F1: Adrian Newey on where the new regulations are going wrong – p16

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Toyota's updated GR010 finished second at Sebring, having had its hybrid capability effectively castrated for the opening round of the WEC in Florida

XPB Images

One-ton F1

Welcome to the world of Formula 1 truck racing!

The 2022 minimum weight limit for F1 cars, including a set 80kg driver mass, has been raised by over five per cent to 795kg. A further increase of 3kg was ratified by the FIA World Motorsport Council in March, as teams struggled to get down even to this figure.

Reasons for this include the new regulations incorporating mandatory parts such as bigger wheels, wheel covers and front wheel air deflectors, plus added safety items, although some weight savings have been made by the outlawing of inerters, hydraulic suspension systems and bargeboards. Nevertheless, by the time the cars line up on the grid with a tank of fuel onboard, they will be around 900kg, or close to one metric ton.

This makes them the heaviest F1 machines ever, comparable only to the pre-WW2 Formula Grand Prix monsters, although their 750kg limit did not include the driver. Just think about that for a moment, 88 years on…

And this, despite carbon composite chassis and components, FEA, CFD, CAD / CAM and 3D printing processes and technologies.

When I was involved in making IndyCars and F1 machines, the aforementioned monsters were looked upon as the industry heavyweights, designed to withstand 200mph impacts with concrete walls. This comparison is now reversed.

Penske Entertainment, Chris Owens

Andretti Autosport is mighty in IndyCar, and a US entry in F1 should be welcomed

The main culprits

Fundamentally, of course, the combined weight of hybrid battery, MGU-K / MGU-H and associated cooling, wiring and so on is the main culprit, along with safety devices. These aren't going to go away any time soon, and so it's difficult to see how this F1 obesity can be addressed. However, I firmly believe there should have been no increase in the 795kg, and attempts should actually be made to reduce this in the future, not add to it.

I don't think it's acceptable to just shrug and say that's how it is. Because racecars should be nimble, as well as powerful. The new cars are even more ponderous than before in slow corners, albeit blindingly fast in quick ones.

Weight saving has been part of the competitive challenge of racecar design and construction forever, and in this environmentally-conscious world should be an integral part of promoting energy efficiency.

So what if teams are struggling to get near the minimum limit? They are all in the same boat. Deal with it. Yes, the budget cap, and other restrictions, prevent a spending war on super-exotic materials and processes that would have occurred before. Driver weight is fixed, along with all the safety measures, so one might argue, why have a minimum weight at all?

Race engineers might need to make a choice – perhaps trade some of the onboard data acquisition equipment to shave thousandths, or maybe even hundredths, off lap times.

Concentrated, imaginative engineering by all involved, including suppliers, can help address this problem, including ongoing development of the whole PU package, as well as coolers, wheels and brake systems – all items relevant to the production car world, too.

The cars are so large now, dictated by having to squeeze in a battery pack and all the associated cooling, as well as a large fuel tank, plus the aerodynamic advantage of greater underside plan area.

If refuelling was allowed – something I've frequently advocated – as well as reducing the race starting weight instantly by at least 50kg, it would allow a significant reduction in wheelbase, width and overall length, and therefore mass. Instead, we have the vicious spiral of more mass requiring *bigger* brakes etc.

Some of the slow corner clumsiness of the cars is attributed to the front tyres not being strong enough in their response to steering inputs, and their propensity for locking up. Part of this is caused by the contrast with the much stronger rear tyres. Is there the opportunity for Pirelli to produce a better front tyre for the remainder of the season? I hope so, because no amount of aero and suspension tweaking can properly overcome a tyre imbalance.

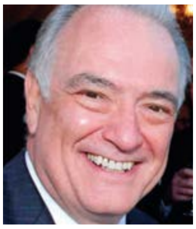
Heat stroke

Managing heat must also be a design headache. Mercedes' (and to some extent Williams') minimalist sidepods have caused puzzlement concerning how the cooling can be effective. The team has reportedly been working with Reaction Engines, UK specialists in air-breathing rocket motors, to obtain extremely efficient heat exchangers. Could it also be that the team is employing nano technology, in the form of graphene particles suspended in the cooling fluids to improve their thermal properties? One would have thought most F1 outfits would have explored these avenues, but perhaps the challenge of transferring potential into actuality has proven too difficult for all but Mercedes?

Ultra-high technology apart, Mercedes' current performance difficulties might be attributed to the team having developed its chassis from the basic, very effective concept introduced with the hybrid PU regulations in 2014. That car evolved considerably – unrecognisably – into 2021, but 2022 is the team's first totally 'blue sky' project. Being probably the most data driven of all F1 teams, but with no ground-effect numbers to work from, this necessity to revert to basic conceptualising has perhaps caught it out? Also, they have lost a number of experienced senior powertrain engineers to rivals.

Something else that pains, but doesn't surprise, me is the arrogant, protectionist reaction by a couple of top teams to the desired F1 entry by Andretti Autosport. Questioning whether Michael's eponymous company has sufficient funding is an insult. It is one of the most successful US motor racing organisations, with a hugely respected and recognised family name and reputation. F1 needs an American team of this stature to come in alongside Haas. Even better if there could also be a Japanese team, to further emphasise F1's world championship credentials. Always think of the big picture.

I don't think it's acceptable to just shrug and say that's how it is



A new challenge

Turbulent times around the world call for resilience and visibility

Just as we escape Covid and recover, unexpected business challenges arise that will dominate management for the foreseeable future, just one of which is conflict caused by Russia. Many pitfalls consequently await the unwary: inconsistent supplies; daily rising costs; payment difficulties; stock control; staff recruitment, to name a few. The basic laws of supply and demand will be tested to the full, and the resilience learned through motorsport will be required.

In the early 1990s, as the USSR collapsed, the US military identified the challenges ahead at the time as Volatility, Uncertainty, Complexity and Ambiguity, hence VUCA. Currently, as management in our industry has to overcome remarkably similar challenges, I recommend you read about VUCA.

In a nutshell, Volatility describes the intensity of fluctuation over a period of time, while Uncertainty arises from unpredictable 'surprises' that occur. Complexity is influenced by the number of interactions taking place at speed – the more there are, the more complex, or complicated, business becomes – and Ambiguity is when details of challenges are explained in differing ways, so adding to misunderstanding and confusion.

In turbulent time such as these, collaboration, participation and debate are vital to allow you to be well informed, remain flexible and take action quickly. The exceptional rise in companies attending MIA B2B engagement events to find new suppliers and partners is a clear indication of this need.

Quick reactions

Governments and business communities have reacted quickly. As there is no way to pay Russian suppliers, nor vice versa, the commercial and moral decisions are obvious, and most have ceased trading with Russia.

Even before the Ukraine conflict, supplies of raw materials, freight, packaging, fuel, energy and electronics, amongst others, have been unpredictable. Rapid increases in costs have reached unforeseen levels, and millions of half-finished products are sitting on shelves waiting for a $5 item before they can be delivered.

Unexpectedly, recruitment and retention of staff is proving extremely difficult. In the UK, hard-working engineers returning to their homes in Europe, as a result of Brexit, is damaging many businesses. Ironically, they would be welcomed back with open arms as it appears the UK workforce has lost interest in the well-rewarded engineering world of motorsport.

The good news is that demand for motorsport products and technologies has gone through the roof. Many companies now exhibit record forward order books and numerous hugely valuable overseas contracts have been awarded.

Porsche Motorsport

Porsche is the first of the LMDh manufacturers to successfully test the spec hybrid system for the class, produced by Bosch, Xtrac and Williams Advanced Engineering

The surge in interest in motorsport around the world, particularly Formula 1 due to Netflix, is certainly helping. Interest in innovative, agile motorsport companies is subliminally stirred amongst engineers, and the more popular motorsport becomes, the more interest there will be for collaborative business ventures.

The depth and breadth of the many 'Net Zero' challenges are fertile grounds. Technologies are changing fast across marine, aerospace, defence and automotive. The rapid response and agility of the motorsport supply chain is, increasingly, in demand in all these sectors.

The West will move quickly away from purchasing gas, oil, energy and raw materials from Russia, currently the world's largest exporter of oil. The UK government is now reconsidering the use of its own supplies of gas, oil and energy and may even overcome its 'fracking' nervousness.

We can expect the timing of Net Zero plans in the UK, and elsewhere, to change rapidly. Security of energy supplies and raw materials is now more important than ever due to Russia's recent actions. This should highlight the dangerous imbalance of future battery, lithium and cobalt supplies, which, by 2030 and beyond, will rely too heavily on China.

There will be a rapid increase in investments in green and blue hydrogen R&D and sustainable fuels. These could combine with the sale of hybrids incorporating ICE to perhaps extend their sales long beyond 2035. Surely, the UK government's 2030 deadline to ban the sale of ICE cars will now be acknowledged as undeliverable.

Growth in motorsport helps catch the eyes of engineers across other sectors. Success in the US of UK companies will attract the attention of other US motorsport buyers. In NASCAR and IMSA, Xtrac, Williams Advanced Engineering and AP Racing are just three MIA members who have secured substantial business.

A proven management action to meet the challenges of VUCA is to give your business real presence, making it visible to others. You must regularly meet and link with others in your business community to build relationships and find out what's going on. Once your presence is established, and your relationships help you make sense of the situation, you can confidently drive things forward and thrive.

Troubled times have seen attendance double at cross-sector MIA motorsport events. I've never witnessed such an enthusiastic reaction to B2B networking, the MIA's EEMS conference in March sold out a month before the event.

Every day my office gets urgent requests for help and we quickly 'match-make' companies to work together and find solutions.

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A proven action to meet the challenges of VUCA is to give your business real presence

Signs of the times

With the first two tests now behind us, how have F1's attempts to reduce costs and improve the show for the viewers impacted on the teams?

By DIETER RENCKEN

Despite at least four years of collective research by some of the best brains in Formula 1, using the most sophisticated tools at their disposal, the overriding reactions as the sport's 'new era' cars got up to speed during pre-season shakedowns in Barcelona (full-blown test sessions followed a week later in Bahrain) were of sheer nervousness – about both teams' own performances, and those of their peers.

Much has been written about the methodologies and research that went into the 2022 regulations, designed to reduce 'dirty' air, thereby (theoretically, at least) upping the chances of running closely enough to overtake, but the acid test came in Bahrain, rather than Barcelona, where teams spent three days checking systems, rather than indulging in close proximity running.

Pre-shakedown, there had been widespread fears that the regulations were too restrictive, leaving little leeway for creativity, and that consequently the cars would all look identical, at least if they were all painted monochrome. True, most of the 2022 contenders had been revealed before formal running commenced, but the majority were clearly 'launch specials'.

Red Bull had gone the full distance and spent $50,000 creating a mock-up livery on a full-size model car using F1's CAD concept car data points to keep incoming sponsors sweet, while at the same time not showing its true hand. 'Marketing costs are excluded from the budget cap,' grinned team boss, Christian Horner, by way of explanation.

Sauber, meanwhile, chose to launch its car after the shakedown, so ran the 'Alfa Romeo' initially in camouflage.

Red herring

Thankfully, the concerns about similarity proved ill founded, as a number of different sidepod designs were revealed, including a rather lumpy version from Mercedes that was clearly a red herring designed to throw the competition off scent. That was followed by a 'zero sidepod' design, which made its debut in Bahrain. After the race, the jury was out on its effectiveness, though, after a tepid showing by the cars now returned to traditional silver hue.

'We'd rather be a second quicker than everybody else and disappear into the sunset, but that's not the case now,' admitted Mercedes CEO, Toto Wolff, during race weekend in Bahrain, where the team was almost two seconds adrift of the front-running Ferrari.

'We started the season well in Barcelona, then went backwards from there. Now it's about really understanding [the car]. Whatever we do now is, in a way, a process. We can do things quickly and we can do more sophisticated and profound changes over the mid-term. This is what we are aiming to do.'

Given the W13's uniquely slim flanks, were people surprised by the vastly different sidepod designs and solutions that emerged up and down the pit lane in Bahrain?

'Not really,' says Pat Fry, chief technical officer at Alpine. 'You get to different forks in the road, you reach a point where you can go A or B and you've got to guess. You can't afford to develop both of them

'We started the season well in Barcelona, then went backwards from there'

Toto Wolff, CEO at Mercedes


Toto Wolff

Mercedes struggled to keep up with Ferrari and Red Bull, though the latter's reliability issues meant the team took third and fourth


Nicolas Tombazis

'I had some comments from our historic racing department, who thought it was a bit funny that we were worrying about this [porpoising] thing when, of course, they got it all the time with their cars'

Nicolas Tombazis, head of single-seater technology at the FIA

Although seemingly able to control ride, the Alpine A522 did not have the outright pace to battle with the top six in Bahrain


Pat Fry

[under the restrictive $140m budget cap and stringent aero test regulations], so you've got to test just one.

'We go one way, it could be that someone else at the same point has gone the other way, so it's not surprising.'

Jody Egginton of AlphaTauri is similarly not surprised: 'I think there's aspects of what [all teams] have done there, which people would have looked at. And yes, if anyone else had put an identical concept in, then I'd have been wondering whether there was something going on that shouldn't have been…'

Side effects

That said, the moment the cars hit the track in Spain it came obvious – painfully so, in some instances – that the ground effects generated by the mandated under-body venturis brought with them the unpleasant side effect first experienced with similar aerodynamics during the late '70s, namely uncontrolled bouncing, or 'porpoising' as it is being called.


Adrian Newey

Whilst undoubtedly unpleasant for the drivers to experience, the phenomenon wasn't unexpected for some, with experienced folk such as Rory Byrne, the former Ferrari chief designer who recently extended his consultancy contract with the scuderia for three more years, and veteran technical director, Adrian Newey, anticipating some bouncing.

Although Red Bull's chief technical officer was still studying at university when this scenario was first experienced, he was obviously aware of it, having had first-hand experienced in IMSA Sportscars, with their wide underbodies. His design team was therefore not taken by surprise *per se*, but still had difficulties pinning down the causes.

Newey discusses the phenomenon in-depth in our exclusive interview on p16, but here are the salient points:

'It's a classic control theory problem. When you have a set of aerodynamic regulations that allow ground effect, the closer the car gets to the ground, the more downforce it gives. If those vortices, or structures, or whatever it might be that give you that downforce, start to stall or separate, you lose downforce, the car springs back up and the cycle repeats itself.

