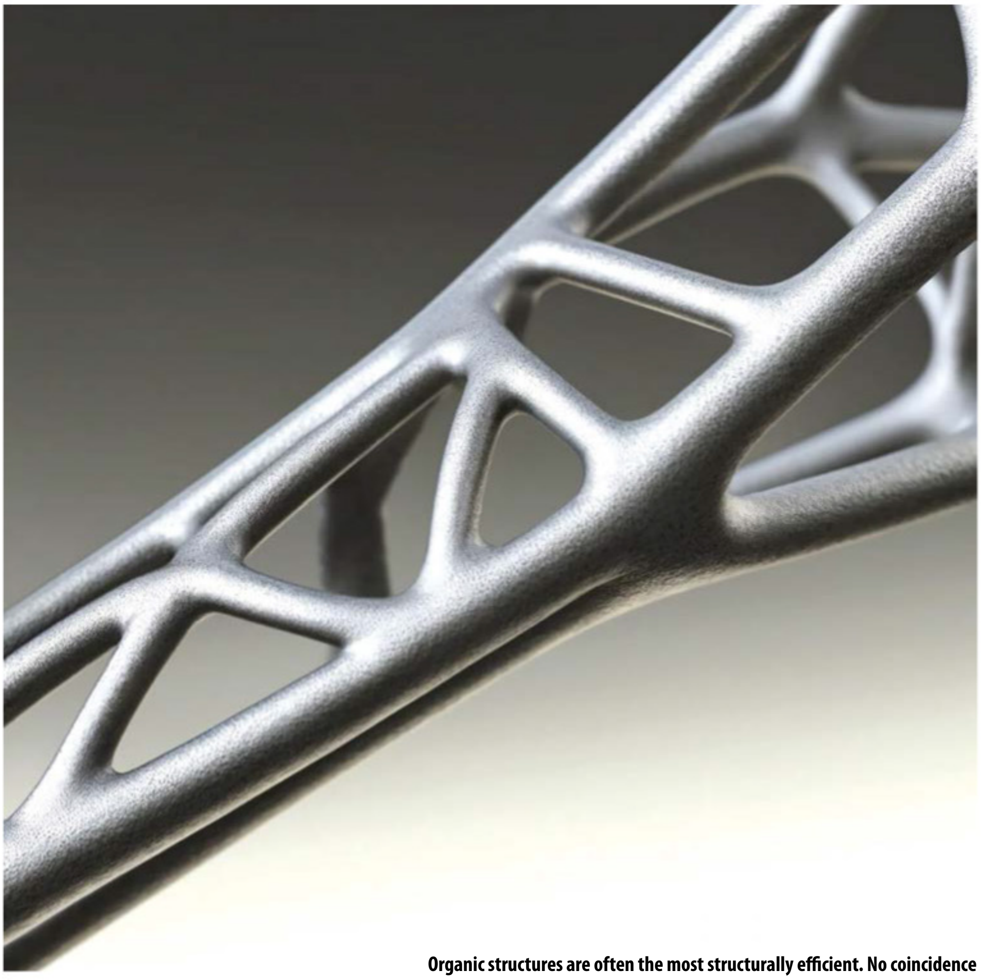
'When we moved on from the Subaru WRC cars and into the BMW Mini Countryman project, we did a massive amount of science and managed to lose around 10kg of unsprung mass,' continues Harty. 'The parts we designed were beautiful, and in CAD looked fantastic. Then, when all the finished parts turned up and we put them on the desk, we looked at them and thought, yes, these look like racecar parts.

'In the end, they worked perfectly, but visually, it was quite a shock to see how small properly optimised parts could be.'

Developments in the precision of algorithms have allowed even better work to be done and, with modern 3D printing and metal sintering techniques, some very interesting and previously unachievable geometries can be developed.

It's no surprise that many of the stress-optimised components produced with this technique are very organic looking.

It can also be prudent to integrate features on a part to ensure it fails in a way that minimises the damage to mated components in the occasion of an abnormal loading.



Wavey Dynamics

Organic structures are often the most structurally efficient. No coincidence

As nature has proved so often, well-designed structural parts look 'right', and are often aesthetically pleasing, too

A salient example of this is in suspension control arms, where stiffness requirements make the part sufficiently strong that it would damage the chassis before it failed. Features such as a small bend or stress initiator act as a mechanical fuse in this way, to force the arm to collapse before bending the chassis.

This can also be achieved by specifying the mating component, for example the chassis, to be five or 10 per cent stronger than the control arm that *might* contact it. This isn't so much a factor of safety, but a way of forcing a desired failure sequence.

'I remember a time when I was in the car on a test with Markko Märtin. We had done some running and he was grumpy about the car's balance. When we came around this one corner, I could feel the car rotating and was thinking, this isn't going to go well, he's not catching this,' recounts Harty.

'Sure enough, we hit the bank at the side, pirouetted and rolled a couple of times.|

Damian Harty

In the inevitable scenario where design loads are exceeded, it's good practice to retain an element of control over the failure modes

The car lost two of its wheels in the incident so had obviously taken a big hit to the suspension but, when we got back to the workshop and took the bent suspension bits off, the subframe was absolutely fine.'

This kind of scenario can be simulated digitally, but validation of any computer predictions is still a highly essential part of the process, especially in safety-critical components such as suspension, chassis and crash structures. Particularly non-linear work.

Validation revolves around gathering physical data from real-world testing to correlate the FEA to observations on prototype parts from tests in a lab setting on test rigs, or running the part on a real vehicle on an accelerated durability test.

By validating FEA predictions with empirical data, engineers can identify discrepancies and refine their models to improve accuracy. This iterative process ensures the final design meets performance targets, ultimately leading to more reliable and robust components.

Meta and nano

The future of structurally efficient design in the motorsport environment will be significantly influenced by advancements in materials science and manufacturing techniques. Part of this revolution will be through emerging technologies such as metamaterials and nanomaterials.

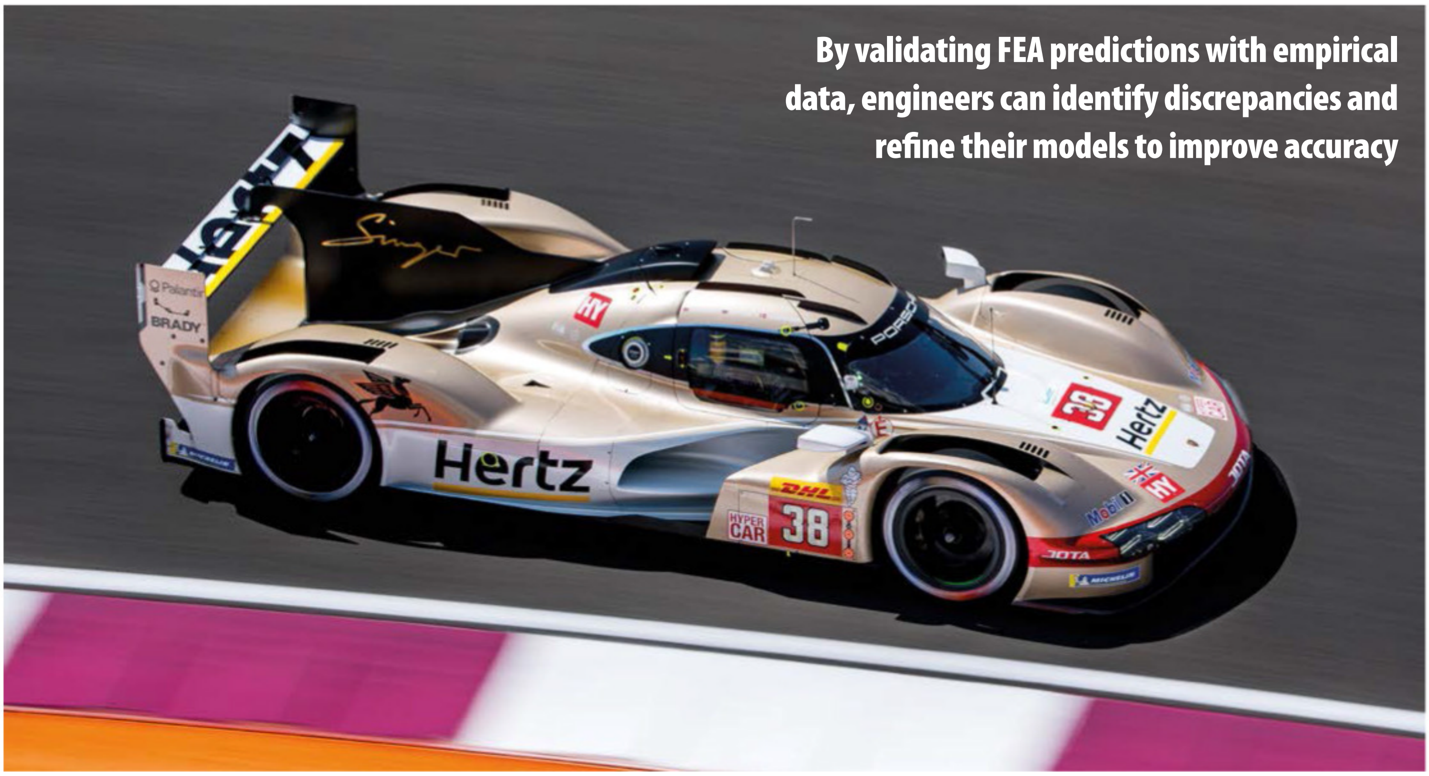
Metamaterials are engineered materials, which exhibit properties not found in naturally-occurring substances. They have been an area of intense research, partially unlocked through improvements in additive manufacturing technology such as selective laser melting (SLM), which allows for the creation of complex, periodic structures with extremely high precision.

Similarly, nanomaterials are making waves. By reducing the grain size of materials like titanium and aluminium, researchers have significantly increased their yield strengths. Carbon nanotubes (CNTs), when integrated into composites like carbon fibre (CFRP), improve stress distribution and provide substantial benefits in terms of fatigue resistance and crack mitigation.