'The first problem is that wind tunnel models, generally speaking, are rigidly held, so you won't see the problem there,' he explains. 'I think it's the same for all teams, trying to come up with solutions where they reduce the problem without losing downforce. Then you're in that classic performance vs comfort trade…'

'You get to different forks in the road, you reach a point where you can go A or B and you've got to guess. You can't afford to develop both of them… so you've got to test just one

Pat Fry, chief technical officer at Alpine

He reiterates the point, somewhat cheekily maybe, by noting, 'There's nothing new to it. It's perhaps unknown to many of the younger generation of Formula 1 aerodynamicists, but it's a well-known phenomenon.'

Full transparency

That is borne out by comments from a number of technical directors, including Jan Monchaux of Sauber (Alfa Romeo), who told *Racecar Engineering* when asked about the team's issue after shakedown, 'To be fully transparent and honest, we didn't foresee [the bouncing]. The first time I saw Valtteri [Bottas] driving past I thought he was a bucking kangaroo.

'We had discussed during the last months about the kind of phenomena that happen but, since none of our wind tunnels and simulation tools were giving a hint of it, we were a bit taken aback.'

The FIA's head of single-seater technology, Nicolas Tombazis, a renowned aerodynamicist who led the regulatory changes on behalf of the FIA, admits porpoising caught them 'a bit off-guard too, despite it not being a new thing.

'In fact, I had some comments from our historic racing department, who thought it was a bit funny that we were worrying about this thing when, of course, they had it all the time with their cars.

'The thing is, it's not very easy to simulate. Although simulation tools have grown a lot, we haven't really developed the proper simulation tools to model it.'

The Greek adds that certain teams had been concerned about overall ride heights being too low (the closer the floor to the track, the better the 'suction', but also the greater the chances of porpoising and floor damage), but says the matter was aired too late during the regulatory process for changes to be made without majority agreement, and so it was dropped.

'If that had [not] happened, probably things would have been a bit better, but [the concerns] weren't aimed at trying to deal with porpoising, as such, at the time.'

Clearly, not all teams have been affected equally, with some seemingly hardly suffering, while others were visibly struggling, particularly in high downforce configuration. Classic 'cures' so far have been a combination of raised ride height, increased rear tyre pressure and open DRS (where permitted).

By effectively switching the porpoising effect on and off, teams were able to gain a better understanding of the issue, opening up various potential fixes that were tried during the second test.

'In very general terms, there's a ride height sensitivity and a stiffness sensitivity,' explains Egginton, 'so a combination of those two gives you tools to sort of manage it. But you don't want to overstep the mark. And then you've got to consider that across low fuel / high fuel, DRS on / DRS off and a lot of [other] factors.

'The idea is to maximise the aero package as much as you can around what you've got while, at the same time, trying to develop in the direction that minimises the chance of [porpoising].'

Tyre performance

Raising tyre pressures is no long-term solution, as the softer the pressure the better the grip (within parameters), plus 'cold' pressures have already been raised due to mandated drops in tyre blanket temperatures from the previous 100degC / 80degC front / rear respectively to a flat 70degC. A rule of thumb is that pressures are raised one psi per 10-degree drop in tyre temperature.

Christian Horner

'Rather than just running as fast as you can and getting as much performance from the car, you've now got to be more selective in what you chose, based on its cost, which drives efficiency'

Christian Horner, team principal at Red Bull

Despite showing significant pace, both Red Bull Racing cars had reliability issues in the opening race of the year and failed to finish

Jody Egginton

'The idea is to maximise the aero package as much as you can around what you've got while, at the same time, trying to develop in the direction that minimises the chance of [porpoising]'

Jody Egginton, technical director at AlphaTauri


Mario Isola


The AlphaTauri AT03 showed promising performance early on, but Pierre Gasly's car suffered a bizarre complete shutdown in the later stages of the Bahrain Grand Prix and then proceeded to catch fire

'There is a difference between high and low-speed balance, and [the new tyres] can push a lot in high-speed corners, but at low speed they generate [understeer], due to the ground effects being lower'

Mario Isola, Pirelli Motorsport director


Jan Monchaux

On the tyre performance side, Pirelli Motorsport director, Mario Isola, is comfortable that, overall, the new 18in rubbers are delivering as predicted, although he concedes degradation was higher in Bahrain than expected due to the 60degC track temperatures. This is a compound, not construction issue, though, and so a relatively quick and easy fix.

'These tyres are different, you have to drive them in a different way,' Isola told *Racecar Engineering*. 'There is a difference between high and low-speed balance, and they can push a lot in high-speed corners, but at low speed they generate [understeer], due to the ground effects being lower.

'Front locking is not unexpected because the cars are a lot stiffer [due to less pliant sidewalls, and higher spring rates to cater for ground effects], so they run close to the track to generate downforce.'

Front tyre stiffness is up by 12 per cent as a result of the sidewalls being reduced from the 165mm of the old 13in tyres to 131mm, with rear stiffness increased by five per cent. The overall damping effect of the sidewalls is 30 per cent less at standstill, converging to zero at top loadings. All this obviously affects tyre behaviour, and clearly affects car dynamics.

Additional weight

Although there were vague mutterings about potential safety issues caused by porpoising in Barcelona – obviously driven by the worst affected teams – these had faded by the second outing as teams worked around their problems. That said, immediately after testing, the FIA approved the fitment of stays to reinforce the floor area, in the process recommending their fitment rather than making them mandatory.

Simultaneously, a weight increase of three kg, pushing car mass up to 798kg, was approved on the basis that all teams were above the limit due to the wheel covers and certain safety items coming in higher than anticipated. Sticking to the lower weight would simply have pushed teams into an expansive race to save three kilos.

'As for the process of how we arrived at those decisions, they might not have been agreed had they not been linked, but they are independent,' says Egginton, in obvious reference to some teams [and the governing body] wanting one or the other, with the net result being a trade-off between the two.

While all this was going down, the elephant in the room was, of course, the $140m budget cap – reduced by $5m from 2021, with a similar reduction following for 2023 – all while the pandemic, supply chain disruptions and Putin's war play havoc with labour and component prices and availability.

The unknowns with the new regulations also mean teams need to have some spare cash for the unexpected.

'Obviously it's a challenge,' agrees Egginton, 'because you've got to spend the money wisely, and when it's a new set of regulations there are more unknowns, so you've got to be focused on that.

'We had a plan very early about what our likely update strategy would be. Everything's new this year so we're really focused on making sure the money is spent on bits of the car that are performance differentiators. We're not throwing money at widgets.

'The main policy is to keep money available for updates. With the new car design, if you find something really performant you want it on the car, and you need cash to do that, so you need to keep money available for as long as possible.'

McLaren struggled at the opening round of the championship with the car well off the pace and difficult to drive

Pat Symonds

Unknown economic factors are also likely impact upgrades throughout the season, meaning what is right from the start is likely to stay ahead a bit longer, as Red Bull boss, Christian Horner, explained during race weekend: '[The cap] is very aggressive, so you have to be strategic in how you apply your funds to developments.

'Rather than just running as fast as you can and getting as much performance from the car, you've now got to be more selective in what you chose, based on its cost, which drives efficiency.

'The added complications we have at the moment with the cap is what's going on in the world and inflationary prices… in the UK [where eight of the 10 teams have bases] we are close to 10 per cent inflation. Freight, logistic and fuel costs are having a significant impact.'

In the final analysis, what has been the biggest challenge for teams so far?

McLaren technical director, James Key, split his response into two parts: 'Correlations have obviously been difficult to figure out because there are no reference points for these cars at all. Hence the porpoising.

'It's all been very sort of R&D and digital for a long time. Then you hit the track and hope everything matches what you predicted.

'The other thing is how you futureproof your car. Which volumes do you protect, what directions do you protect, what may or may not work in the future? You don't really have too much redundancy. It's all very efficient, but you can't pin yourself down to only one solution at this stage.'

For Monchaux, the biggest challenge, it seems, was a lack of testing time, which impacted on reliability: 'If I could get three days more testing, I would be happier. I'm an engineer who wants to reduce the risks, and to reduce the risk I need more time. But it is the same for everybody.'

Ironically, that is exactly what F1 and the FIA set out to achieve when framing the new regulations: to level the playing field via a reset button. In the process, a level of sporting technical jeopardy was introduced, one that saw Ferrari on pole in Bahrain, with the fastest Mercedes almost a second adrift and the second behind an Alfa Romeo and a Haas.

F1 technical director, Pat Symonds, who oversaw the research summarises: 'At F1, we don't just do technical things like cars, we do an awful lot of very, very advanced research into what our fans want, and in all sorts of different ways, particularly our viewers.

'What we found is that, while a lot of people talk about overtaking, overtaking's not the real entertainment, it's the battle.

'When the overtake does takes place, very often that's the end of the battle. So what you want is cars that follow closely, and then the better driver will win. But we want to see a good challenge to make that overtake.'

Early signs are that it is working.

'At F1, we don't just do technical things like cars, we do an awful lot of very, very advanced research into what our fans want, and in all sorts of different ways'

Pat Symonds, F1 technical director

James Key

'You don't really have too much redundancy. It's all very efficient, but you can't pin yourself down to only one solution at this stage'

James Key, technical director at McLaren

On the right track?

Thoughts on Formula 1's new era from Red Bull Racing's chief technical officer, Adrian Newey

By DIETER RENCKEN

The consensus throughout the Formula 1 paddock is that the 2022 technical regulations see the most significant changes to any rule set in the sport's history. At time of writing, the 2022 season was about to get underway, with both pre-season tests complete and teams carrying out final engineering on the cars ahead of the first race in Bahrain.

The journey into the new era of the sport has been a bumpy one so far, in every sense of the word, as teams faced a plethora of technical challenges throughout the testing weeks, primarily revolving around so-called porpoising – a bouncing phenomenon caused by the car's inability to control its platform, stemming from extreme swings in downforce generated by the ground-effect aerodynamics. However, the chances for teams to explore how their cars behave in the real world before competition starts in earnest is now almost over.

Racecar Engineering (**RE**) had the opportunity to sit down with Red Bull Racing's chief technical officer, Adrian Newey, and ask his views on this latest era of Formula 1.

RE: First of all, can you explain the porpoising challenges?
Newey: 'It's a classic control theory problem. When you have a set of aerodynamic regulations that allow ground effect, the closer the car gets to the ground, the more downforce it gives. If those vortices or structures, or whatever it might be, that give you that downforce starts to stall or separate, you lose downforce, the car springs back up and then the cycle repeats itself.

'It's nothing new. I believe the venturi cars of the late '70s and '80s had it. Certainly, plenty of Group C cars and so forth have struggled with it, including the current crop of LMP2s, so it's a well-known phenomenon. But while there's nothing new to it, it's perhaps unknown to many of the younger generation of Formula 1 aerodynamicists.'

RE: So, if it's not new, why is it so difficult to manage, or even simulate?
Newey: 'The first problem is wind tunnel models, generally speaking, are rigidly held. And, if you hold the model of the car rigid, you won't see the problem.

'People in the past have tried to do transient movements of wind tunnel models, but that becomes a whole art form in itself. Just as you have Reynolds number for the scaling of speed and scale, you have another thing called Froude number, which governs the frequency vs scale vs speed (the ratio of the flow inertia to the external field) that you have to move the model at to replicate what goes on on track.

'If you have a car on the track bouncing along at five or six hertz, you have to go to a much higher frequency on the scale model, which creates dynamic problems. If you had a full-size model, you'd actually be able to replicate that, or at least replicate it far better than you can at the moment. But you would have to find some way of suspending the car non-rigidly to do it. That would ultimately, or *could* ultimately, resolve the issue.'

RE: How difficult is it to actually solve the porpoising problem then?
Newey: 'First of all, you have to understand the problem properly, which is not that easy in itself. Then after that, it's about trying to come up with solutions that reduce the problem without losing downforce.

'You're in that classic performance vs comfort trade if you like.'

RE: Is this porpoising occuring at a different point of the car to the ones from the 1970s and '80s?
Newey: 'I was still at university in those times, so I can't completely answer the question. But I think the phenomenon of flow structures breaking down will be exactly the same.

Adrian Newey is regarded as one of top engineering minds in the sport, winning no fewer than 10 Formula 1 constructors' titles with cars he's overseen

The first problem is wind tunnel models, generally speaking, are rigidly held. And, if you hold the model of the car rigid, you won't see the [porpoising] problem

Red Bull Racing's Adrian Newey and driver, Max Verstappen, on the podium after winning the 2021 Monaco Grand Prix

Photos: XPB Images

Red Bull Racing driver, Max Verstappen, preparing for a test run in the team's new RB18

Where they break down on those cars didn't have any significant vorticial structures as we have now. So I'm sure it's different.

'However, the basic principles are the same. These cars are aerodynamically reasonably complicated underneath in their flow structures. So, what's actually going on, and where it's breaking down, is going to vary from team to team.'

RE: Moving on, how do you find the new 18in tyres?

Newey: 'Taking the new tyre parameters compared to those from the last few years, the rim diameter change hasn't particularly changed anything because the sidewall behaviours are about the same. And it is the sidewall that tends to govern the stiffness and the characteristics.

'They're a little bit different, of course, and we're still in the early days of understanding them. Still, they don't obviously seem to be hugely different to previous generations' Pirellis. Though they're a lot heavier, of course. Personally, I think the reason behind going to these big rims is to make it look more like a road car, which is a bit of a funny thing to do.'

RE: Does this lower profile tyre allow you better control of the suspension?

Newey: 'As I say, the sidewalls have very similar behaviour, it's just the tyres are bigger.

Much has been said about the porpoising effect due to the new ground effect aero package, not so much about the weight gain

So the rim diameter has gone up, the tyre's overall diameter has gone up and the sidewall isn't a lot shallower.

'The bottom line is that the tyre spring rate is about the same, so there is very little change from a dynamics perspective.'

RE: How do you conceptualise the aerodynamic regime of these cars?
Newey: 'I think the principle of trying to help cars to overtake by reducing the sensitivity of the following car to the one in front is okay. And so, I think it will help [drivers] to overtake a little bit. I don't think it will be a significant shift, but it will help a little bit.

'In reality, the only thing I would say is that these are the most considerable aerodynamics regulation changes we have ever had since Formula 1 banned venturi cars at the end of 1982. So, if you're going to have such a significant regulation change, which inevitably will bring all sorts of other changes, it's probably going to spread the grid of cars in the early seasons.

'Let's just say I think there are different ways it could have been done though.

'The reality is you've now got cars at over 900kg start line weight. That's well into what used to be considered heavy for Sportscars. In a few short years, the weight limit has gone from low 600kg, and carrying onboard around 30-40kg of ballast, to cars that are 800kg and then some. And we're all working like mad to try and get to that currently prescribed minimum weight limit of 795kg.