These cutting-edge materials share the common goal of enhancing the strength and stiffness of components while, at the same time, minimising weight. Although there are still challenges to overcome, the future certainly looks promising.

The pursuit of structurally efficient design is a dynamic and evolving field. From the historical advancements in basic mechanical principles to the sophisticated integration of modern materials and computational techniques, the journey is a remarkable one.

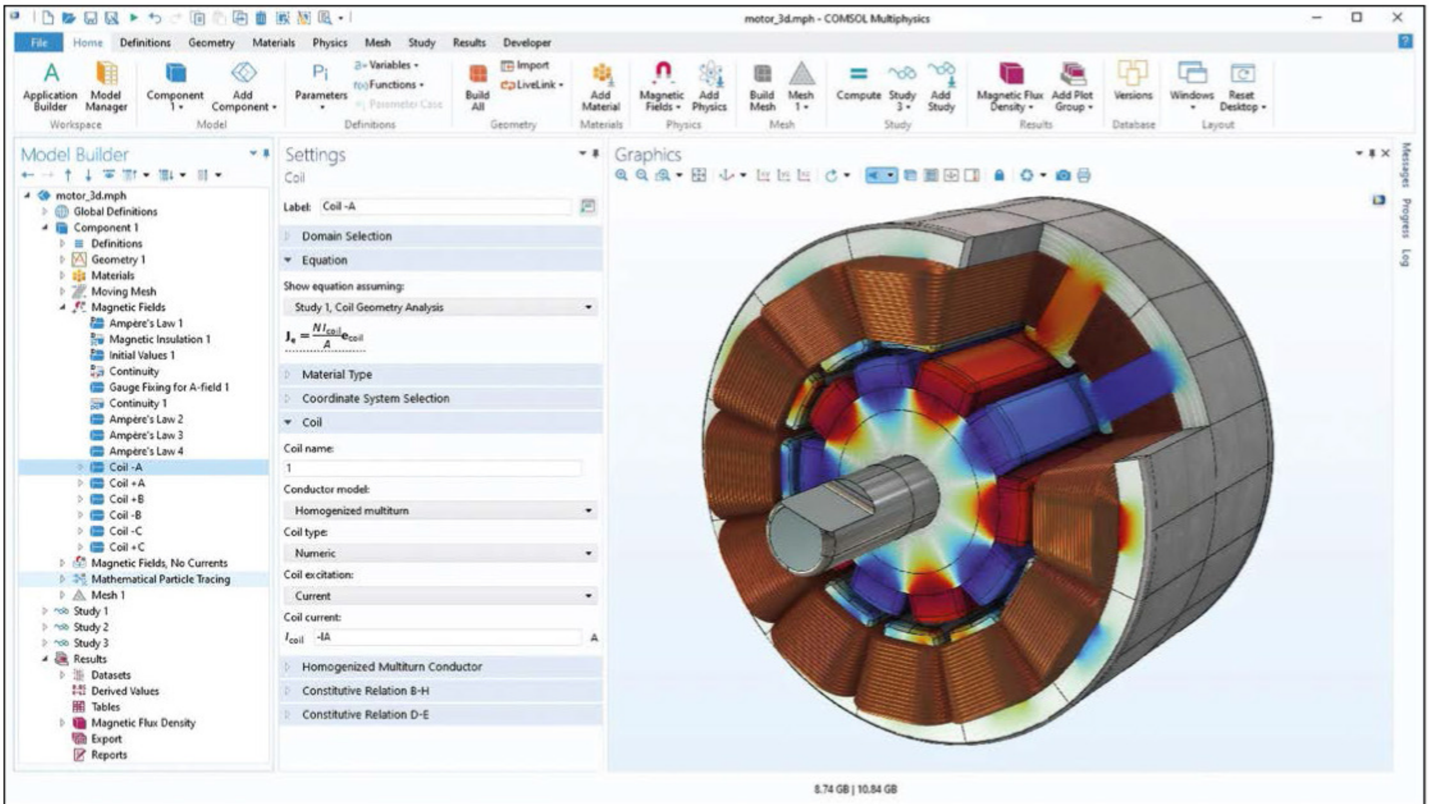
Continuous improvements in material science, coupled with advancements in simulation and optimisation algorithms, promises a future where designs are not only lighter and stronger but also more adaptable and resilient. If there are benefits to be found, we can be sure motorsport will find them.



By validating FEA predictions with empirical data, engineers can identify discrepancies and refine their models to improve accuracy

Porsche

Despite all the recent advances in computing and simulation technology, validation of simulated work must always incorporate some level of physical testing, either in the lab or at the track



With electric racecars, the ability of the battery packs to effectively and reliably deliver the power demanded by the motors is key to optimising performance, but the efficiency of both depends on a host of complex, interconnected factors that must be understood and accounted for in the overall powertrain design

Ever decreasing circles

There may be similarities with their ICE counterparts, but simulating electrified powertrains is on another level of complexity

By LAWRENCE BUTCHER

Electric and hybrid racecars present many of the same engineering challenges as traditional internal combustion, but with some key differences when it comes to modelling and simulation at the design, development and performance optimisation stages.

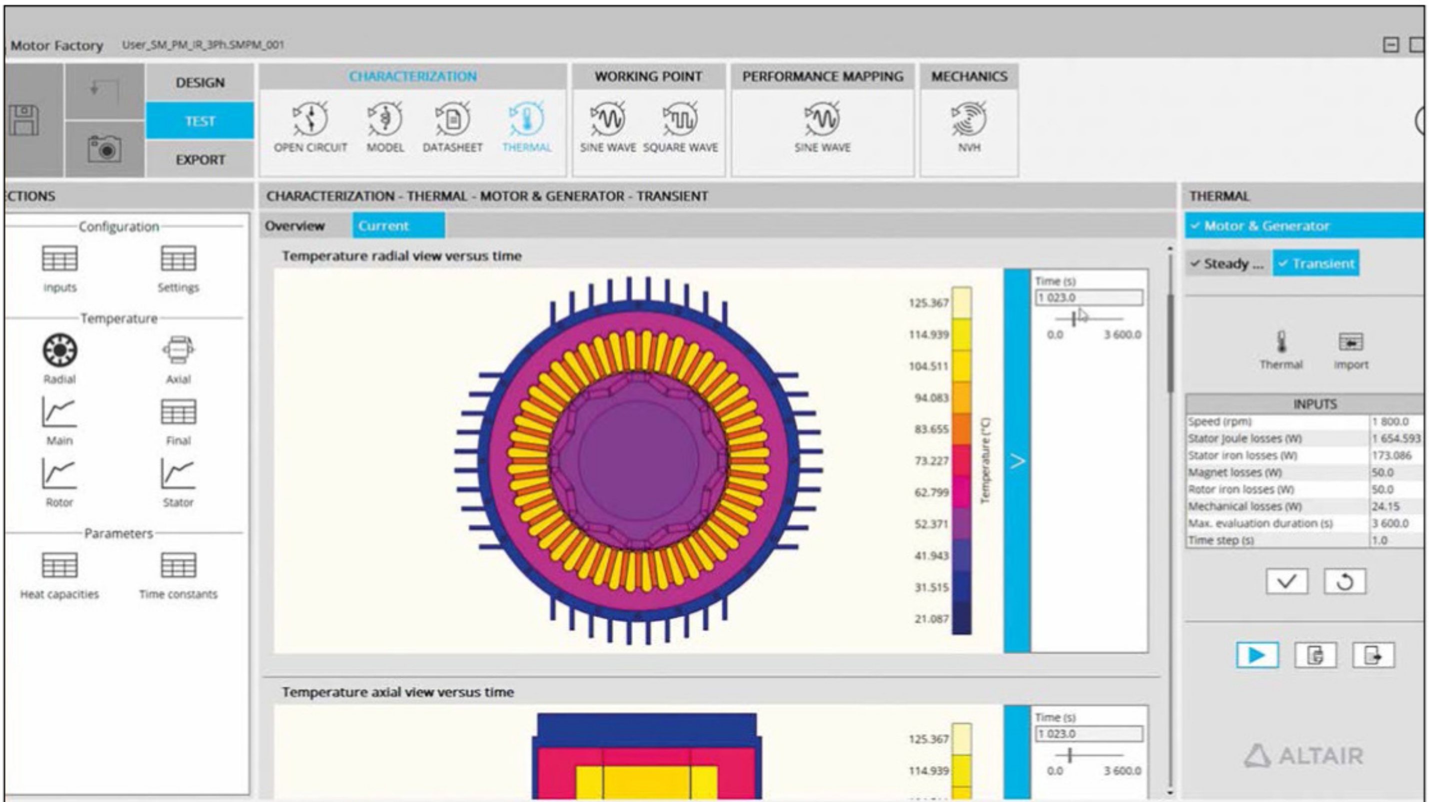
On the one hand, both present thermodynamic and mechanical engineering problems, with some aerodynamics thrown in for good measure.

However, with an EV, there is also the matter of electrochemical reactions occurring in the batteries, and electro magnetics in the motors (not to mention a bunch of EMC-related issues). It is also a fact that all the elements of an EV powertrain are more interconnected than in an internal combustion engine and, with energy density of batteries still pathetic compared to petrol, the efficiency of those interconnections is of utmost importance to performance.