'In short, the cars have got bigger and heavier and aerodynamically not particularly efficient because they have lots of drag. I think it is a bit of a shame that Formula 1 has gone this direction, especially because there's the need and opportunity at the moment to go the exact opposite.

'Obviously, that wrong direction is the same sort of direction general automotive has gone recently, driving ever bigger and heavier cars all the time, and people obsessing about whether it's battery or petrol. Well, the biggest single problem is the amount of energy it takes to move the damn thing, regardless of where that energy comes from.

'It seems Formula 1's technical book doesn't grasp that because, of course, the big car manufacturers don't want to.

'I think just getting the cars to the minimum weight limit is the big challenge of 2022 for a lot of teams, for sure.'

In a few short years the weight limit has gone from low 600kg, and carrying onboard around 30-40kg of ballast, to cars that are 800kg and then some

RC: There are discussions about adding 3kg to the minimum weight to try and make the job of weight saving less intense. Does 3kg really make such a difference?
Newey: 'Well, you have to remember that, very roughly speaking – and of course, it varies from circuit to circuit – you're talking approximately 3/8 of a second per 10kg of car weight. So, that [3kg] weight difference equates to around 1/8 of a second.

'I don't have a benchmark figure for per kg saved, or per 10kg saved in terms of cost, but in truth it must be enormous.'

RE: How has the budget cap affected the whole development of the car?
Newey: 'It is difficult for everybody. I totally agree that Formula 1 needs to avoid constant arms races and reduce costs. Whether you do it mainly by cost cap – which is obviously the route Formula 1 has taken – or you do it by other means is heavily debatable.

'The reality is trying to do it financially is very complicated. So I'm sure there will be lots of acquisitions, and some people, as you can imagine, taking liberties in some areas.

Sergio Perez gets to grips on track during testing with the team's 2022 challenger

'And it's going to be very difficult to police that down to the nth degree.

'Now, you could say, if you can't police it, does the last five per cent matter? But the problem is we all have an enormous fixed cost. So the bit you have left over is the bit you can put into research and development. Look at it that way, and those last few per cent *do* make a big difference.

'And when we are in the position we're in now, where just about every team on the grid has hit the cost cap, you can easily argue the cost cap is actually too low. In my opinion, it should be preventing an arms race amongst the top two or three teams, not bringing the whole grid down.'

RE: Do you find it more of an engineering challenge to design a car to a regulation set than to an accountant's directive?

Newey: 'I don't mind that because it's just another constraint, and in a way it's an interesting thing to have to take into account. So that itself is okay.

'I think what I fear is the kind of room for manoeuvre it potentially still leaves within the regulations in terms of fairness. And also the fact that we, like many of the other teams, have unfortunately had to let some people go. That really doesn't feel right.'

Red Bull Racing

The cost cap is making life difficult, so Newey says we should expect lots of acquisitions between teams as the new era progresses

RE: I know it's early days, but overall, how does this era compare to previous ones?

Newey: 'Nowadays, of course, we have this incredibly tight and lengthy rule book that very much constrains the shape of the cars. But, on the other hand, we have these fantastic research tools, which means we can have a decent level of understanding.

'Of course, you still get surprises, and the porpoising problem is a perfect example. But, by and large, the cars perform as expected, particularly once you understand them.

We need smaller, lighter cars that are more energy efficient. Unfortunately… with these new rules, Formula 1 has done precisely the opposite

Much of the plan view profile of the 2022 Formula 1 cars is prescribed, though there are many detailed areas of freedom that teams can exploit in line with their individual design philosophies

Adrian Newey (right) sits alongside Red Bull Racing's team principal, Christian Horner

'If there is a significant regulation change, it will not be too dramatic if the cars are well understood. It's unusual to get nasty surprises.'

RE: Okay, so what would be your ideal regulations for a Formula 1 car?

Newey: 'Light weight and aerodynamic efficiency are the two most important features. Formula 1 often talks about road relevance, and it has had its place in popularising certain areas in the showroom. Carbon fibre trim is an easy example. And Paddle-shift gear change.

'When the turbo era of the 1980s got underway, the automotive market saw more turbocharged cars produced. So, whilst there may not be any direct technical exchange, Formula 1 can certainly popularise trends.

'Correctly, ecology is a massive subject at the moment, and Formula 1 can, and *should*, play its part in that. But there is all this debate about where your energy source should come from – whether it's electrical, biofuels, synthetic fuel, hydrogen etc – and a lot of misinformation on this stuff, particularly on the electric side. People are starting to realise that the carbon footprint of manufacturing, and eventually disposing of, an electric vehicle is much higher than a petrol one.

'But the assumption that the electricity that comes from wind or solar is somehow zero emissions is just not valid. You look at a wind turbine, particularly an offshore one, a tremendous amount of concrete goes into putting the structure in place. And concrete is one of the worst things for CO_2 emissions.

'There is also a lot of aluminium and copper in these structures, which are also very polluting materials in the manufacturing phase. So it's good, but it's not zero.

'What nobody seems to be talking about is the amount of energy that is used to move the vehicle. So, rather ridiculously at the moment, manufacturers get a dispensation if they make their cars bigger and heavier in terms of their CO_2 emissions, provided they make them less polluting at the tailpipe. I mean, where is the logic in that? It is driven by the government, which is lobbied by car manufacturers, which is very much like motor racing these days.

'Some of the changes that happen in Formula 1 are a result of lobbying, too. So, in terms of where we need to get to, in my opinion, we need smaller, lighter cars that are more energy efficient. Unfortunately, at the moment, with these new rules, Formula 1 has done precisely the opposite to that.'

RE: Should we have a weight limit for all the safety stuff perhaps, and then have a maximum weight for the rest?

Newey: 'Some of the safety stuff, of course, becomes a self-feeding problem. The heavier the car, the stronger it has to be. Some of [the weight increase] stems from power units, some of it from the safety stuff, and some of it comes from other regulations.

'To me, it just needs a complete review. The cars need to be quick, of course they do, because we all know that television has the effect of slowing it down and making them look less dramatic. Because of that, to look good on television, they have to be properly quick, which they are.

'But there are other ways of doing that, which would be much more efficient than the routes F1 is currently pursuing.'

Early days

AlphaTauri's technical director, Jody Egginton, explains the challenges ahead for 2022 Formula 1 following pre-season testing

By STEWART MITCHELL

XPB

'Within a new regulation set, you're forced to learn some new tricks, understand the rules and see where you can optimise the weight'

Jody Egginton, AlphaTauri's technical director

The 2022 Formula 1 cars adorned with the long-awaited, and then Covid-19 postponed, technical regulation changes finally arrived at the Circuit de Barcelona-Cataluña for pre-season testing at the end of February. At the initial test came the first glimpses of the challenges the teams face in this new era of the sport, and for the teams, the first chance to explore the potential of their radically re-designed machines.

With the regulations being a case of revolution rather than evolution, designers started from a clean sheet of paper, working with rules that have simplified the aerodynamics, emphasising the underside of the car, and accounting for larger diameter, low-profile tyres.

The only carryover from the previous seasons is a team's ability to produce a competitive car. This was no different for Scuderia AlphaTauri and its AT03, which took to the track for the first time in Barcelona, providing a huge eye-opener for the team.

Of course, the chassis is the core element around which the entire AT03 is built, able to absorb more energy than previous generation Formula 1 cars in front, rear and lateral impacts. The nose section is also longer to further protect the driver from frontal impact.


The AlphaTauri AT03 enters the pit lane after a test run in 2022 pre-season testing at Circuit de Barcelona-Cataluña

Stewart Mitchell

Despite the AT03's tight packaging and heavily sculpted chassis, the design team have left scope for developing it around alternative philosophies, should they find one that better suits the 2022 rule set

Stewart Mitchell

The 2022 design brief requires the power unit to separate from the chassis in a crash without damaging the fuel cell. These changes have seen the car's minimum weight increase by approximately five per cent to 798kg.

Design philosophy

The new chassis regulations allow for very different design philosophies to be used, and teams across the grid have chosen their own paths to follow. The AT03 is relatively conventional and conservative in both its design and layout. The side impact structure supports the leading edge of a rectangular heat exchanger intake on either side of the driver cell. The cooler housing lays very flat, with the upper surface sweeping downwards towards the car's rear. The underside of the cooler housing is heavily sculpted away for aerodynamic benefit.

However, with so much scope for different design concepts, AlphaTauri has built some flexibility into its concept to give it scope for change if the team discovers a better one later down the line.

'We have reasonable fluidity in our design,' confirms AlphaTauri's technical director, Jody Egginton. 'It's been this approach for several years now in this team but, with a new regulation set, we are all starting from the same new point. We focused very much on making sure what's under the skin gives lots of scope for us to develop the aerodynamics of the car without having to make expensive and non-performing architectural changes.

The AT03's front wing has all its elements attached to the nose, unlike some of its rivals who have opted for a separated lower section to condition the flow to the floor

'We'd hate to be cornered by an architectural bit of hardware under the skin that we probably could have dealt with, so we believe we've built in as much scope as we can to make quite reasonable changes in something like sidepod geometry, or engine cover, without having to do new radiator packages etc.

'It's the same story with the front wing / nose interface. I'd imagine many teams are working on that simply because of the newness of the regulations, but the way we've done that will not limit us if we want to change it. However, I'm sure there are concepts out there we couldn't adopt.

'We focused very much on making sure what's under the skin gives lots of scope for us to develop the aerodynamics of the car without having to make expensive and non-performing architectural changes'


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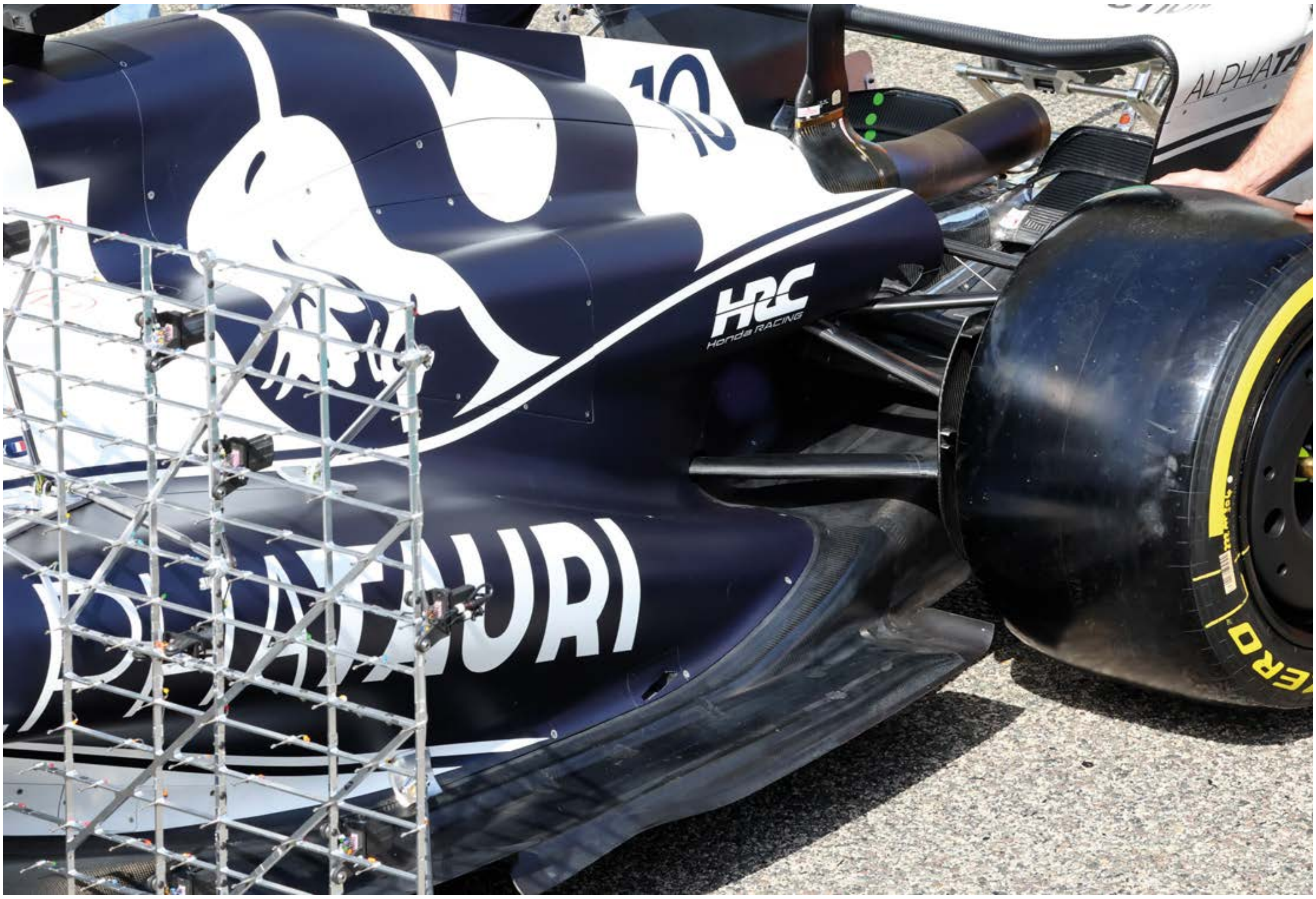


Unlike recent seasons, when AlphaTauri has been using Red Bull Racing's previous year's components, the rear suspension and gearbox are current year elements bought from its sister team

For example, we're running pushrod front suspension. If we decided to go to a pull rod layout, that's unlikely to be happening in season.

'As we get more familiar with the regulations in later years, we will probably get a better read on where we need to focus. For now, we want to develop quickly without having to do a lot of extra work to get the aerodynamic surfaces you want onto the car.'

Weight watchers

The weight limit for car plus driver increased from 752 in 2021 to 798kg for this season to reflect the change to 18in wheels, and new, additional safety features. However, many teams produced overweight cars in the early 2022 season, and then found it hard to bring them down to that limit.

'The weight increase wasn't a surprise,' notes Egginton, 'because the regulations have been formulated over a long period, but the changes to the safety-related regulations added mass and structure to the chassis.

An unexpected factor has been the need to beef up the ground effect floors, which proved more vulnerable to damage and flexing in early testing than expected. On top of that, geometrically, the regulations have changed regarding the minimum sizes of some chassis elements. Consequently, the cars are physically larger.