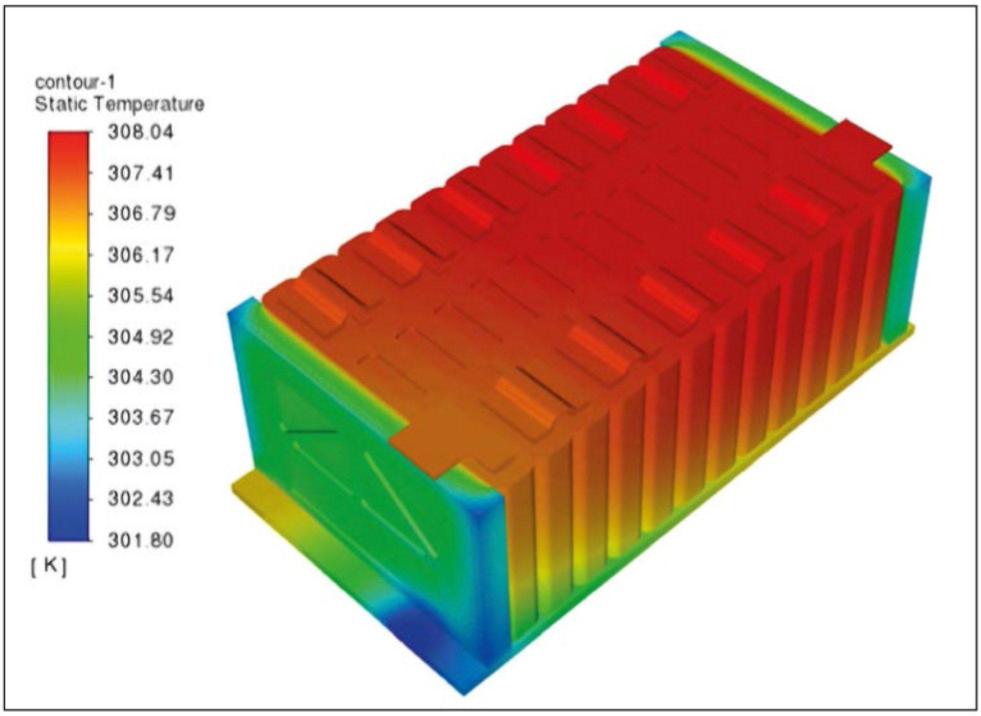
This has been true since electrification came into racing. Before KERS arrived in Formula 1, being both an engine and powertrain manufacturer was useful, allowing for the two elements to be developed in harmony. However, once batteries and electric motors got involved in 2014, having the in-house expertise to optimise both the packaging of the different powertrain elements - and ensuring they all work seamlessly towards the goal of energy efficiency - became vital. It is no coincidence that only works, or pseudo works teams (Mercedes and Red Bull) have won championships in the last 10 years.

Effective interaction

The average combustion engine doesn't care about its fuel tank. So long as there is fuel in it, and it is picked up, the ICE doesn't even know it's there. This is not the case with a battery. Its ability to deliver the power demanded by the motors varies depending on a host of factors, which need to be understood and factored into the overall powertrain and vehicle design. Most boil down to thermal



Just as with internal combustion engines, thermal management is of critical importance in EV powertrains, especially in racing environments, and is where a large percentage of a team's resource is spent in modelling. Thermal and fluid dynamics models are used here to develop both battery packs and their associated battery monitoring systems



management but, to achieve this effectively, everything from the reactions taking place inside the individual cells of the battery to the flow of coolant through the pack need to be taken into consideration.

In turn, the motor, or motors, rely on a host of battery parameters for performance, the state of charge, temperature etc. Conversely, the battery is affected by the operation of said motors. This has been demonstrated with Gen 3 Formula E, where the battery initially couldn't keep up with the planned charge and discharge rates of the front and rear powertrains.

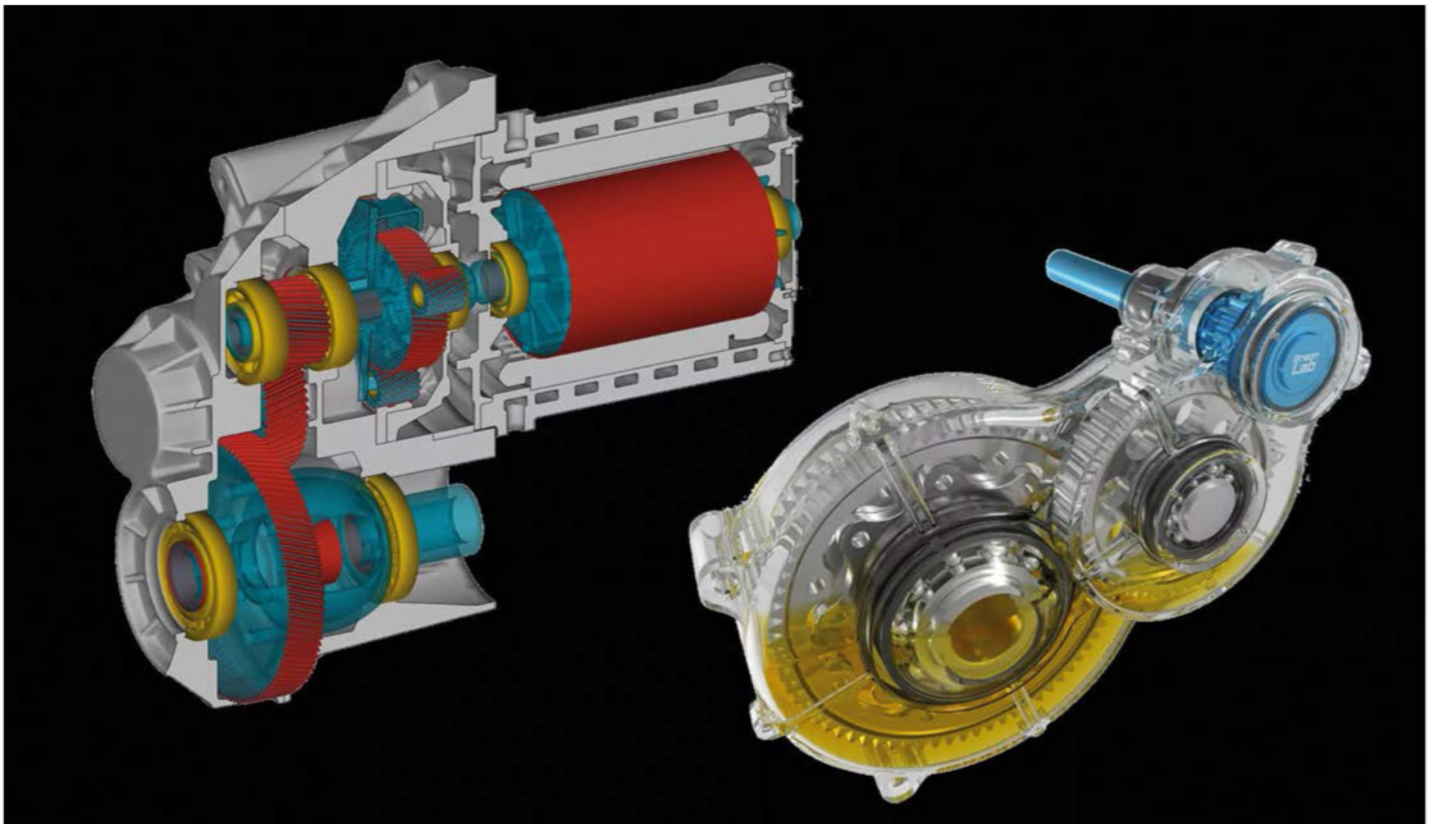
As with any system level or full vehicle modelling approach, the complexity of models when it comes to EVs depends on the end goal. For example, complex models of cell chemistry, thermodynamics and fluid dynamics can be used when developing a battery pack or its control battery monitoring system (BMS). Then, in the context of an overall vehicle model, the results of simulations using these can be used to create simpler models that feed into the whole.

It is no coincidence that only works, or pseudo works teams (Mercedes and Red Bull) have won [F1] championships in the last 10 years

Multiphysics models

Just as with an ICE, thermal management within an EV powertrain is of utmost importance. In electric motors, particularly permanent magnet synchronous motors (PSMs), excess heat will lead to performance loss or, in the worst case, de-magnetisation of the motor magnets. Unfortunately, the hotspots within motors tend to be the areas where it is hardest to effectively cool, such as the windings of the stator and the core of the rotor. Here, both thermal and fluid dynamics models come into their own, with the added complexity of electromagnetics in the mix.

Sticking with the electric motor example, the latest developments lean towards multiphysics approaches, made possible by the availability of extremely powerful (now often cloud-based) computing resources.

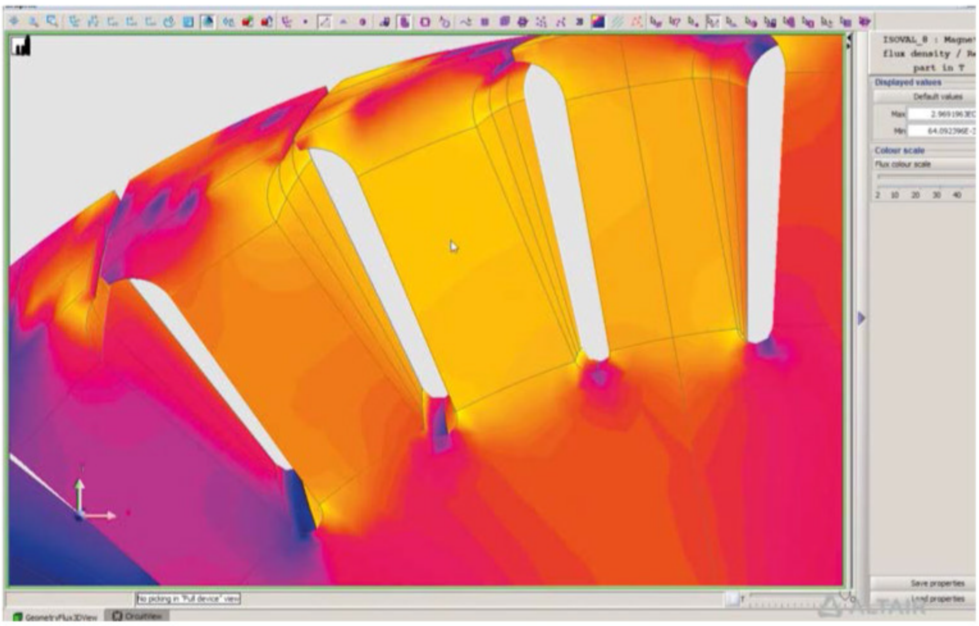


Today's extremely powerful, cloud-based computing resources enable multiphysics modelling approaches to be applied to racecar components

Multiphysics modelling does what it says on the tin: simultaneously solving mechanical, thermal, fluid and electromagnetic problems and considering the effect of each element on the other.

The electromagnetic, mechanical and thermal characteristics of a motor are intrinsically linked. For example, the phenomenon of magnetostriction means the mechanical properties of motor materials, particularly the laminates in stators and rotors, can change as they are magnetised, and conversely the stress in materials can change their magnetism. Then one has the thermal loads created by ohmic (ion losses) at high currents. The concentration of these loads throughout the rotor and stator needs to be well understood to maximise performance and reliability.

Multiphysics modelling does what it says on the tin: simultaneously solving mechanical, thermal, fluid and electromagnetic problems and considering the effect of each element on the other



Understanding, and optimising, factors such as flux density and distribution within a motor are key to unlocking its performance

Mechanical integrity

The mechanical stresses on the rotor certainly need to be factored in the generally high motor speeds, often more than 20,000rpm, seen in high-performance units used in racing. The integrity of the rotor needs to be ensured from both a durability standpoint, such as the retention of the magnets (in exterior permanent magnet (EPM) designs particularly), as well as consistently maintaining the air gap between rotor and stator.

At the same time, the usual demands for mass reduction wherever possible – and in many cases, cost control, too – still apply. In the latter case, material and manufacturing choices need to be made to keep costs in check.

As is often the case, a reduction gearbox is also used to transmit power, which requires its own modelling to match ratios to desired wheel torque and minimise frictional losses.

The complex matter of electromagnetism within the motor is at the heart of its performance. Factors such as finding the ideal combination of slots and poles for the stator, balancing the harmonics within the motor,

optimising the fill factor of the windings, minimising magnetic and ohmic losses, and optimising magnetic flux distribution within the motor are just some of the factors at play.

Fortunately, there are a host of products on the market that help with modelling of even the most complex and novel motor architectures combining electromagnetic thermal stress and vibro acoustics simulations.

Clues from the road

It is clear why a multiphysics approach is beneficial, tying all these elements together and accounting for the effect of one on another. Though manufacturers often keep such details close to their chests, the current state-of-the-art threads in roadgoing automotive gives some hints at the complex modelling that goes on behind the scenes.

Take Audi and Porsche's latest range of electric drives for their Premium Platform Electric as an example. These combine direct oil cooling of both the rotor and stator, alongside the use of varying grades of magnet through the rotor (in this case to reduce the use of expensive, rare earth magnets) and optimised geometries on the magnet pockets to achieve high power densities and reliable operation. This level of optimisation can only be achieved by having an in-depth understanding of the various phenomena at play and their interactions.

Batteries are another excellent case for a multiphysics approach. The electro-chemical reactions within a battery cell influence how much heat is generated during charge and discharge and, conversely, the temperate of the cell impacts those same reactions. Therefore, the influence of the cooling system on the way cells operate is important. Being able to create reliable models of these interactions leads to the creation of a more effective BMS, meaning more of a pack's potential can be exploited before catastrophic issues such as thermal runaway become a problem.

One engineer well versed in battery simulation described understanding the electro-chemical reactions as like chess. Though they are governed by simple rules, understanding the implications of each simple move on the outcome means repeating the moves or, in the case of a cell, simulations many times under different conditions before you can fully understand its behaviour.

Once the cell behaviour is understood, it can then be placed in the context of an overall pack, and the implications of different thermal management solutions and elements such as current distribution can be considered, all with the intent of optimising its behaviour.

The current state-of-the-art in roadgoing automotive gives some hints at the complex modelling that goes on behind the scenes

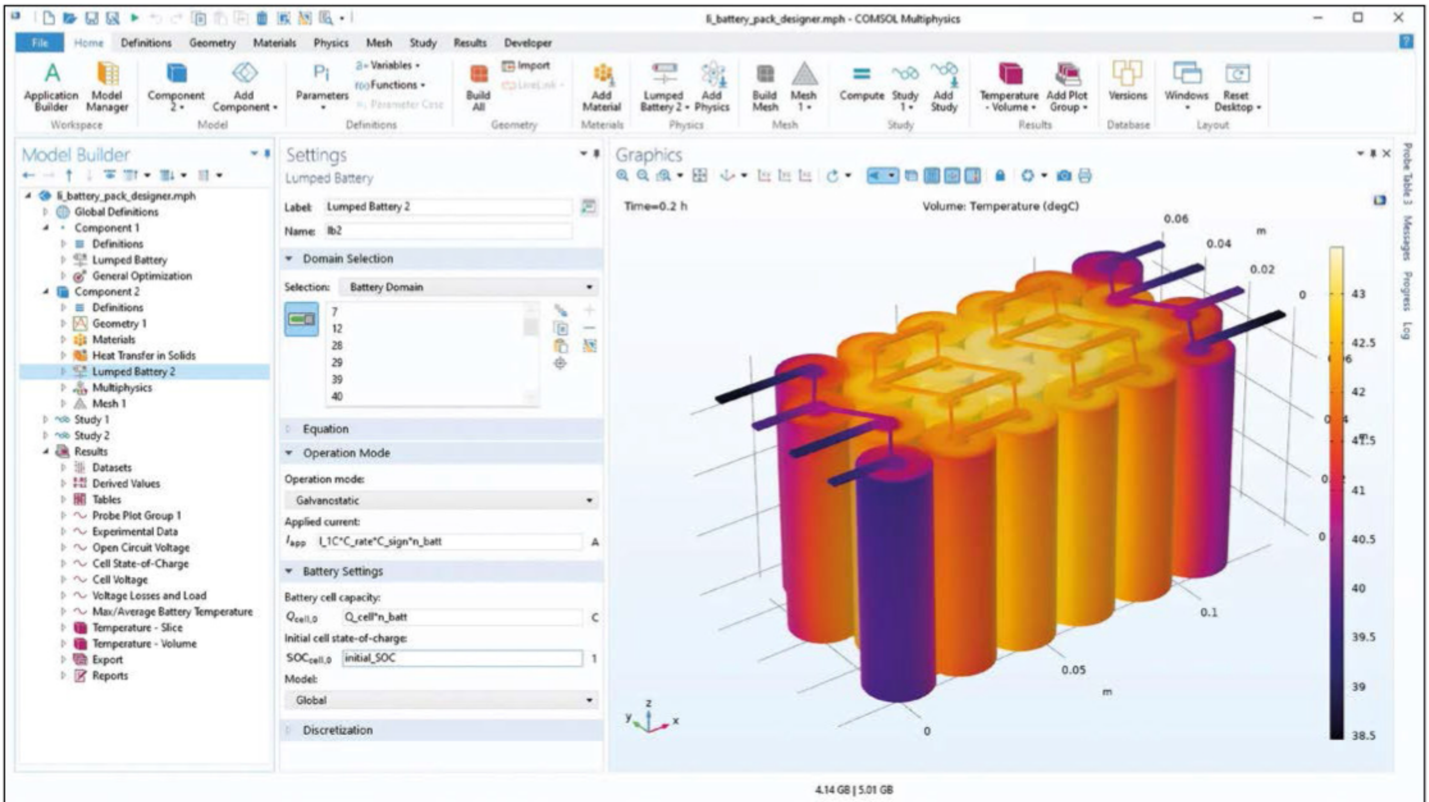
Generally, the guts of a cell will be refined by the cell supplier, leaving the battery pack manufacturer to characterise the cell behaviour and then build the rest of its systems around it.

Even with the excess of computing power now available, it is not practical to simulate every element of a battery concurrently. Therefore, simplified models will be substituted where possible. For example, a cell may be represented as an equivalent circuit model (ECM), which can be run in real time. These are then combined to form a virtual battery module. This virtual module can then be used as an input for a model of the BMS. Each element of a powertrain can be built up from different model blocks of varying levels of complexity, until an overall model is formed.

AI advances

Several software companies have developed dedicated packages that make the labyrinthine process of finding the best balance less daunting and, increasingly, are turning to artificial intelligence (AI) and machine learning (ML) tools to speed up the process and allow for further optimisation of electrified powertrains.

These can combine a systems-based modelling approach, coupled with AI to explore potential design avenues. These tools can be applied to a host of applications but are particularly well suited to the design of elements such as battery packs.



Understanding the electro-chemical reactions in a battery have been described by one leading simulation engineer as like chess – the rules are relatively simple, but knowing the implications of every move on the outcome is key to optimising a battery's behaviour

One such approach sees the architectural constraints of the vehicle, required performance parameters, cell characteristics and thermal targets defined. Models of the cells, the cooling medium used and many other factors are then used as inputs for processing using AI.

First, what are known as design tree algorithms generate hundreds, or even thousands, of design solutions within those predetermined parameters, which are then steadily refined down using a statistical, AI-based approach, until a number of final options are determined.

Key here is that this process is accessible via an interface that doesn't require an in-depth understanding of data science, and this can be harnessed by the engineers designing the powertrain.

Of course, the input data for these AI models must be validated in order for the outputs to be of any use. Once physical testing of systems begins, the data generated can be used to further refine the AI models.

In many cases, the functionality of AI-based tools can be integrated into standard modelling platforms such as MathWorks.

Material development

Another interesting area of development for AI in the context of electrification is materials research, particularly when it comes to batteries. For example, there have been several successful projects using combinations of high-performance computing and AI-based large language models (LLMs) to identify promising electrolyte materials.

With the correct training data, such approaches can narrow down potential materials from millions of options in a matter of days or weeks, a process that in the past could take years, or even decades.

Ultimately, it is possible to have an entire EV powertrain running, driven by a DIL simulator… feeding data back for the refinement of models, creating a virtual circle to increase performance and reliability

There are then the myriad uses of AI-based systems for topological optimisation of motors and other components, which, when coupled with additive manufacturing technologies, open routes to lighter weight machines, but also previously unachievable electromagnetic designs. For example, there are now soft magnetic composite (SMC) materials that can be printed.