'We expected that mass increase, and the mass increase we've got on our chassis is reasonably close to what we predicted. On top of that, you've got the new wheel and tyre package that has picked up a lot of mass. Again, that's known, but then some of the other things like the brakes are larger, and the brake ducts are therefore larger to go around them. So essentially, you've just got more material in play there.

'Other things like the wishbones are heavier because they are now a structural part, and they're shrouded in the aero element. And when you put a shroud on something, you need a bracket. In the past, the structural section of the wishbones would also have been the aerodynamic section.

'None of this is a surprise, but it's tough to do an underweight car. I can't understate that. And I think within a new regulation set, you're forced to learn some new tricks, understand the rules and see where you can optimise the weight.

'Year one, you just want to get your car out. You want to get through homologation, and you want to start learning. What you don't want during the six days of testing is bits dropping off it. So you're balancing risk and reward. How lightweight can we make it? How long are the bits going to last?

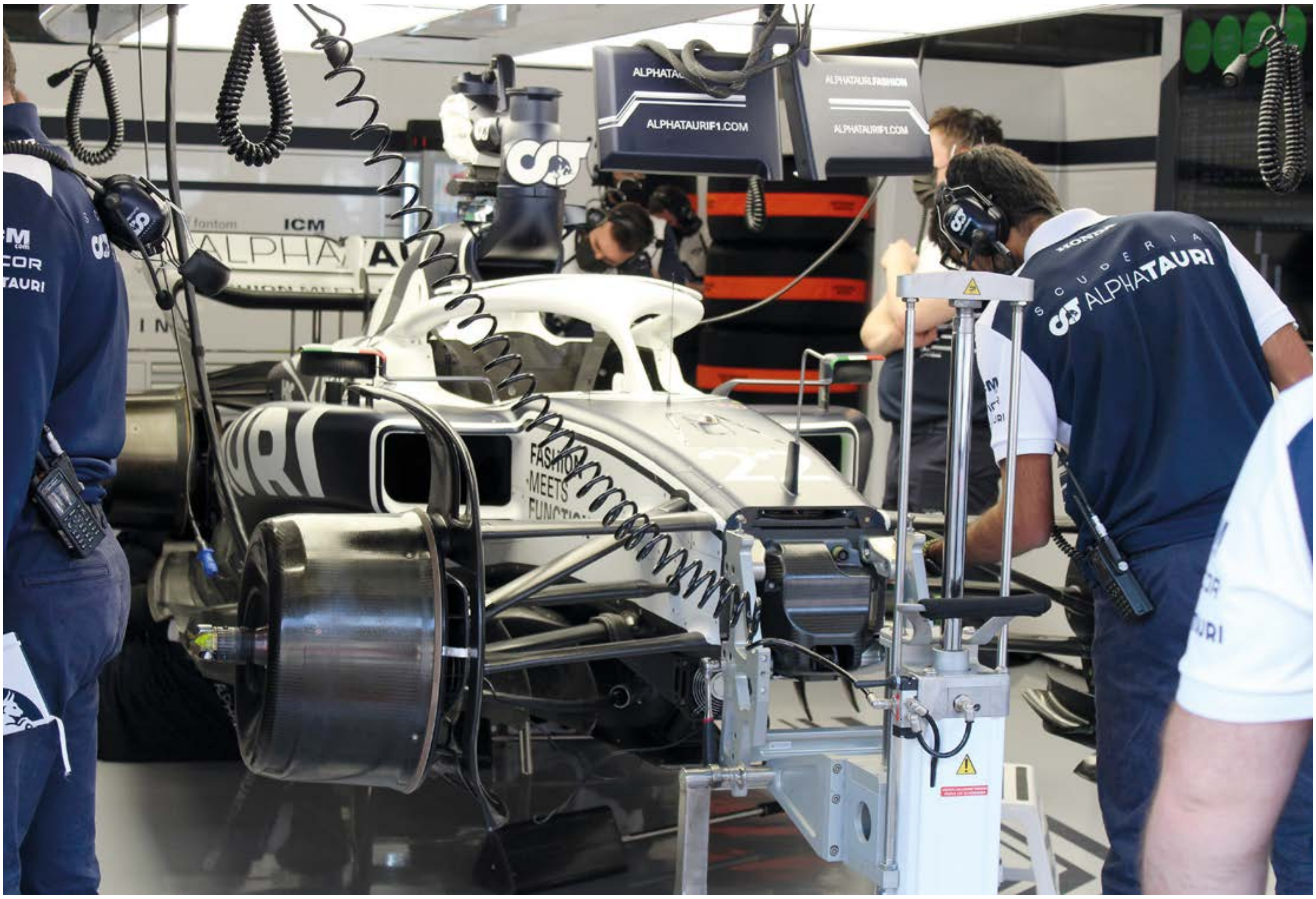
'This floor is very different though. It's contacting the racetrack a lot more than the old regulations. The last thing you want is to be leaving large pieces of the floor on the track because you've tried to take it too far.

'On top of that, there's the budget cap. You've got to be spending your money wisely, and that's another balancing act.

'It is challenging. It's tight, but weight management challenges are not a surprise to me. It's just that you're having to learn as you go along.'

With teams facing the extra challenge of the cost cap, at the Bahrain pre-season test teams requested a further increase in the limit to make it less necessary to commit additional

'Year one, you just want to get your car out. You want to get through homologation, and you want to start learning. What you don't want during the six days of testing is bits dropping off it'



Stewart Mitchell

The AT03 is one of only two cars on the grid utilising similar suspension design front and rear, both pushrod activated. This is a design choice that looks unlikely to change in the near future

'We're using identical parts to Red Bull in the case of the gearbox, the hydraulics and rear suspension'

budgets to weight-saving programmes. A 3kg increase from the originally proposed 795kg was agreed, so as not to penalise those who run closer to the limit than others. That change was ratified by the FIA WMSCl and implemented into the technical rule book shortly before the first Grand Prix.

Parallel evolution

As per the past few years, AlphaTauri bought the gearbox and rear suspension parts for the AT03 from Red Bull Racing. Before 2022, however, AlphaTauri would run the previous year's components from Red Bull so, in 2021, it used the 2020 Red Bull parts, in 2020 it used the 2019 parts and so on. This saved on resources, and meant AlphaTauri had access to a lot of information on the parts, and a year to understand them, before they were implemented on track. However, in 2022, because of the extreme changes in car design, the team had no choice but to wait for Red Bull to finish the design and optimisation of the gearbox and rear suspension on its car before it had a chance to see the final design.

'We're using identical parts to Red Bull in the case of the gearbox, the hydraulics and rear suspension,' notes Egginton. 'When you're taking current year parts, they're evolving the design, and we're in the loop with what's going on as the design is evolving. It means things come through later, and the changes have more impact on what we're doing, whereas when you take one-year-old designs, you know what you're getting, it's fixed. You just take the parts and put them in the wind tunnel. That's it. You might fiddle with shrouds and other bits and bobs, but it is what it is.

'This time we've been evolving quite rapidly as Red Bull evolve and, the way the regulations are now, the aerodynamic surfaces are owned by ourselves anyway.

'It's been an extra challenge, and I think we've navigated it quite well. The launch specification car and development of that car has been sensible. We've had good support from Red Bull, and its extra overhead for them as well. There's a good chance of us going back to the year-minus-one specification for these parts for next year. The beauty of it is that we can look at what is available each year and mix and match.

'This is the fourth year of the partnership with Red Bull taking their parts, and we haven't done the same thing any two years. It's been an extra variable this year, but we've managed it well, and the designers in the aero department have done a good job of making sure we're up to speed as much as we can be.

'So, we'll see what we are able to buy, and what we want to develop going forward, and we'll just keep evolving.'

Push not pull

AlphaTauri is one of just two teams with a similar suspension choice at the front and rear, utilising pushrod suspension all around. Freezing the front suspension architecture is a decision teams make, in relative terms, earlier in the programme than a lot of other decisions. Egginton explains: 'Front suspension was decided before we did floor development, or even the car concept was finished. We looked at pushrod and pull rod options. We were mixing and matching that with floor directions, front wing directions etc.

'But at the point in time when we had to make the call, the pushrod was the most performant for us at the front. So, based on our numbers, that's the direction we went, and then we developed around it because you can't wait forever.

'If we visited it any later, we would have compromised the chassis. The pull rod design has benefits in managing some of the flow structures, but from where we were with the car at that time, the pushrod was the best solution. It will go into evaluation again as we start looking more deeply into what we want to do next year, and it will come back on the table again with a lot of other developments.

'But the rear of the car was different. As the customer, when Red Bull made their decision on what they wanted to do mechanically with the suspension, that was what we were given, and that's what we worked with. And we've developed our car aerodynamically around that layout.

'Regarding what it does on the track, as suspension, it functions as we want. We've got the stiffnesses we want and the range of adjustment. That is the downside of being a customer, but we're pretty happy with it.

'It's an aerodynamic exercise at the point where the decision was made on rear suspension by Red Bull. We took it on board, and we developed our car around it.

'It's the same at the front, other than we oversaw the decision. So, I don't feel that Red Bull dropped either of those concepts on us last minute. It's something we've been fully in control of and working around.

'There's a range of approaches to suspension design, and the key point is it matches your car concept. I'd have hated to have been given something we couldn't make work because then we'd have a car that's not performing. So overall, it is what it is, and we've developed the car around it well.'

'Like everyone else, we've got to learn about the tyre and then optimise it'

Tyre learnings

The 2022 season sees the switch from 13in wheels that have been the norm in F1 since the 1960s, to 18in wheel rims, with just one wheel supplier – BBS Motorsport – for all 10 teams. Aesthetically more pleasing and modern, the objective of the bigger, lower profile Pirelli tyres is to make them less prone to overheating so the drivers can push harder for longer. However, they still have a performance drop-off, which allows teams to make individual strategy choices.

The compounds are also new this year, with Pirelli producing five different dry weather compounds, of which three are chosen for each grand prix, along with two wet weather options.

Teams had their first opportunity to get to grips with the new wheel / tyre combination the week after the last race of the 2021 season in Abu Dhabi, using their 2021 cars. However, the first test in Barcelona in February was the first time teams had used them on their 2022 cars. Egginton explains how the tyres stacked up against expectations: 'Some of the things Pirelli has been focusing on are evident in the new tyres. Even though the cars are different, a few things are still apparent now. So, some learning has transferred over to the new car.

'Right now, with the work we've managed to do, we're reasonably happy. But, at the same time, I would say a cold day in Barcelona on a hard compound is not representative of the season.

'Like everyone else, we've got to learn about the tyre and then optimise it.'

Not only was testing the first time teams had used the wheel / tyre package on the 2022 cars, it was also the first time the cars ran with the newly permitted wheel covers, new larger brakes and tyre deflectors, which all influence the flow field around them.

'The regulations are formulated around simplifying the wheels and tyres, removing some of the complex things we used to do,' notes Egginton, 'and so far, no unpleasant surprises. We will learn a lot more in the race in Bahrain, where all the usual things that can catch you out, like not managing temperatures of the brakes, tyres and all the electronic boxes around them.

'I do expect we will be challenging ourselves in Bahrain, when we're running the brakes in a more aggressive environment, but so far, nothing major.'

Aerodynamic effects

During testing in Barcelona, AlphaTauri, like many other teams, was getting to grips with so-called 'porpoising' – a bouncing phenomenon caused by the car's inability

Flow viz used on the front section of the floor and the sidepod intakes isn't just to make pretty patterns, it helps the team understand the flow fields around these critical areas of the racecar

The pitot arrays fitted to the sidepods collect data on the front tyre wake in order to correlate real-world turbulence with the simulated models developed by the engineering team

to control its platform, stemming from extreme swings in downforce generated by the new ground-effect aerodynamics. As the aerodynamic load comes on, the car is pushed closer to the ground, increasing under-floor load. But, if the car's floor is *too* close to the ground, or even hits the tarmac, the under-floor flow field is destroyed, suddenly shedding the load, and the car shoots back up towards static ride height. Of course, once the ride height goes up to a point where the flow field can recover, the aero load recuperates and the process repeats.

Egginton explains: 'With a ground-effect floor, getting the most aerodynamic load means running the floor as close to the ground as possible. There's an attractiveness in that, and an aerodynamic benefit to doing it. But the closer you get to the ground, the higher the risk of inducing instability from things like the floor choking.

'Floor stiffness can affect behaviour, or lead to an oscillation, which means you're picking up the load and then losing it. Ultimately, that's upsetting to the car's performance as the aero load on the tyre contact patch varies. Load means performance, which translates to better lap times, so we will fight for peak load and, logically, we all try to exploit that.'

'We had an awareness of potential porpoising in the development process, but it's hard to correlate to the full-scale car. It wasn't until the car was physically running for the first time that we could get a good read on it and, like anything else, try to correlate it to our model.

'As part of the development process, we want to maximise the operating window and minimise the points where this oscillation starts to become a problem. We keep an eye on not upsetting the platforms to the point that we start being overly compromised.

'There are nuances with the car's behaviour that don't easily correlate. So, when porpoising occurred on track, there were some differences between what our simulator showed and how the car reacted on track. We didn't go into great detail to model that in the simulator because we wanted to avoid it.

'We certainly know where we want to go to get maximum aero performance, and what we've got to do, and how to do it in a way that the driver can handle it without making the car too difficult to drive. We'll find aerodynamic solutions to de-sensitise the floor with minimum load loss.

'Ultimately, we want to maximise the load over the biggest possible window. The aerodynamicists in every team will be looking to get as much as they can, while minimising the risk of the floor stalling. It's just a trade-off between ultimate load and giving the driver a car to operate over a large window.

> **'We're exploring everything now and just scratching the surface, so we'll probably have to take the car to an uncomfortable place to learn more about it'**

'We're exploring everything now and just scratching the surface, so we'll probably have to take the car to an uncomfortable place to learn more about it.'