AI tools don't obviate the need for the modelling approaches already described but, when used correctly, allow for optimal designs to be arrived at more quickly and with more efficient use of the available computing power.

HIL, SIL and DIL

When all is said and done, modelling can still only go so far. There still comes a point where physical testing must take place. Enter hardware and software-in-the-loop simulations (HIL and SIL for short).

In-the-loop simulation can be broken down into three broad groups. SIL simulation is where the control code for a device – for example, an inverter – is tested as part of a simulation model. The model, in this case, will provide inputs to the control unit software and the software will respond as if it were running the control unit, with the outputs it generates fed back into the model. The functionality of the control software can then be checked, modified and the effect of refinements on the operation of the model (and therefore the final engine) can be investigated.

HIL simulation takes this idea to the next level, by implementing pieces of hardware within the simulation loop for overall assemblies. Here though, rather than having the control software running on a virtual control unit working with the model, the control unit is integrated into the model.

The control software will be run from the control unit, with all the inputs and outputs functioning as if the controller was running an engine. The various inputs for the controller will be provided by dedicated sensor simulators, which generate either analogue voltages or digital signals, based upon the operation of the model.

The benefit of this approach is that it allows for a controller to be put through its paces without needing to be attached to the device it is controlling, be that a battery or a motor. This can be useful for several reasons.

Firstly, the device it is supposed to control may not yet be in existence. HIL simulation allows devices and controllers to be developed and tested in tandem, saving time. Secondly, it may be preferable to not test a new and unproven device on a potentially very expensive component. The material cost of a failure caused by an error in a controller, battery or motor is considerable, so it is better to have a controller cause a virtual meltdown than a real one in the dyno, or battery, test cell.

Mechanical hardware-in-the-loop (MHIL) simulation moves the idea of HIL to a mechanical rather than just electronic level. Instead of only using electronic controllers, such as ECUs, as an integral part of a simulation model, MHIL gives the ability to introduce entire mechanical assemblies as physical inputs to drive a model. This way, one can ensure the physical behaviour of a system tallies with its behaviour as a model. Theoretically, when used as part of a larger model, this can improve the accuracy and resolution of the results from that model.

Ultimately, it is possible to have an entire EV powertrain running, driven by a driver-in-the-loop simulator, as close as possible to the actual conditions found running on track, feeding data back for the refinement of models and creating a virtual circle to increase performance and reliability.

At the same time, all this effort will contribute to race strategy. The greater the understanding of the powertrain and how it uses energy, the more accurately energy use can be predicted and the increasingly fine margins exploited.

More is not always better

Multiphysics simulation is a computational approach that integrates multiple physical phenomena to analyse complex systems. It allows one to simulate and understand the interactions between different physical processes occurring simultaneously within a single system or device.

In traditional simulation methods, each physical phenomenon is typically analysed in isolation. However, in the real world, most phenomena involve the coupling or interaction of multiple physical processes. Multiphysics simulation enables the comprehensive analysis of these interconnected phenomena, providing a more accurate representation of their actual behaviour.

Even with the massive increase in computing power at today's engineers' fingertips, there are still limitations, and good reason to simplify models where possible, particularly at a system level. For example, 1D simulations still have an important role to play, especially when coupled with 3D approaches, such as CFD, in a co-simulation. A complete thermal management system can be assembled using simple 1D model elements, to narrow down potential options at a relatively low computational cost. More complex 3D CFD can then be used to validate only the chosen individual model elements.

The ultimate goal, as always in racecar engineering, is optimisation.

Danger money

Further evidence to support the need to stop the rot in motor racing

By DANNY NOWLAN

This isn't the first time I've written an article about the dangers of dumbing down motor racing. I've touched on it frequently since, but in *RE* V32N4 I discussed at length the problem of spec formulae and the increasing regulation of tools such as data acquisition and dampers.

One of the recurring themes in any discussion on this topic is the creation of a generation of engineers who are fundamentally disconnected from the work they are doing and, consequently, can find themselves out of their depth when they make it to the big time. This is an abyss we must avoid at all costs, and will be the focus of this article.

As we roll into the 2024 season, the situation is worsening, not improving. Recently, I have done some work for customers in junior and cost-capped formulae such as the TCR Australia Touring Car Series. Here, my traditional lever of data pots would save these small teams a fortune in expensive testing, yet they are no longer available because the regulatory bodies, in their infinite 'wisdom', decided to ban them.

I was almost going to let this go, until a colleague and good friend of mine asked, 'What the hell is going to happen if the first time a performance engineer encounters damper pots is either in F1, factory sportscars or IndyCar?'

This is why I feel so strongly that this situation has to be dealt with, and quickly.

The reason we are in this mess can be traced back to the mid-1990s when costs were spiralling out of control. The Williams F1 team, in particular, was making everyone else look silly with its active suspension system and so the motorsport regulatory bodies panicked, fuelled by the resident techno hysteria that is always burbling beneath the surface of motorsport.

Mischief maker

Don't believe me? Rock up at a motorsport event and mention traction control to a scrutineer and see what happens. Then, for grins, wander round any junior formula pit with a laptop showing a fancy, 3D display with source code visible underneath and see how it riles people.

Working against this sort of backdrop, you are going to be hard pushed to make informed decisions in racecar engineering.

I would also contend the biggest mistake the motorsport regulatory bodies made in the 1990s and beyond was to believe they need to make all cars equal so the racing becomes all about the drivers. Nice idea, in theory, but in practice all it does is lead to boring, nose-to-tail racing with minimal passing. You see this abound in spec formula series these days.

If you don't get the magic start off the gird, you very quickly end up in a glorified conga train. The first generation of GP3 cars (that morphed into FIA F3) were notorious for exactly this.

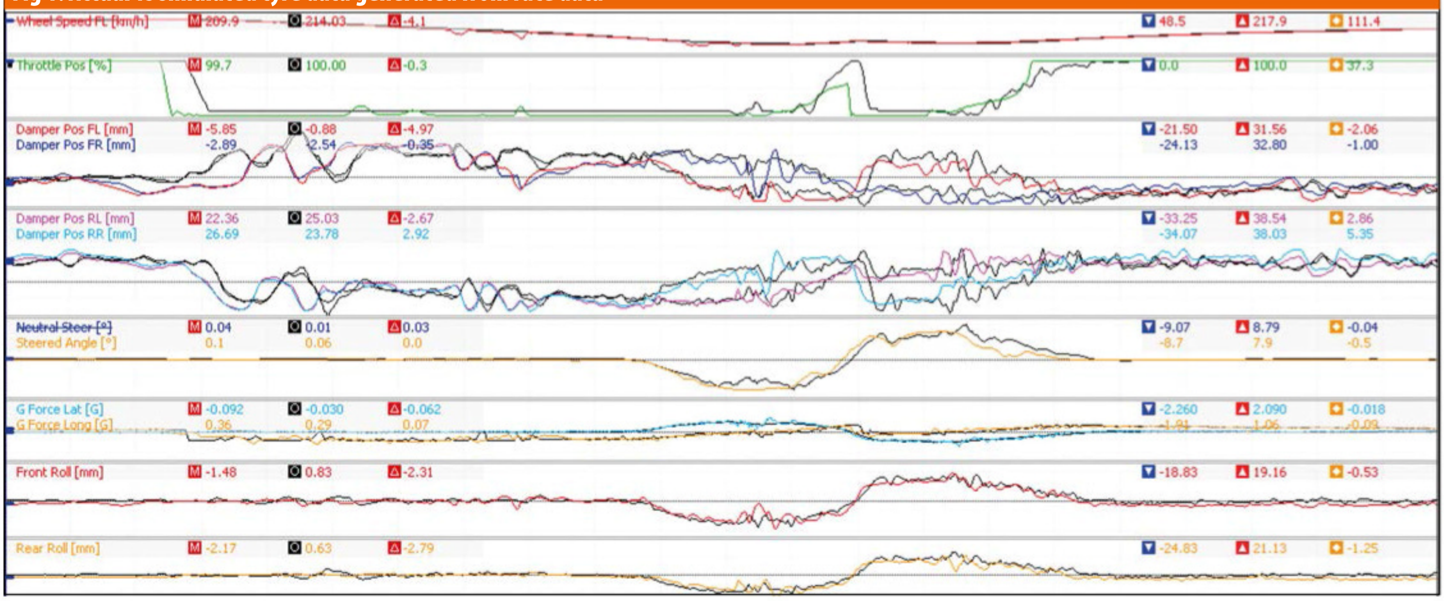
The really crazy thing is, the war being raged on technology in motorsport has no basis in fact, and this is particularly apparent with data acquisition. One of the things I speak about in the ChassisSim bootcamps is the importance of the ChassisSim monster file. Not because I love the sound of my own voice, but because the contents of that file allow you to reverse engineer the circuit properties and, more importantly, the aero and tyre properties of the racecar.

Pudding club

As always, the proof of what I'm saying is in the pudding, and the comparison of actual vs simulated race data shown in **figure 1** proves this. As usual, the actual trace is coloured, simulated is black, and you can very quickly see the correlation between speed, lateral *g* and damper traces, which speaks volumes about the veracity of this method.

Cost is the first item that advocates of not using data acquisition will mention, so let's look at just how onerous the investment required for this is. To do that, I'll refer to a previous article I wrote on data acquisition. See **table 1**.

Fig 1: Actual vs simulated tyre data generated from race data



'What the hell is going to happen if the first time a performance engineer encounters damper pots is either in F1, factory sportscars or IndyCar?'

Table 1: Core data channels you need to log

Channel	Role	Frequency
Engine rpm	Engine / chassis	50Hz
Engine temperature	Engine	10Hz
Oil pressure	Engine	10Hz
Lateral acceleration	Chassis	200Hz
Vehicle speed	Chassis	50Hz
Inline acceleration	Chassis	200Hz
Vertical acceleration	Chassis	200Hz
Steering	Chassis	50Hz
Throttle	Engine / chassis	50Hz
Front brake pressure	Chassis	50Hz
Rear brake pressure	Chassis	50Hz
Gear position sensor	Chassis	10Hz
Damper position (FL)	Chassis	200Hz
Damper position (FR)	Chassis	200Hz
Damper position (RL)	Chassis	200Hz
Damper position (RR)	Chassis	200Hz
GPS altitude	Chassis	10Hz

Table 2: Breakdown of prices for data logging equipment (MoTeC option)

Item	Price (AUD / GBP)
MoTeC ADL 3	$5000 / £2640
Three-axis accelerometer	$1200 / £630
Damper pots	$400 / £210
Steering sensor	$200 / £105
Throttle sensor	$200 / £105
Temperature sensor	$200 / £105
Pressure sensor	$400 / £210
Brake pressure sensor	$197.50 / £104
GPS package	$400 / £210

All in all, you have 17 channels that will get you 90-95 per cent of the way there. If I wanted the cherry on top, I would put in laser sensors and tyre temperature and pressure sensors, too.

What **table 1** is showing forms the basis of the ChassisSim monster file and, if this didn't work, I'd be out of business.

A rough idea of the outlay necessary to kit yourself out with all the above in best quality is shown (in Australian dollars) in **table 2**.

If you are on a tighter budget, you might choose an AIM, or MoTeC club-spec logger. Both are capable of handling all the above and come in around AUD$2500 (approx. £1320 / US$1675).

The suggested sensor suite comes out to about AUD$3000 (approx. £1580 / $2010) and you can cut some corners there too if you need to reduce cost further. They probably won't last as long, but they'll get you going.

Add all this up and you can get going for around AUD$5000 (approx. £2640 / $3350), plus install charges. To put that in perspective, that's about what you would expect to spend on a day's track hire in the upper formulae, and maybe three or four sets of tyres in a lower one.

The pay off

Where the outlay really pays off, however, is in what you can do with this equipment. The most striking example is the high-speed oval comparison of simulated versus actual data presented in **figure 2**.

Once again, actual is coloured and simulated is black. You'll notice the speeds, lateral acceleration and front pitch (the average of the front dampers) are equivalent, yet the actual rear pitch (average of the rear dampers) is about half that of the simulated dampers.

Guess what? You have just identified a hole in the aeromap and saved yourself a (significantly more expensive) trip to the wind tunnel.

That, combined with the tyre modelling (the end results in **figure 1**) and some good old fashioned brain power gives you the ability to actually quantify what the car is doing. This information is invaluable and, when properly used, allows a small team to compete on level terms with its bigger counterparts.

So, I ask again of the motorsport regulators, how exactly does the use of data acquisition spoil the show?

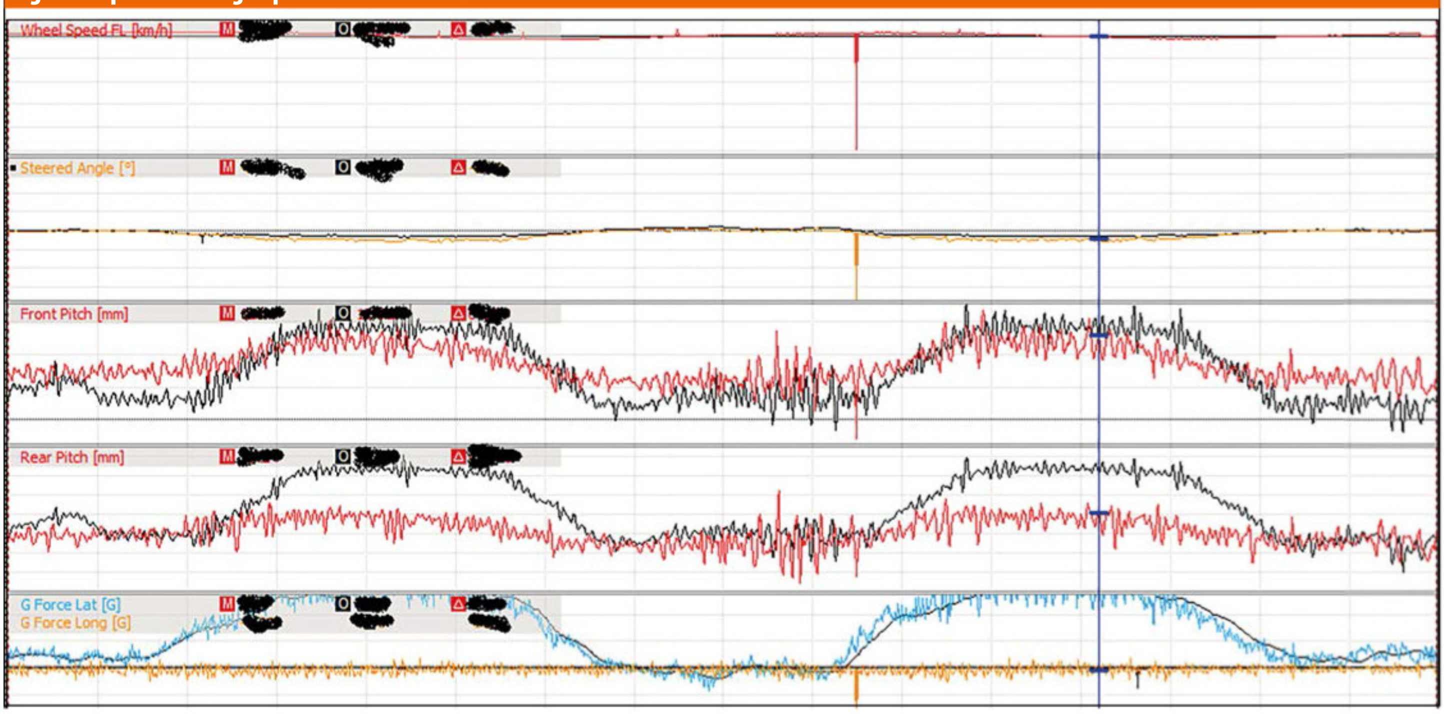
Alarm bells

The other thing that regularly sounds alarm bells is the thinking that understanding damping is too difficult, so we should lock it all away and have a sealed damper. I'm here to tell you this train of thought is so intellectually bankrupt, it would actually be funny if its repercussions weren't so serious.

Let me break down why.

The first thing you need to drive a damper properly is a damper dyno. There are a couple of ways you can do this. The first is to buy a damper

Fig 2: Comparison of high-speed oval simulated vs actual data



dyno from someone like CTS Automation, the price of which is between $8000 and $13,000 (approx. £6330-£10,280). It will fit in a regular garage and you'll be good to go.

Again, there are lower price options out there, and ChassisSim's US dealer, John Hayes, even went so far as to build his own. In short, obtaining a damper dyno is not going to break anyone in motor racing's bank.

The next thing you need to know is how to specify a damper curve. I have done this to death in previous articles but, to really ram the point home, **equations 1** and **2** will give you a quick helicopter overview.

$$\omega_0 = \sqrt{\frac{K_B}{m_B}} \quad (1)$$

$$C_B = 2 \cdot \omega_0 \cdot m_B \cdot \zeta$$

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_B} \quad (2)$$

Where,

K_b = Wheel rate of the spring (N/m)
C_b = Wheel damping rate of the spring (N/m/s)
m_b = Mass of the quarter car
ω_0 = Natural frequency (rad/s)
ξ = Damping ratio

As you can see, all of this is high school level maths, so should present no problem whatsoever to any motorsport engineer.

Next, you combine this with the damper workbook guide shown in **table 3**.

This pretty much forms the basis upon which I specify dampers. I then use this as a start point

Table 3: Damper ratio selection guide

Damping ratio range	What this applies to
0.3-0.4	Ideal for filtering out bumps
0.5-1.0	Dealing with body control
1.0+	Dealing with extreme body control / driving temperature into the tyres

and employ tools like the ChassisSim shaker rig toolbox to fill in the gaps for a complete damper specification. I'm the first to admit it's far from perfect, but it is brutally effective.

Manual work

The final part of the process is to 'RTFM!' (Google it if you need to…) for the damper so you can start playing with the damper curve and obtain the shape you want.

You might at this point be asking what is involved in distilling the damper elements together? Well, this requires practice, homework, patience and dedication. Like anything worthwhile in life. Is it going to break the bank? Hell no! What it is going to do, though, is allow a skilled performance engineer to quickly have a small team punching well above its weight.

By dumbing down the feeder formulae, we are starving our junior engineers of this opportunity to learn.

Conversely, if they are on top of everything we have discussed here, they will be able to hit the ground running, rather than start burning through time and money because they don't know which way is up.

That only leads to senior engineers like me having to clean up the mess, and blows out timelines. Bigger teams may be able to tolerate this, but smaller ones cannot.

Bridge building

Some still contend that Formula Student / FSAE bridges this gap but, as we have discussed before, the very nature of those cars, and the way the competitions have evolved, means the cars are too slow (limited to 112km/h) and the curvature of the circuits they run on way too high (peak corner radii of 0.2/m) for them to be representative of any real-world motorsport.