On most of the 2022 cars that were suffering from porpoising, it seemed to cycle several times a second when the car is in this condition. With the DRS open, it appeared to reduce the peaks of the oscillations, but it still occurred as the flow field was unstable. When the cars took to the track for the second test in Bahrain, despite development done in the interim, none seemed to have mitigated much of the porpoising issue. Clearly, there is much work still to be done.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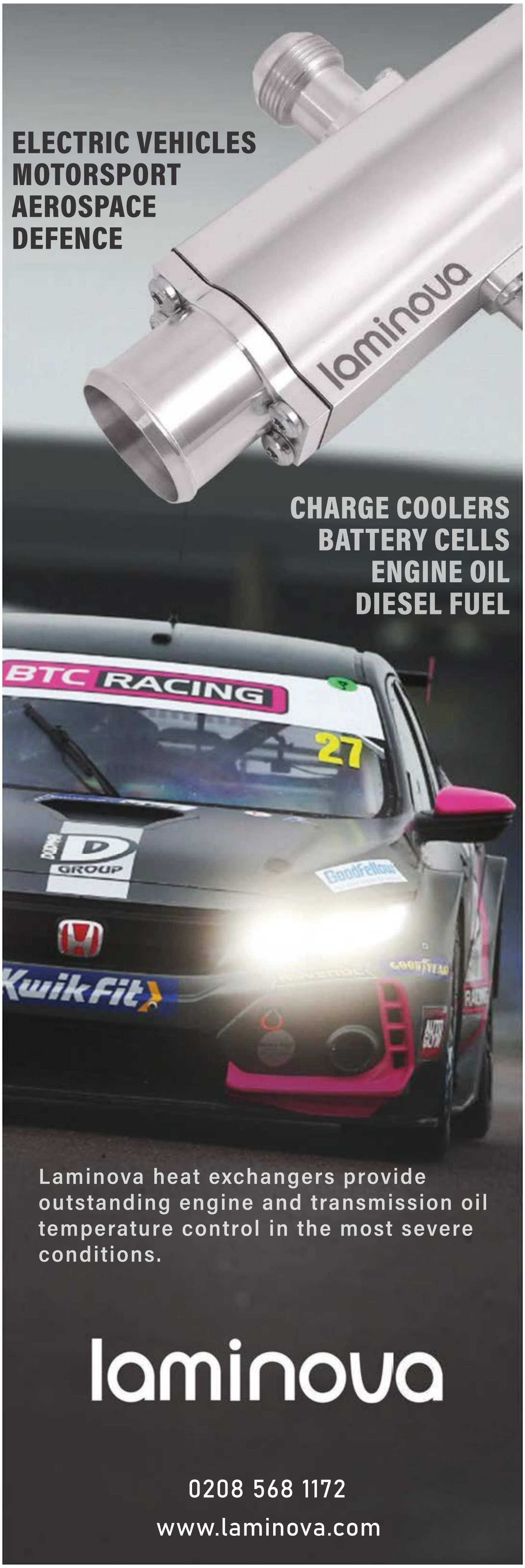
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Evolving doors

Toyota returned to the FIA WEC with an updated car, but is saving its 'joker' package for 2023

By ANDREW COTTON

Toyota Gazoo Racing

Toyota may have had a dominant season in the 2021 FIA World Endurance Championship, having won every round, but that did not mean that the team could stand still for 2022. Having completed the first season of the Hypercar era against opposition from Alpine and Glickenhaus, there were a few issues with the team's GR010 that needed to be addressed for the forthcoming campaign.

Upgrades to the aerodynamic kit were introduced over the winter in order to accommodate the rapidly changing regulations, designed to bring the cars into line through Balance of Performance.

The team introduced a new tyre size, changing from 31in tyres all round to a narrower 29 at the front and 34 at the rear, similar to LMDh tyre sizes, to accommodate the change in weight distribution since the car was first designed. These tyre sizes also bring the car into line with the new convergence regulations between two and four wheel drive cars for 2023.

As a result of this, according to Toyota, the aero package had to change in order to maintain stability at both high speed and in yaw. The team also had to work on the airflow around the front wheels, as well as modify the rear diffuser to fit the wider wheel.

Minor upgrades to the engine have also been made as the car runs on the new bio-fuel developed by TotalEnergies, though this had a smaller effect on the car, and particularly cooling, than was expected.

Significant change

Since the original regulations were produced, the Sportscar world has changed significantly. Aston Martin and McLaren both stopped their programmes to bring production-based cars to the top Hypercar class leaving just Toyota, Peugeot and Ferrari as OEMs supporting the rule set. Since the Hypercar regulations were announced, there has been a new development in that LMDh cars, based on customer chassis but with OEM engine and aero kit, will be allowed. All of this has led to some significant regulation changes, particularly for the LMH cars, and among them Toyota which was first out of the blocks and has faithfully supported the WEC through its transition years before others arrive.

For the 2022 season, the WEC once again sees Glickenhaus with a non-hybrid Prototype, and a grandfathered LMP1 car from Alpine for the second year in succession. As a side-note, Alpine won the opening round of the series at Sebring as Toyota had further hybrid restrictions introduced.

Peugeot has now confirmed it won't race until at least July this year, missing Le Mans, so the class will not change between the first race at Sebring and Le Mans in June.

Clumsy introduction

The way that the new regulations have been introduced can only be described as clumsy. Multiple delays, changes of concept and broken promises have been highlights of this process thus far. However, Toyota was the first of the OEMs to create a Hypercar and, following all the changes to accommodate new concepts, was given dispensation to change its car for 2022 without penalty.

Under Sportscar rules, the car homologation is fixed for five years, but within that timeframe a series of 'jokers' can be played, where performance can be improved. Toyota successfully argued that the changes it made were not performance enhancing, rather that they were simply adapting the GR010 to the changing rules. Perversely, once this package had been agreed and tested in the wind tunnel, the regulations changed *again* and the minimum speed the car was able to deploy its hybrid system at increased significantly at Sebring in order to further balance the Hypercars.

'BoP is the reason they keep changing,' says the team's Hypercar project leader, John Litjens. 'We have three Hypercars on the grid, one is an LMP1 carryover and the difference between the other two [Toyota and Glickenhaus] is significant. Within the parameters they've set they try to balance it.'

The reduction in base weight changed from the original plan in 2018, from 1100kg to 1040kg, but at Sebring the car raced again at 1070kg. Toyota originally took ballast out of the car at the front, and tried to take weight out of the hybrid system and engine to keep the car balanced, but that was not allowed.

With the weight distribution as it was originally, it made sense to have the same size tyres all round. But, once the balance shifted to the rear, the tyre concept changed, too. Co-incidentally, by bringing the car into line with the tyre sizes required to balance LMDh and four-wheel-drive LMH cars in 2023, Toyota has also opened the door for a US campaign in the future.

'Development in the Hypercar class is tightly controlled by homologation rules,' says the team's technical director, Pascal Vasselon. 'Consequently, there are relatively few changes for our GR010 Hybrid in 2022. Hypercar manufacturers can choose between 31 / 31 or 29 /34 tyres, and this year we moved to the 29 /34 option, triggering some bodywork changes for cooling and to maintain aerodynamic performance within the homologation window.'

New Hypercars introduced from 2023 onwards, notably Ferrari, will have no option but to run 29 / 34 tyres, so the change for this year was welcomed by the organisation.

Obvious changes to the Toyota were to the rear wing end plates, the fin over the engine cover and strakes added on the roof.

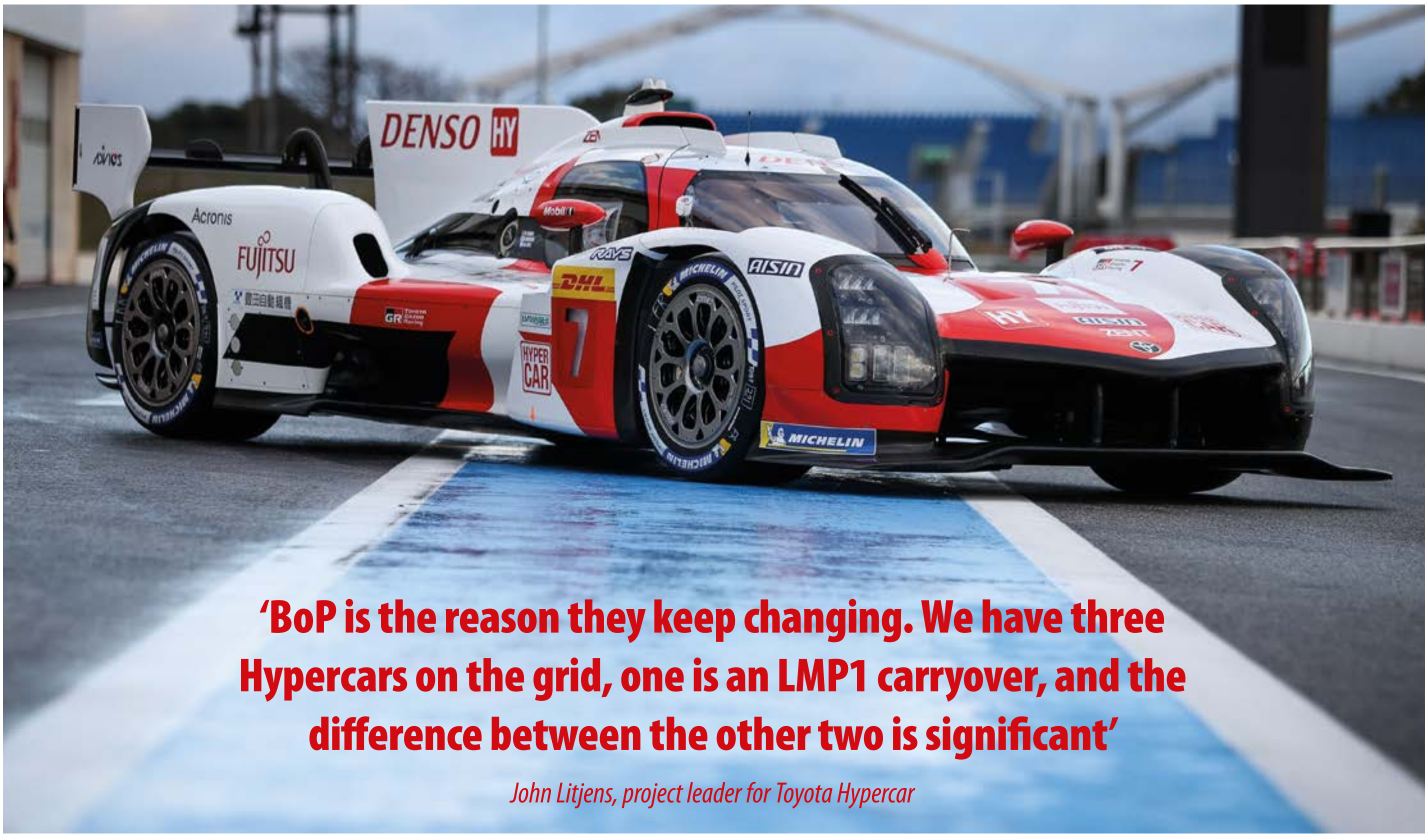
'We did some adaptations to the aero because you have the different size tyres, so you have different air flow,' confirms Litjens.

'You see the rear wing end plates, the fins over the cockpit and so on are all for stability regulations. There are two stability criteria, one is stability in yaw, and the other is take-off speed. You have to calculate yaw, and your point of rotation, and the other is more like a land speed record car, that you go in a straight line and don't lift off.'

Efficiency drive

Toyota had originally tried to design the car without a fin on the engine cover, using only the rear wing end plates to ensure stability in yaw, but in the end decided against that for simplicity's sake. The fin is just a more efficient device. However, with the changes to the tyres and subsequent airflow, the design team then had to increase the size of the fin.

'The fin is now higher, the maximum that we could go because of the stability of



Toyota Gazoo Racing

'BoP is the reason they keep changing. We have three Hypercars on the grid, one is an LMP1 carryover, and the difference between the other two is significant'

John Litjens, project leader for Toyota Hypercar

Obvious changes to the 2022 car are a taller fin and revised wing end plates, but ducting has changed front and rear, due to a change from 31 / 31 to 29 / 34 tyres, and strakes appeared on the roof


XPB Images

Just when the team thought it had its revised aero package sorted, the regulations changed again, this time restricting the effect of the hybrid system from track to track

the car,' notes Litjens. 'We then looked at the rear wing end plates and cockpit strakes [to further balance it].'

Airflow around the front brakes changed significantly, and the team worked to increase cooling to them, rather than decreasing it, as might be expected with a smaller tyre.

'In the end, we tried to keep the number of changes to the minimum, so the brake drums stayed the same. But although the tyre is narrower, and you have a different flow around it, our inlet ducts are actually bigger than they were last year,' confirms Litjens.

'The ducts are also bigger at the back. The front was a surprise for some people because they thought a smaller tyre would lead to more air, but it still has to pass in the same way. And as that changed, so the temperatures changed.'

Revised aero

So, with more ducting to the brakes, bigger rear wing end plates and a larger fin on the engine cover, the revised aero package was complete. Or so the team thought.

However, over the winter, the FIA and ACO decided that, as a performance balancing measure, they would restrict the effect of the hybrid system from track to track, and at Sebring set the minimum speed the system could be deployed at to 190km/h. Some within the team muttered that, with the nature of the Sebring track, it might be better to leave the system off altogether, but that was not to be.

With the speeds around the Florida track, it could still be used for fuel saving, but the GR010 gave up significant performance as the traction control and engine maps were all set around the hybrid system working at lower speeds. Although Toyota had tested extensively with deployment at different speeds, Sebring saw the GR010s out-paced.

'Every BoP adjustment that is made we have to see how the car behaves,' comments Litjens. 'We have different car weights again [this year under BoP]. You have to be flexible because at a certain point you have more teams [coming in July for Peugeot, and 2023 for Ferrari in LMH] and you might have to again take the weight out. But that is the normal set-up parameters of the car. We are not starting from zero [at every track], though there is not a great deal of carry over either.

'We did the last bits of this design in November of last year, and then we had to produce things, wind tunnel tests at Sauber again to go testing. The change to the hybrid system then came after that so, although that is more on the control side of things, it affects the set-up because you have a more two-wheel drive car than before, that's clear.'

The team has adopted the attitude that it will just spend the time learning about the car, and hope to be able to use that learning later in the development programme, though there are already rumours of a new car coming in 2023. In order to face the Peugeot, Ferrari, Glickenhaus, and possibly the ByKolles, along with the LMDh cars.

The team has adopted the attitude that it will just spend the time learning about the car, and hope to be able to use that learning later in the development programme

'Part of it will be corrected by the BoP, but you can see now that's challenging. We have to do something though. We are looking to do some upgrades, but we have to see.'