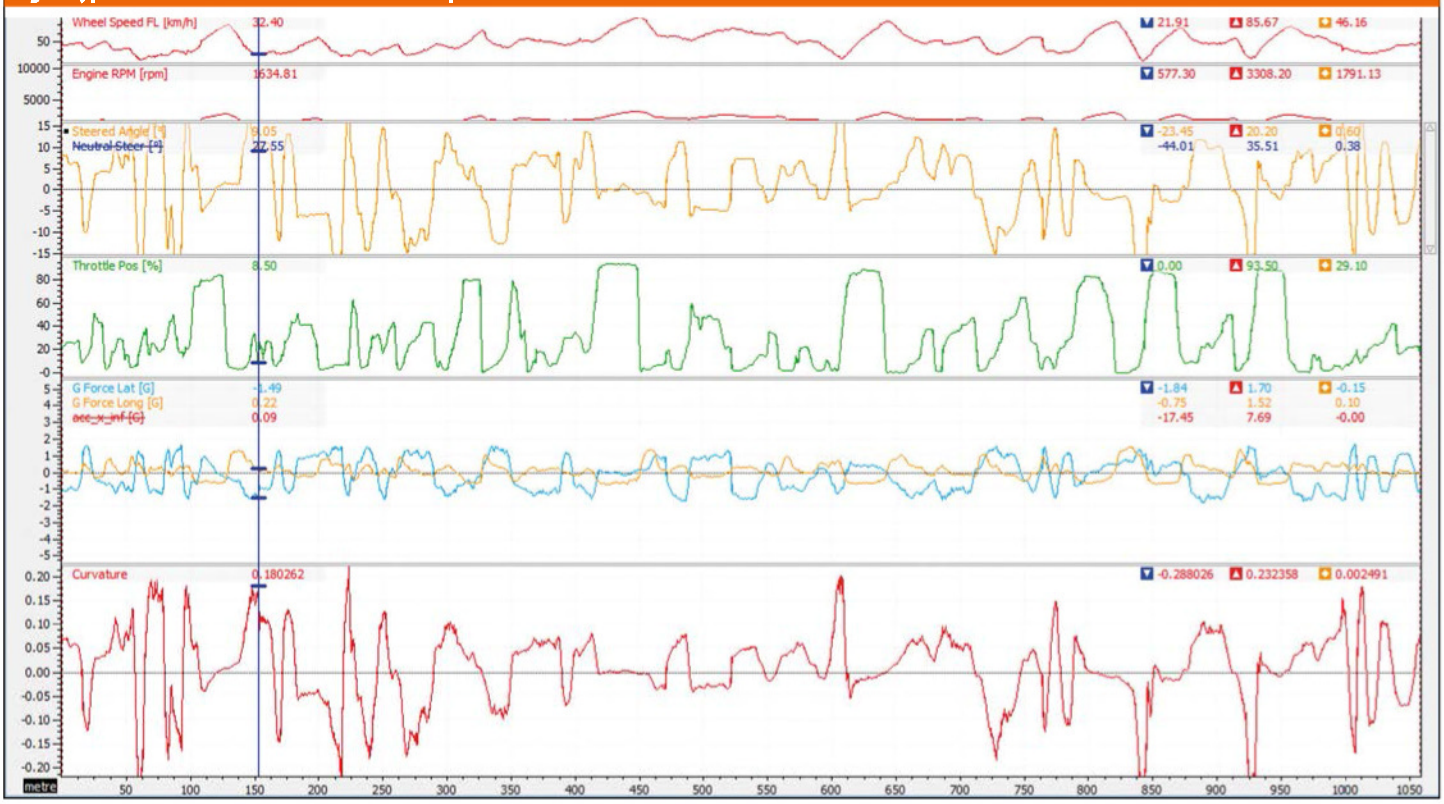
To prove that point, **figure 3** shows a typical set of Formula Student slalom data.

Don't get me wrong, these competitions offer a great taster for understanding dynamic behaviour, but the equivalent data trace on a real racecar looks nothing like that shown.

The other key issue I see with Formula Student / FSAE is a lack of appropriate mentoring, and a part of what takes up my time is keeping Formula Student alumni on the straight and narrow.

Coming at this point from another angle, it's no accident that Adrian Newey is so sought after these days. If you have read his book, *How To Build A Car*, you'll already know about the sheer breadth of experience on the subject he has. If you haven't, we're talking open-wheel cars, sportscars, flat-bottom cars and ground-effect cars. This vast, hard-won knowledge base is something motor racing engineers have lost in recent years and, if we want to prevent one team consistently racing away with a championship, we *must* take steps to address this.

Fig 3: Typical Formula Student / FSAE slalom speed trace

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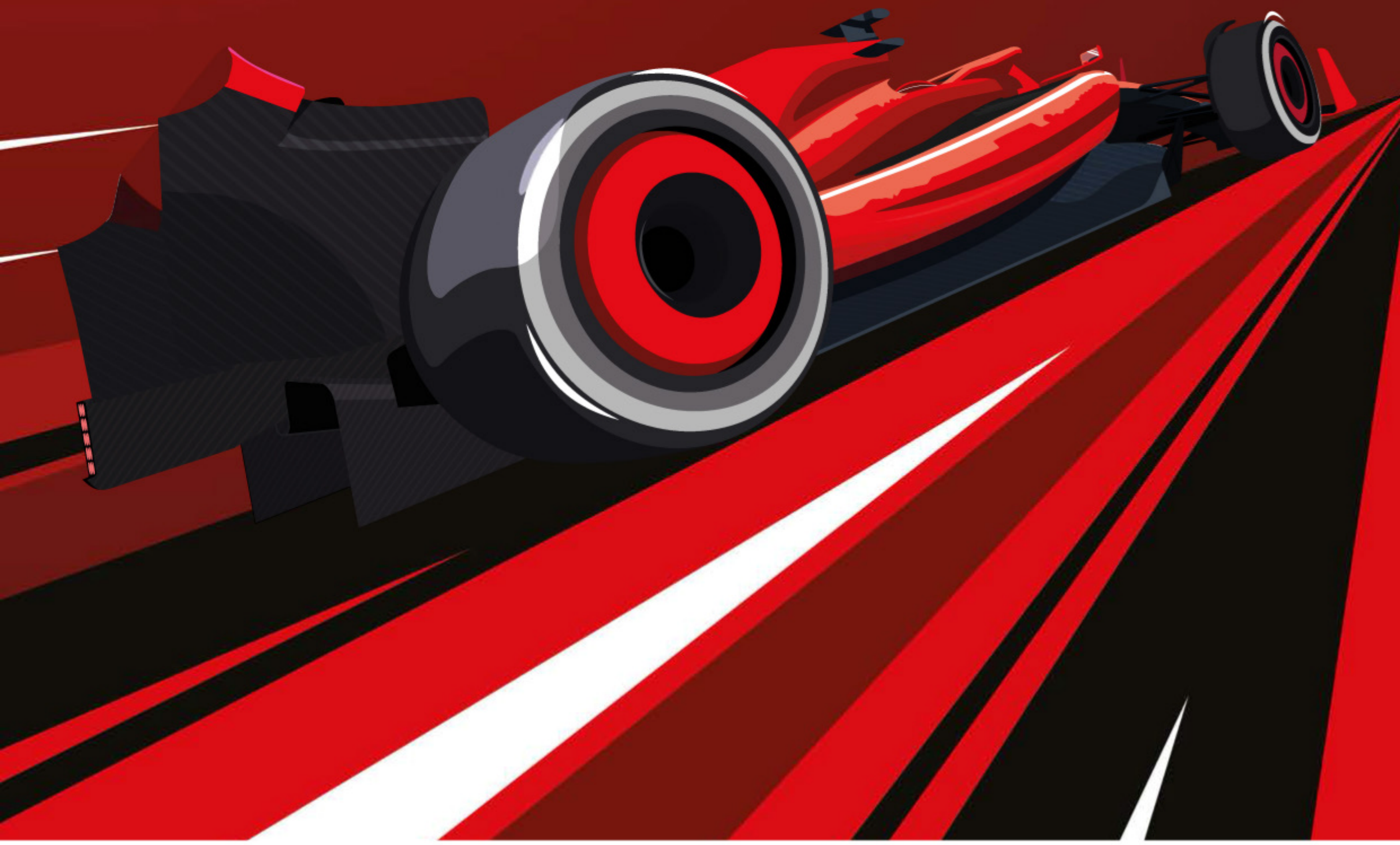


IndyCar confirms hybrid date

IndyCar has confirmed it will debut its new hybrid system during the ninth round of the season at Mid-Ohio in early July. Each of the cars will be fitted with a low voltage (48V) MGU and energy storage system comprising 20 ultracapacitors located in the bellhousing, along with the Xtrac gearbox.

The drivers will be able to regenerate on the brakes on road courses, and will have a paddle they can use on the ovals to quickly charge the ultracapacitors which is expected to be used in traffic.

The extra power delivery will be via a button, similar to the existing push-to-pass system.

Push-to-pass will still have a restriction on the amount of time per use and total time over the course of a race. Rules for the hybrid power unit will limit the amount of energy deployed per lap, based on track length. Used in combination on road and street circuits, the added boost is said to provide an additional 120bhp.

The system will be tried by all competitors at a test, scheduled for June 11 at Milwaukee, although the system has been tested at multiple circuits in the past few months.

'This is exciting new technology and, like all things new, has presented challenges to us at HRC as we have stepped in with our competitors to help IndyCar make the hybrid system compact enough, powerful enough, light and reliable enough to work within the restricted confines of the IndyCar chassis,' says Honda Racing Corporation USA president, David Salters.

Chris Owens

After starting the season without, IndyCar is finally introducing a hybrid system to its racecars. The series has been validating the new system, with an all-teams test scheduled for June this year

Michelin feeling the pressure after 2025 tyre test rained off

French tyre manufacturer, Michelin, is facing a squeezed timeline to have its new prototype tyres ready for the 2025 sportscar season after a recent test was rained off.

The tyre supplier planned to hold its final development test with its new slick range for all LMH and LMDh cars – which is set to include over 50 per cent sustainable materials – at Portimão in March, but the weather did not play ball.

Michelin looked at organising a replacement test in late June, but manufacturers were reluctant due to a tight gap between the 24 Hours of Le Mans and air freight departing for the 6 Hours of São Paulo. It subsequently identified a private test at Austin in late July involving Ferrari, Toyota, BMW and Porsche.

Unforced disruption has been a thorn in Michelin's side this year as it develops its 2025 range

Michelin wanted to test the day after that session, but was scuppered by plans to re-surface part of the track. The test has now been pencilled in for the day before instead.

Michelin's endurance racing programme manager, Pierre Alves, said the first 2025 tyre now won't be ready until mid-September, leaving a tight window for batches to be sent to Bahrain for the FIA WEC rookie test and an IMSA BoP test in November.

He added that any disruption to the Austin test could force Michelin to re-think whether its new tyre makes the opening races of 2025.

'[With a test in June] we would have been comfortable to be ready for the rookie test and sanctioned test, sending tyres by boat,' said Alves.

Michelin is also developing a new wet tyre that it had considered introducing this year. However, Alves suggested race data shows the current product has worked well, alleviating any urgency to replace it. Michelin will instead undergo more testing in October as it refines the future wet product.

Newey exit headlines F1 engineer market moves

The arrival of spring saw multiple high-profile changes in Formula 1's engineering job market, including the major news that Red Bull Racing's chief technical officer, Adrian Newey, will leave the title-winning team after 18 years.

At time of writing, Newey's future direction had not been defined. However, during an appearance as a driver at the Monaco Historic Grand Prix, the 65-year old indicated that he will likely 'go again' at some point after taking a break.

Newey was a key part of Red Bull's two waves of F1 dominance, including its current ascendancy during the championship's ground-effect era that started in 2022.

For that first year, he worked mainly on defining the RB18's suspension concept, which proved to be a key factor in the team unlocking superior platform control without the porpoising other teams struggled with.

Until his departure from the Red Bull organisation in the first quarter of 2025, Newey's focus will be on the rollout of the RB17 hypercar, which he has designed around an engineering team at Red Bull Advanced Technologies. The RB17 will make its public debut at the Goodwood Festival of Speed in July.

After 18 years and six Constructors' titles with Red Bull Racing, 65-year-old Newey has yet to confirm where he intends to go next, but has indicated that he has no intention of retiring

In other engineering job market news, Ferrari has attracted two key figures from Mercedes. On the technical side, it has appointed Loïc Serra as head of chassis performance engineering, reporting to the team's technical director, Enrico Cardile.

Serra previously spent 14 years at Mercedes, attaining the role of performance director.

In the same announcement, Ferrari revealed that ex-F1 driver, Jérôme d'Ambrosio, has joined as deputy team principal. The Belgian will also lead the team's young driver talent programme, reprising a role he had during a one-year stint at Brackley. Both Serra and d'Ambrosio will start with Ferrari on October 1.

Sanchez completes Alpine's technical shuffle

Elsewhere in F1, Alpine has signed David Sanchez to the role of executive technical director. Sanchez will oversee the three technical leaders, Joe Burnell (engineering), Ciaron Pilbeam (performance) and David Wheater (aerodynamics), whose posts were established earlier this year after the resignations of technical director, Matt Harman, and head of aero, Dirk de Beer.

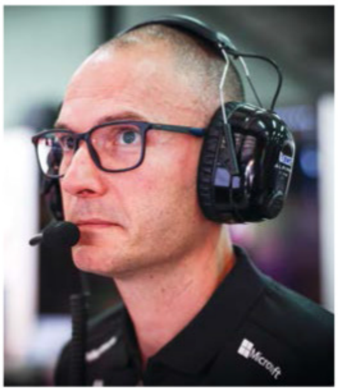
The Frenchman returns to Enstone, where he started his career with Renault in 2005, after a brief spell with McLaren that ended abruptly in April. Sanchez had agreed to join McLaren from Ferrari in early 2023 but needed to complete a period of gardening leave before starting work for the British outfit, only then to leave after just three months due to a 'misalignment' between expectations for his responsibilities and the reality.

Sanchez started his new position with Alpine on May 2, reporting directly to team principal and VP of Alpine Motorsports, Bruno Famin.

The team had a tough start to the season with the Alpine A524, scoring no points in the first five races with an initially overweight car before finally making it onto the board at Miami.

'I'm looking forward to working at Enstone again, the place where I started my Formula 1 career,' said Sanchez. 'This team has always had so many fantastic people involved and there is clearly so much potential to unlock.'

Famin told Burnell, Pilbeam and Wheater that Alpine would be appointing an executive technical director above them, though the timing of Sanchez's arrival was sooner than expected.


After an abrupt end to his McLaren tenure, Sanchez is excited about the next chapter

'He has already said there are good points, weak points and very weak points,' reported Famin. 'There are good people. The challenge is to make it work and to bring forth our good points and to be able to manage as soon as possible our weak points.'

IN BRIEF

After dropping off the Formula E support bill, the **NXT Gen Cup** for all-electric Minis has found a new home with the DTM. It was originally supposed to support two of the German series' rounds but will now follow the full eight-stop calendar.

Porsche is the latest manufacturer to commit to Formula E's Gen4 regulations, which will run from 2026 to 2030. Nissan and Jaguar have already confirmed their participation in the new formula which will see four wheel drive and peak power set at 600kW.

The FIA has invited companies to tender for a new, lightweight **Halo** device that will be used in Formula 1 between 2026 and 2030. The final technical specification of the device, including the weight, will be issued at the end of June 2024 and companies will need to submit their technical dossiers by March 31, 2025.

The German motorsport scene was shaken up once again when the **Nürburgring Endurance Series** (NES) cancelled all remaining race dates for 2024 in order to focus on training 'neutral' marshals for a 2025 campaign, according to a series press release. The NES event scheduled for early May was cancelled when 88 marshals withdrew their support on the Friday afternoon of the race.

Penske Autosport has added Ansible Motion's Delta S3 driver-in-the-loop simulator to its arsenal as the team mounts a challenge in the Formula E World Championship. The team is the latest in a long list to use the sim, following Honda, Ford, Sauber, Pratt Miller and other teams in Formula E.

F1 chief technical officer, **Pat Symonds**, is leaving the organisation to join the Andretti Cadillac F1 team programme as a technical consultant. Symonds started working for F1 in 2017 and was involved in developing the current and 2026 regulations. His switch to Andretti Cadillac is a scoop for the American project, which had its initial entry request rejected by F1 in January.

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All-star experience

Why European racing could learn a lot from a NASCAR shootout

There was so much to enjoy about attending the NASCAR All-Star Race at North Wilkesboro, a historic oval track built in 1947. Not least because when the main grandstand was being repaired, it was found to have a vast hidden cavity underneath that may have been a moonshine store, harking back to NASCAR's rebellious early days. True or not, it's a great story.

There were other updates to the track too, including re-surfacing and installing Tecpro barriers, yet the original feel of the place has been preserved perfectly.

From the old painted stickers of the Winston Cup Series on the wall of one grandstand, to the refreshment stands that certainly belonged to another era, it was a wonderful window of opportunity to enjoy racing as it used to be.

The visit did make me wonder about recent upgrades made to circuits in Europe, though, where the emphasis is on having a Formula 1 track surface, making it challenging for other series to use.

If you were a VIP at North Wilkesboro, there were no frills, no team hospitality masking the drivers or team managers from fans. Some boxes high up may have served food, more likely beer, but guests could use the concession stands, same as everyone else. I like that.

The track itself is a 0.625-mile oval, which meant that even for the reduced-size grid for the All-Star race, the pit lane extended for more than half the track, around the tight bend between turns three and four. To add excitement, the track featured a large bump around that corner, meaning the cars were somewhat lively over it at racing speeds.

> **For those who have spent a lot of time in European racing, this was a very welcome blast from the past**

Be prepared… for a fight

Standing in the pit lane for the Open race, in which drivers could qualify for the main event, I watched as mechanics meticulously prepared the surface outside their car's pit. Using blowers to clear it and create grip where possible, they ensured everything was perfect for their all-important stop. However, when Ricky Stenhouse got punted into the wall on lap two of the main race, he parked his broken car outside the immaculate pit of Kyle Busch, whom he felt was responsible. The fans in the grandstand laughed and took pictures, while the TV cameras picked up their fist fight afterwards. Turns out both can throw quite a punch.

The paddock was just how it used to be in Europe, but sadly is no longer. Teams worked out of trailers, and the cars were there for all to see as the mechanics prepared them.

There were no garages, no huge trailers joined by tents, manned by security guards who protect the mountains of spare parts and prevent all, including media, from entering without being escorted. Everything in the paddock was open. The drivers could hide in the cabs, which was fine, and when they did emerge they weren't mobbed.

It was also refreshing to witness the partisan crowd, who cheered the drivers they liked, and booed those they didn't.

Seeing blue

One other thing I rather enjoyed, and felt European racing could consider, was the lack of blue flags for unlapped cars. On such a short track it didn't take long for Joey Logano, involved in a tussle for the lead with Denny Hamlin, to catch the back markers, and he came upon Bubba Wallace. Bubba knows how to drive a racecar, and was allowed by regulation to defend his position. The battle lasted more than 50 laps (not that long, admittedly, when it's an 18-second lap) but Bubba kept his foot in and Logano could not get by before the caution was thrown at lap 100 to allow the teams to change tyres.

Here, Goodyear had given the teams the option of a soft tyre, which was compulsory for the start, and a medium. Teams had two sets of each for the 200-lap race, and could use them as they wished.

The first caution, on lap two when Stenhouse was punted off, saw more than half the field stop and switch to the more durable rubber. Logano didn't, keeping softs on for half the race, and then chose softs again for the second half.

He took the win, and the million dollar prize. Again, that's unheard of in Europe. The GT World Challenge does hand out *some* prize money, but is one of very few series to do so. IndyCar recently held its own million dollar challenge at Thermal Club, but that doesn't quite match the historic allure of North Wilkesboro. The grandstands were pretty full, and the fans were enjoying themselves immensely in the spring sunshine, so it's worth a thought by other series.

The only negative to a wonderful weekend was the rain on Saturday night, which delayed the truck race, blocked the drains and flooded the infield. For those that race pretty much every week in the main series, this event is a bit of a sideshow, but for those who have spent a lot of time in European racing, the Wilkesboro weekend was a very welcome blast from the past.

ANDREW COTTON Editor