Volatile environment

One of the unknowns is the availability of raw materials due to the war in the Ukraine. Long lead time parts, such as the tub, have not only become more difficult to source in terms of materials, but the lead time itself has been extended. 'Every manufacturer will be struggling more in terms of supply, and for some parts the lead time has doubled,' confirms Litjens. 'The metallic parts for example are taking a long time. In terms of the carbon parts, there are a few specific fibres [that might be a challenge] but we didn't struggle yet. However, driveshafts, hubs and this kind of stuff doubled in lead time and increased in cost, and we have to see how this ends up.'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GM to race 24 hours

2023 could see the return of Stock Cars to Le Mans for the first time in almost half a century

By ANDREW COTTON

NASCAR's Next Generation Stock Car will race at the Le Mans 24 Hours in 2023 if plans by Hendrick Motorsport, Chevrolet and Goodyear come to fruition. The go ahead to race still needs to be given by the ACO's selection committee, but the idea is to run a Gen 7 car fitted with a hybrid system taken from the manufacturer's LMDh platform as a Garage 56 entry.

The plan was hatched in 2020 between NASCAR president, Jim France, and ACO president, Pierre Fillon, and unveiled at Sebring. If it goes ahead, it would be the first time a Stock Car has competed in the great endurance race in nearly 50 years. The last time was in 1976, when the Grand International category was formulated specifically for such cars, following a vision laid out by NASCAR founder, Bill France, with a view to expanding the global exposure of his top class. Two Stock Cars raced that year, a Dodge Charger owned and driven by Hershel McGriff, and a Junie Donlavey-owned Ford Torino driven by Richard Brooks and Dick Hutcherson.

'From the early days of NASCAR, it was important to my father that we played a visible role in international motorsports, and there is no bigger stage that the 24 Hours of Le Mans,' said Jim France, NASCAR chairman and CEO.

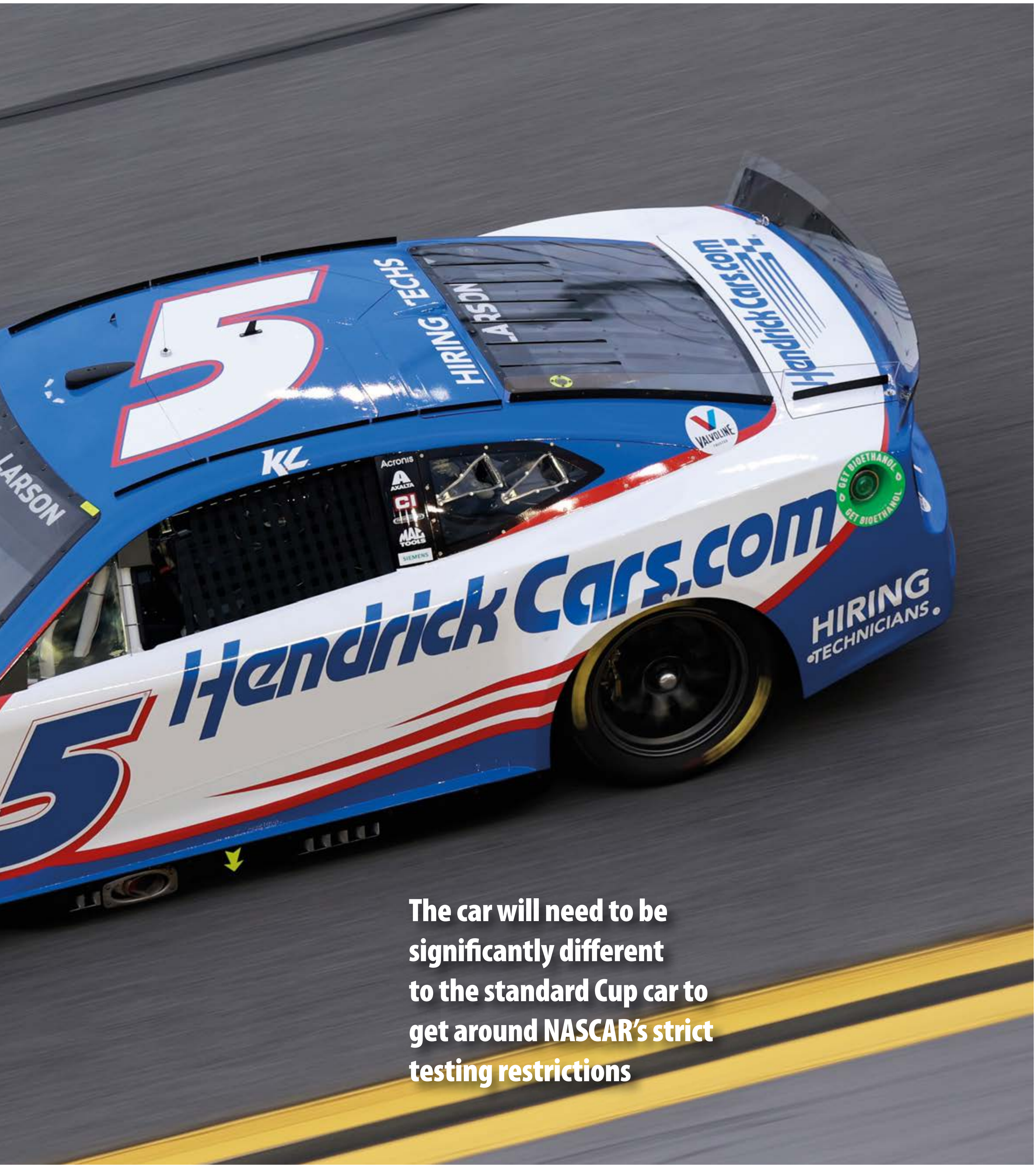
'In partnering with Hendrick Motorsports, Chevrolet and Goodyear, we have the winningest test, manufacturer and tyre in NASCAR history. We look forward to showcasing the technology in the Next Gen car and putting forward a competitive entry in the historic race.'

Forging links

Confirmation of the programme marks the latest in a series of announcements that closely link the American IMSA series to the ACO and FIA, following the revelation over the same weekend in March that the LMH cars will be able to race in IMSA's series in 2023, provided they take part in a test in December.

The Garage 56 entry (so named when Le Mans accepted only 55 regular entries, plus one for innovative technologies that operates outside the normal class structure)

Getty Images



The car will need to be significantly different to the standard Cup car to get around NASCAR's strict testing restrictions

will replace one of those entries on the grid as Le Mans only features 62 garages. However, while the Hypercar and LMDh cars will fill the majority of the Prototype grid next year, there is some uncertainty as to what the GT field will look like with a transition year from GTE-Am to GT3 cars in 2024.

The NASCAR showcase model run by Hendrick Motorsport will be based on Chevrolet's Camaro ZL1, but will have to undergo some major changes before it can be accepted to race at Le Mans. Not only will it need to be technically modified to achieve the target lap times, it will need to be significantly different to the standard Cup car to get around NASCAR's strict testing restrictions.

'We don't want one team to have an advantage over another,' said NASCAR's Steve Phelps. 'We are not interested in letting that happen.'

To start with, weight will need to be removed from the 3300lb (approx. 1500kg) car in order to achieve the target lap time of 3m50s – 4m00, in line with the approx. 1300kg GT3 cars that will race at Le Mans in 2023.

The reduced weight should help the team achieve the necessary crash testing criteria, conducted by the ACO and the FIA before the car can be considered for the event.

That won't be easy, though, as the Gen 7 NASCARs feature tube frame construction and, although Le Mans has made major changes recently in a bid to improve safety and meet FIA criteria, the Gen 7 car has been designed to accommodate the types of accidents NASCARs normally have; glancing blows on full oval tracks. And as speeds on the road courses the series run on are significantly lower than those seen at Le Mans, getting the Gen 7 car through the required crash test may take significant work.

Getty Images

NASCAR chairman and CEO, Jim France (left), and Rick Hendrick, owner of Hendrick Motorsports, at the announcement at Sebring

Expand to contract

However, Rick Hendrick, owner of Hendrick Motorsports, promised it will be a 'full bore, full blown effort,' from the team, which may have to expand in order to make the programme happen.

'We want to run 24 hours and post competitive times,' said the veteran team owner. 'With the aero, weight and bhp, we are not going there just to ride around. We will put in a big effort and finish the race…

'Even though Garage 56 is a 'class of one', we are competitors and have every intention of putting a bold product on the race track for the fans at Le Mans.

'It's a humbling opportunity – one that will present an exciting challenge over the next 15 months – but our team is ready.'

Part of that huge development programme is the tyres. Goodyear, which provided the rubber for the last NASCAR entry in 1976, will have to develop all-new specifications for the event from its base in Akron, Ohio, due to the different demands Le Mans places upon the tyres. A global collaboration between the European and US bases will help formulate the constructions and compounds, based on Goodyear's previous experience in GT racing, coupled with the latest Prototype technology.

There will be a push for NASCAR's sole tyre supplier to develop 18in slick, wet and intermediates that will be capable of double stinting at Le Mans to meet with the ACO's mission to reduce the number of tyres used in a race.

Hendrick's vice president of competition, Chad Knaus, will oversee the project, but there was no official word at the announcement on who would drive the car, other than that it would be a Cup series driver.

One possibility that has been mooted is Jimmie Johnson, who has been racing in the IMSA series in a Cadillac.

In order for a Cup driver to race, NASCAR would need to accommodate not only the Le Mans 24 Hours race week in its schedule, but also the test weekend, too.

Hybrid future?

Although there has so far been no confirmation from the team behind the programme, Fillon did reveal the car will feature a hybrid system and the engine would use TotalEnergies' synthetic fuel, developed from the waste products of wine making.

The Gen 7 car was designed from the start to have hybrid capability, and series insiders

'We are not going there just to ride around. We will put in a big effort and finish the race…'

Rick Hendrick, owner of Hendrick Motorsports

hinted the car would likely use the hybrid and gearbox system developed for LMDh by Xtrac, Bosch and Williams Advanced Technology.

Testing the car is going to be a problem as NASCAR operates strict rules to prevent any team gaining an advantage. Consequently, the car will need to be suitably different to the standard racecar in order that the team does not have the opportunity to take learnings from the programme into the Cup series, where it is already the most successful team.

The car will likely be fitted with a new engine, developed by ECR, although Hendrick confirmed the current engine and transaxle would be capable of completing the race in current spec.

Getting the project even this far has taken significant work. 'When the ACO receives an application for a Garage 56 programme, we begin by talking with the designers, team partners and suppliers in order to set out performance parameters such that the programme can be successful for everyone involved,' said Fillon. 'We will continue to work with NASCAR and all their partners as they work towards their proposed 2023 Garage 56 project.'

The Garage 56 car will likely be GM's third class entry in 2023, as the brand's Cadillac LMDh will race in the Hypercar class, plus there is a good chance its Corvettes will be back to contest the GTE class in addition to the NASCAR project.

ACO

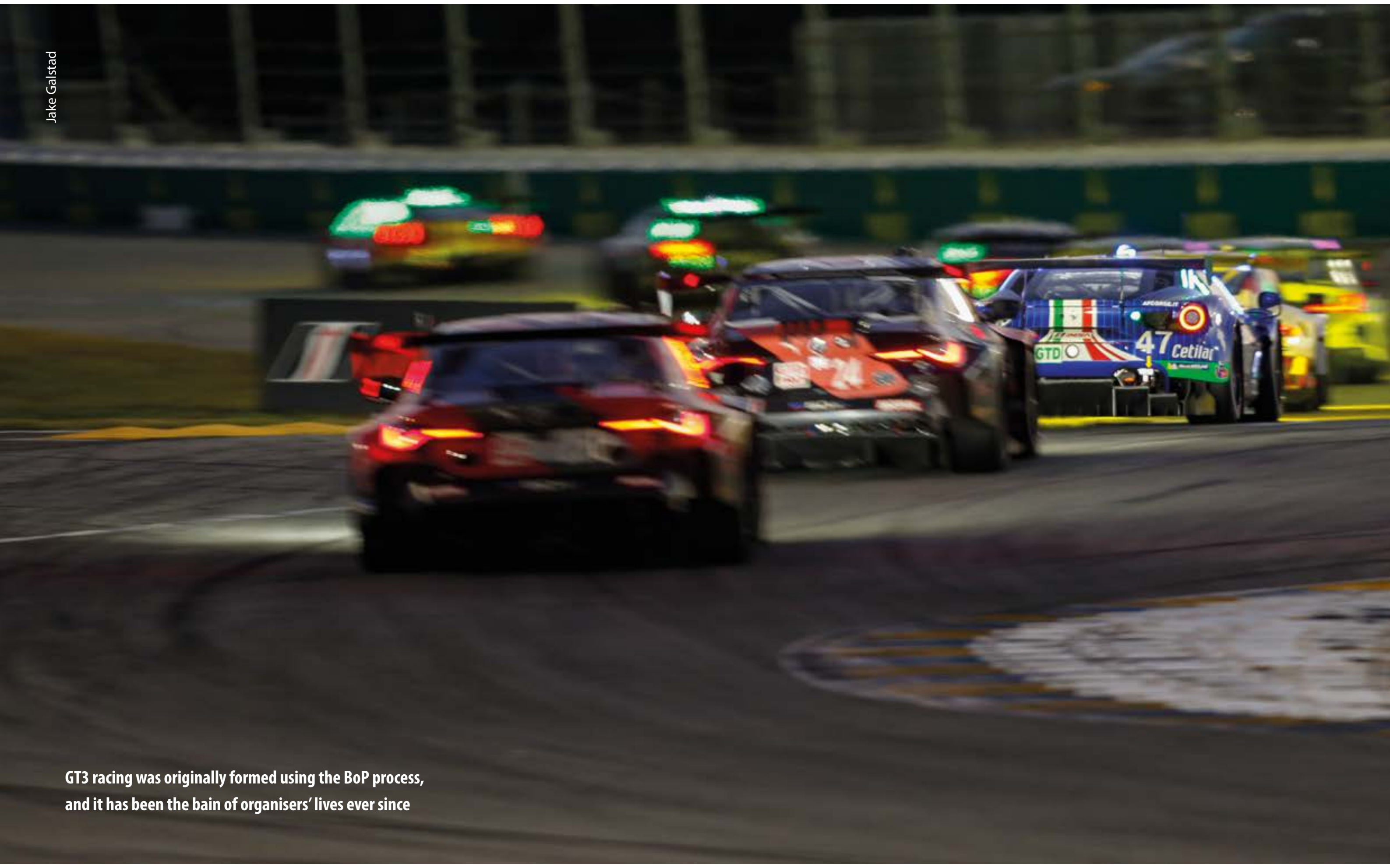
The last time NASCARs competed at Le Mans was in 1976, in a bid to make the series more visible on the world stage


180 MPH WITHOUT MOVING AN INCH

Raceability (part one)

Explaining the concept using first-hand experience of imbalance of performance

By SCOTT RAYMOND



Jake Galstad

GT3 racing was originally formed using the BoP process, and it has been the bain of organisers' lives ever since

Raceability is not a real word, but what I mean by the term is the ability of cars to race each other. When all cars are the same, or at least within the same class, I am referring to following each other on track, and being able to set up and execute passes. The idea is similar to when cars from different classes are on track together, although in that case passing, or being passed, are givens, so raceability in that sense refers more to the cars' ability to deal with traffic between disparate classes.

With respect to Balance of Performance, it is one thing to balance lap time performance, but ensuring balanced cars can properly race against each other is a much more difficult thing to achieve correctly.

Let's go back in time over a decade to examine a first-hand experience I had with a situation where the raceability between cars was not well balanced. Okay, I'm being kind, it was horribly imbalanced!

In 2009, I worked as a performance engineer with de Ferran Motorsports, and we ran an Acura ARX-02a LMP1 car against the likes of Audi R15 TDI and Peugeot 908 at a few races in what was then called the American Le Mans Series. The Audi and Peugeot were both diesel-powered with lots of torque and, while I believe the Acura produced more overall downforce and had excellent mechanical grip (thanks to running wide rear tyres on the front axle), we didn't stand a chance against the diesel engines when it came to pure straight-line acceleration.

At the 2009 Sebring 12 Hour race we qualified the Acura on pole and showed the world that, on pure pace alone, the Acura was quick over a single lap to be competitive. In hindsight, some might argue that our pole position that day came down to the Audi and Peugeot teams not being willing to show too much performance in the lead up to that year's 24 Hours of Le Mans. Nevertheless, I was about as excited as possible for the race, though I knew in my heart it could be a total shit show.

Scott Raymond worked with the Wayne Taylor Racing Acura team at this year's Daytona 24 hours

Richard Dole

Multi-class racing is not limited to GTs, and adds a critical extra dynamic to a race – traffic

Michael L Levitt

Now, I should mention here that my wife and friends call me an eternal optimist, so it must have been pretty evident that potential problems existed if I was remotely pessimistic.

Areas of concern

The layout of the Sebring circuit presented a couple of areas of concern to the team and me. The first was the very long back straight between turns 16 and 17. Any car getting a good run out of turn 16 could easily employ the draft and set up a leading car for a pass before the braking point for turn 17. Now, imagine exiting that corner with a torque-monster diesel following behind.

The other area of concern was the front straight between turn 17 and turn one. While not as long as the back straight, the exit speed of turn 17 is quite high, so a similar problem was easily imaginable. The optimistic side of me hoped we would exit turn 17 so quickly that the diesels wouldn't be able to swallow us up in the distance before turn one. I knew we had an advantage there because that first turn is a high-speed, aerodynamically dependent corner. If we could just *keep* cornering faster than the diesels, maybe we stood a chance of winning the race.

At least I wasn't alone in being concerned. In a pre-race interview between Chris Neville of *Speed TV* and Scott Dixon, who had driven the car on our pole-winning lap, Neville remarked, 'You've got four diesel beasts behind you, what's the strategy when the green flag comes down?' To which Dixon replied, 'Gil [de Ferran] is starting the race and he's going to have his hands full going into turn one. The diesels have a lot of torque and a lot of power down the straight, so hopefully he can keep it in front in turn one. We've then just got to be aggressive and try to remain in front as long as possible.'

Simple when you put it like that. However, at the start of the race, the no.2 Audi, driven by Allan McNish, had passed the Acura before the start / finish line…

I told myself that was okay, we'd get past the Audi in the infield with its slower corners.

Still on lap one, de Ferran beautifully defended an attempted pass by the no.7 Peugeot, driven by Pedro Lamy, into turn nine. (I forgot to mention above that there was a shorter straight section out of the infamous Sebring Hairpin that I hadn't even considered would be a problem because of our higher cornering speeds). *Speed TV* announcer, Dorsey Schroeder, said the following after the attempted pass:

'Here's the problem with the Acura… it is making its speed in the corners, so he's going to have to be aggressive throughout this 12-hour race. He cannot give up corner speed because he gets out-drag raced between the corners.'

No shit, Schroeder.

'If this was Long Beach, or the Belle Isle circuit in Detroit, we would have kicked their diesel butts'

De Ferran reached my area of highest concern on that first lap still in second position, but the Peugeot was following close behind. Sure enough, out of turn 16, on the long back straight, the no.7 Peugeot simply drove past our no.66 car before the braking zone like we were standing still. Another *Speed TV* announcer, Calvin Fish, noted:

'These Acuras are going to be fighting this all day long.' To which Schroeder retorted, 'No question. And traffic is going to be another problem for them because if they get hindered on that corner speed… mid-corner speed is their forte… if they get slowed up mid-corner they're going to just fall back into the hands of these more powerful diesels.'

Just as Schroeder finished that comment, out of turn 17, the no.1 Audi of Mike Rockenfeller blew by our Acura going into turn one. My concerns were proven on the very first lap, while my hopeful prediction of us manhandling the diesels in the infield? Well, not quite.

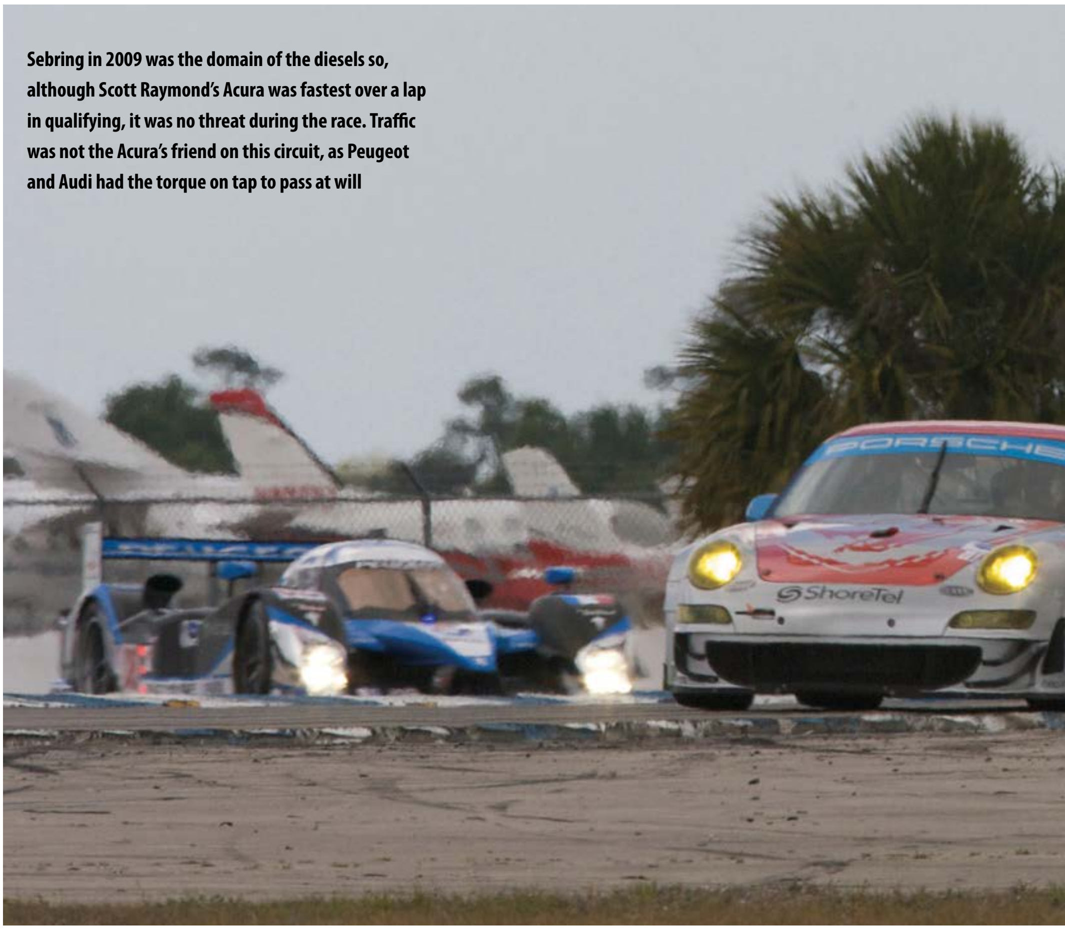
Speaking of the infield, as we drove through that section on lap two, Schroeder offered up this pearl of wisdom:

'The entire design of this new Acura was to make speed in the corners. They said, "We cannot do battle with the diesel power down the straightaways, we'll make our speed and time in the corners," but at a track like Sebring, with long straightaways, that's a long road to home, is it not?' Indeed Schroeder, indeed.

Traffic report

Now, let's remember that Schroeder had predicted traffic would be a problem for the Acura. To demonstrate just how much of a problem it would be, we need to look at what happened with the second Peugeot I have not mentioned yet. It's not that we were faster than this car and pulling away from it like some magical petrol-powered unicorn. No, this car had started the race from pit lane behind the entire field because of a pre-race hydraulic issue, and just hadn't caught up to us yet.

So, while we were out there fighting – and losing – to the other diesels, the no.8 Peugeot 908, driven by Franck Montagny, had been slicing its way through the GT field. With the race still less than two laps old, and under four minutes having elapsed on the clock, 'Franck the Tank' had passed all the GT cars. And not all on that long back straight I was talking about either, he was through the entire GT field before turn 14!



Sebring in 2009 was the domain of the diesels so, although Scott Raymond's Acura was fastest over a lap in qualifying, it was no threat during the race. Traffic was not the Acura's friend on this circuit, as Peugeot and Audi had the torque on tap to pass at will

The Acura ARX-01 ran the same size tyres front and rear, had a huge development for 2009 and was quick, but didn't have the raceability to compete for the overall wins

No less than four minutes into a 12-hour race, we had been put in our place

What was even more telling about Montagny's passing prowess was his lap time while he chewed his way through the GT class. Below are the lap times for the cars in question on the second lap of the race:

- No.2 Audi R15 TDI (Allan McNish): 1:46.271
- No.7 Peugeot 908 (Pedro Lamy): 1:47.182
- No.1 Audi R15 TDI (Mike Rockenfeller: 1:47.453
- No.66 Acura ARX-02a (Gil de Ferran): 1:50.319
- No.9 Acura ARX-02a (Driver??): 1:49.521
- No. 8 Peugeot 908 (Franck Montagny): 1:50.125

XPB

So, Montagny was able to carve the diesel-powered Peugeot through the traffic of the GT field with ease and go 0.194 seconds per lap faster than de Ferran, who was running in clear air because he had been passed by the Audi at the beginning of that lap. No worries about traffic for him then!

No less than four minutes into a 12-hour race, we had been put in our place.

To make matters worse, the lack of relative torque compared to the diesels caused no end of headaches when it came to passing GT cars as we navigated traffic. Where an Audi or Peugeot could motor past two GT cars with ease, we could only get past one. Montagny's performance on lap two was just a prelude to the passing nightmares we would experience through the race.

There is no happy ending to this story. We didn't beat the diesels. At no point did an Acura lead the race. In fact, both Acuras fell out of the race with mechanical failures. But still the optimist in me said, 'If this was Long Beach, or the Belle Isle circuit in Detroit, we would have kicked their diesel butts.'

Career philosophy

Needless to say, this experience certainly left a mark. It helped cement an engineer philosophy I have employed throughout my career since, which is to play to a car's strengths rather than compromising a set-up in an attempt to rectify an impossibly overcomeable discrepancy.

For example, later in 2009 we raced the Audis and Peugeots again at Petit Le

XPB

Nürburgring 2014 was a haven of multi-class racing, with everything from GT3 cars to this BMW 235 out on track at the same time. Balancing lap times and stint times require different calculations

Mans. De Ferran wanted us to trim the car to reduce drag on the Road Atlanta circuit but, in doing so, we would have been compromising the cornering speed of the car with a reduction in downforce. The problem was there was no way we could close the gap in top speed to either diesel car. Rear wing angle changes aren't typically worth 20km/h, so all we would have been doing was hurting our cornering speed to still be slower on the straights than our competitors.

I recall adamantly telling de Ferran that we had to 'play to the car's strengths', and explaining that over a 10-hour race the car would be easier to drive. Hopefully, this would mean less chance for errors.

In racing, it is always better to be good at one thing than mediocre at everything.

The other impact this experience had on my engineering philosophy surfaced later in my career once I had gained more experience and credibility in the world of Balance of Performance. Recall that I started working on BoP in 2014 when I was technical director at IMSA. At that time, the primary goal of BoP was balancing lap times, so the idea of attempting to balance cars over a stint or improve raceability was honestly not at the forefront.

Of late though, as I contemplate changes to the BoP for the Nürburgring 24h GT3 cars, I find myself asking what I can do to improve the cars' raceability? What can I do to make sure the cars are balanced over a stint?

I recall a paraphrased conversation prior to last year's qualifying session for the Nürburgring race where a manufacturer representative said to me, 'You are really willing to let that car do well in qualifying just to improve their performance in the race?'

'Yes,' I replied. 'I want to improve the raceability of that car. I want them to have just as much chance of winning the race as you do.'

Work to be done

And that is just it. As someone responsible for the Balance of Performance between cars, I am no longer satisfied by just balancing lap times. It must be better. It must take more into account. Hence the idea of balancing raceability.

It was with those thoughts in mind that I started down the path of writing this article. I am in a unique position to be working directly with a racing series, a manufacturer *and* a racing team, so I get to see the consequences of good and bad BoP from all sides. With everything I have experienced first hand, I honestly do not feel like most BoP processes, even my own, adequately address the issue of raceability.

I am no longer satisfied by just balancing lap times. It must be better. It must take more into account. Hence the idea of balancing raceability

But, by the same token, I am just one person, with my own opinions on the matter. The topic of raceability is much bigger than my own field of experience, so I felt it was important to gather input from other people within the motorsport industry to make sure my opinions did not skew the facts too much in one direction. To obtain a broader perspective, I reached out to several people representing racing series, car manufacturers and racecar drivers. Thankfully, I received some excellent feedback from people across my desired spectrum, so what is presented here, and in the article(s) that will follow, are some quotes and discussion around the topic of raceability from the perspective of those who most certainly have the knowledge.

In this first article, we speak with a representative of a sanctioning body / racing series.

The sanctioning body perspective

One of the first people I heard back from was Nicolas Aubourg, the head of performance for the *Federation Internationale de L'Automobile* (FIA). I have known Nico for about eight years now and have always been impressed by his knowledge and skills. I have no idea how he handles all the responsibilities he has, especially when you consider the sheer number of racing series that fall under the FIA umbrella, but somehow he does it, and does a very good job of it.

When I first approached Nico about the topic of raceability, he said, 'Very good topic. Raceability and BoP are discussed a lot with manufacturers. Balancing lap time is one thing, but not enough to get good BoP.'

Good. At least I am not alone in thinking about this, and it is good to hear that the manufacturers who participate at the Nürburgring are also not the only ones interested in raceability.

Speaking strictly about BoP, he followed that with, 'Because of all the progresses achieved by all of us in the bopped championships in the past years, the level of requirement is now very high. Competitors require less and less differences between cars. 10 years ago, a BoP with a delta of 0.6 seconds / lap was acceptable. Now, a BoP with a range of 0.3 seconds / lap is the standard.'

Aubourg's point supports my own opinion that progress with respect to BoP has been made over the years. The fact that we now target just 0.3 seconds per lap speaks volumes just by itself. I remember introducing this target of 0.3 per cent while working at IMSA. At the time, it worked out to roughly 0.3 seconds on a lap of Daytona.

The side effect that occurred with such an aggressive BoP target was that suddenly other aspects of races rose in importance. As we started getting better at achieving the targeted performance deltas, the importance of pit stop refuelling times rose to the surface as a priority. Not only was it important to balance lap times, but an aspect of racing that I attribute more to execution of the race became just as important.

It is just such progress that I believe is the reason why the topic of raceability has become more important. As with any complex problem, the low-hanging fruit needs to be addressed before the more difficult items can be tackled.

Nicolas continued: 'Actually, we not only have BoP to ensure good competition, we also have homologation, which is usually forgotten by competitors, but which is very important in the achievement of close competition.'

So, the FIA looks at making competition closer using a two-pronged attack: homologation and Balance of Performance. Let's briefly discuss both of those.

Homologation

The homologation regulations for a vehicle category define the fundamental design characteristics for any new vehicle destined to compete in a category homologated by the FIA. Cars must be designed to comply with these requirements if the vehicle manufacturer wishes to receive approval from the FIA. For categories that employ Balance of Performance measures, such as Hypercar, GTE and GT3, the FIA has implemented the concept of performance windows.

These consist of defining acceptable windows of performance for specific vehicle parameters, including power, weight and aerodynamics. Both downforce and drag targets are imposed with respect to aerodynamics, and Aubourg feels the aerodynamic targets are of the highest importance. For the performance windows, minimum and maximum values for each parameter are prescribed, which, in turn, defines the desired performance targets for the vehicle manufacturers at design time.

Manufacturers then work with the FIA during the design process to keep themselves on track and within the desired performance windows. Once the vehicle is completed, manufacturers must bring the car to the Sauber wind tunnel for testing. The FIA uses this tunnel to ensure the vehicles fall within the performance windows defined by the homologation regulations.

Once vehicles have successfully passed the wind tunnel testing, all bodywork design is frozen and the FIA completes a 3D scan of the car to generate a reference point.

The objectives of the homologation performance windows are to ensure acceleration, top speed and speeds in high-speed corners are similar between cars in the same homologation category.

As Aubourg notes, 'It's a powerful tool to gather not only the lap times, but also the speed profiles.'

Balance of Performance

The vehicle parameters used by the FIA in the Balance of Performance process are similar to those used by most racing series. The FIA starts out by freezing a range of

XPB

Allan McNish leads into the first corner at Sebring in 2009, having used the torque of the diesel to power past pole-sitter, Gil de Ferran, on the short shute to the first corner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XPB

The Spa 24 hours is another of the classic races but, with up to 70 GT3 cars taking part in the same race, it's a perplexing computation to get the BoP right

rear wing angles, which has the effect of fixing the maximum top speed of a car. In addition to this aerodynamic parameter, the FIA uses ballast (mass) and power to then adjust two performance parameters at the same time: lap time and PDST (power dependent sector time).

Regarding the latter performance metric, Aubourg has this to say: 'PDST is a virtual loop timing we compute with the data logger, GPS and a specific sensor to estimate the acceleration time of each car on straights.' The use of virtual timing loops is clever because it does not allow savvy competitors to manipulate the PDST metric when they know the physical location of a timing line.

The sensitivities of power and mass on acceleration and lap time are different, so Aubourg explains there is a unique combination of these two vehicle parameters required to achieve a target lap time and PDST.

Combining targets

By addressing performance targets at design time through the homologation regulations and performance windows, and at race time through the Balance of Performance, the FIA hopes to achieve the best balance possible when the cars are on track.

In summary, the performance metrics the FIA is looking to balance include lap time, acceleration, top speed, high-speed cornering, low-speed cornering and braking. Lap time is addressed with mass, power and aerodynamics both during homologation and with BoP at race time, with BoP adjustments used to fine tune lap time within the homologation performance windows.

Acceleration is also addressed at homologation, and through BoP, by setting power and mass targets with the performance windows, and then fine tuning as needed at race time. Top speed is locked in at homologation by setting a minimum drag level and maximum power level through performance windows.

High-speed cornering and braking are both addressed during homologation through aerodynamic downforce, while low-speed cornering is addressed by mass and making sure all cars use the same tyres.

'This is the theory, and it works quite well,' says Aubourg. I tend to agree.

Conclusion

It is clear the processes surrounding BoP have evolved over time, and hopefully the experiences I had racing against the diesel cars in 2009 are now 'a thing of the past'. Again, targeting 0.3 per cent lap time delta between cars, which is literally the blink of an eye, should say a lot about what engineers like myself are trying to do with Balance of Performance. The FIA leads the way in terms of homologating vehicles and, by focusing on first principles that limit the lateral and longitudinal accelerations of vehicles during the design phase, it is making the BoP process easier. After all, it is much easier to balance two vehicles that are already relatively close out of the box.

By focusing on first principles that limit the lateral and longitudinal accelerations of vehicles during the design phase, [the FIA] is making the BoP process easier

I still don't know that we are doing enough. As I have said in the past, racing is an entertainment and marketing industry. I sincerely wish (with all my naïve optimism) that every single race has a 'made-for-TV' finish where no one can predict who is going to win a race until the chequered flag falls. Only when finishes like that regularly happen will I feel like I am doing my job well enough.

I don't know right this second what areas to focus on to help achieve that, but I can promise you I will keep searching for the answers until I can figure it out.

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Free Radicals

With record sales, expanding markets and a groundbreaking new car, the world's second largest racecar constructor has much to celebrate in its 25th anniversary year

By MIKE BRESLIN

When Radical first put a superbike engine in the back of a pretty Sports Prototype 25 years ago, at first glance there was little actually *radical* about it. Motorcycle-engine racecars had already been around for decades. In the 1950s, they were the lifeblood of grass roots British motorsport in the then Formula 3, and there had been many variations on the theme, few of which were particularly successful.

But where Radical got it so right was in its execution. It was the engineering, rather than the concept, that made the car work, and its focus on performance, useability and aesthetics was, indeed, quite radical.

Consequently, that car, and the many that followed it, proved hugely popular. To the point that today, the Peterborough UK-based company is the second largest racecar producer in the world, beaten only by Porsche Motorsport. It has sold over 2800 cars since that first Radical Clubsport burst on to the UK race scene.

Yet despite all this, the company has not, until recently, been quite as good at making money as it is at making cars.

The SR10 was only launched at the tail end of 2020, yet more of these have now been built that any other car in the Radical range

'Last year [2021] was the first year in almost a decade that we actually made a profit,' says Joe Anwyll, CEO of Radical Sportscars. 'It marked the end of [our] turnaround and was the first step in the journey of securing Radical's long-term future.'

Last year also saw a record 176 cars roll out of the doors of Radical's factory, its largest ever annual output of vehicles.

All change

This success has largely come about due to a change at the top. A new management team, led by Anwyll, was installed in 2016, and other new faces joined the board in 2021, including group sales and marketing director, Daniel Redpath, who came to Radical from Aston Martin. Yet while there are now new decision makers at the company, it's a re-focusing on what made Radical successful in the first place that's actually made the difference.

'Most people involved in motor racing know what a Radical is,' notes Anwyll, 'and they know what it means. The brand has tremendous value. That's an incredible achievement given our relatively small size, and it's been achieved by focusing on our core product, and the 32-strong dealer network we have spanning 21 countries. Over the years there have been a few occasions where we've deviated from that formula. It's always been huge fun, but often not terribly successful.'

The fruits of this back-to-basics approach include one of Radical's most pulsating racecars to date, the SR10.

'We took the brave decision to develop a new car with a unique powertrain consisting of a highly modified Ford EcoBoost engine and a new gearbox that Radical commissioned from Hewland'

Joe Anwyll, CEO at Radical Sportscars

'The first big decision we made was to invest in product, and that's really paid dividends with the SR10,' says Anwyll. 'We listened to our customers, and built the car they wanted us to build for them. They told us they wanted to spend longer on the track, so we took the brave decision, during the Covid lockdown, to develop a new car with a unique powertrain consisting of a highly modified Ford EcoBoost engine and a new gearbox that Radical commissioned from Hewland.

'Together with other new features, this concept car became the SR10, which, after its launch in late 2020, has become the fastest-selling model in our history. We've already built more SR10s since it was launched than any previous model made by Radical.'

Success factors

The car's success, Anwyll believes, is down to a number of factors: 'It's the speed of the car. We're approaching LMP3 lap times with the SR10, and there's nothing else available that comes close to that for the money.

'It's also the way the SR10 drives. A beginner can get in at a low engine map setting and slowly work their way up as their skills and confidence develops to the full 425bhp setting.

'And finally, it's the ownership proposition. The RPE EcoBoost engine in the SR10 has an 80-hour rebuild cycle.'

Because the cars are being raced all over the world, the engine also needed to be able to perform in a wide range of environments.

'One of the key challenges was thermal management, ensuring the complete powertrain would always stay within its optimum condition, regardless of ambient conditions,' says James Pinkerton, head of powertrains at Radical.

'These days, it's relatively easy to produce engines with ridiculous power outputs. The trick is producing a durable platform that's repeatable and produces the same horsepower, whether it's a frosty day in the UK, or a scorching one in the Middle East.'

Key challenges

The car also needed to be user friendly. 'We faced other key challenges, like ensuring the SR10 has linear and useable power throughout the rev range,' adds Pinkerton. 'Again, with forced induction it's easy to make huge numbers, but you could end up with an engine with a throttle delivery of an on-off switch, which is incredibly frustrating, so we put a lot of time into making the car as driveable as possible. And we've improved it even further for the 2022 model year.'

Some might feel that a road car-derived, four-cylinder engine marks a step away from the company's original bike-power philosophy but, rest assured, motorcycle engines have not been abandoned.

The SR10 packs a twin turbo Ford EcoBoost engine and six-speed Hewland sequential 'box, both developed with endurance in mind

With Radicals racing in all environments (Abu Dhabi shown here), thermal management is a key aspect of engine development

'Our RPE [Radical Performance Engines] Suzuki Hayabusa-based engines have been a mainstay of our business,' confirms Anwyll. 'They're integral to the spine-tingling drama, light weight and balance of the SR1 and SR3 [see box outs on p55 and p56].

'For our larger cars, though, there has long been a need for something more, and we've utilised an RPE-modified version of the twin-turbocharged EcoBoost V6 in the RXC [see box out on p58] since 2013.

'Motorcycle and car engines can happily sit alongside each other in our range as both offer something unique for their application.'

> **'Motorcycle and car engines can happily sit alongside each other in our range as both offer something unique for their application'**
> *Joe Anwyll, CEO at Radical Sportscars*

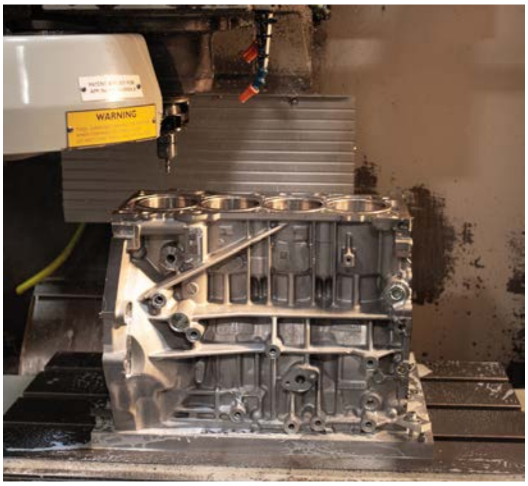
Skeleton benefits

While the engines are the beating heart of any car, it's the skeleton that often provokes comment when it comes to Radicals, as the firm has always been a great believer in the benefits of spaceframe chassis (its only carbon car is the SR9 LMP2 of the mid-2000s).

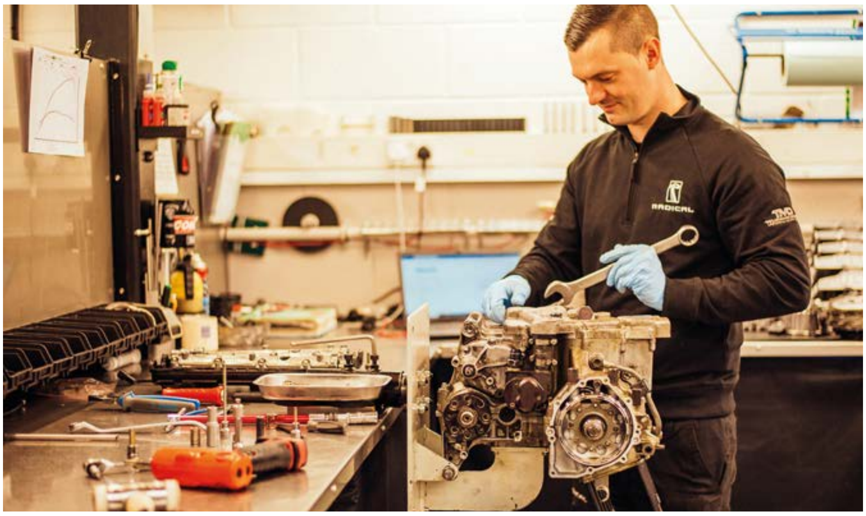
'We are big proponents of the spaceframe chassis, and it remains incredibly relevant for the ways in which our customers use their cars, as well as having an impeccable safety record,' says Pinkerton, who is also test and development driver at Radical.

'They are cost effective for us to build, which keeps the price of the car in check, but, more importantly, they are very easily repaired, and this is a very important consideration for the club racer.

'We see it all the time at the track in our racing. If a customer has an incident and tears a pick-up off the chassis, or bends a corner, we can fix it at the track and get them racing again the next day. This is important if you're fighting for a championship.

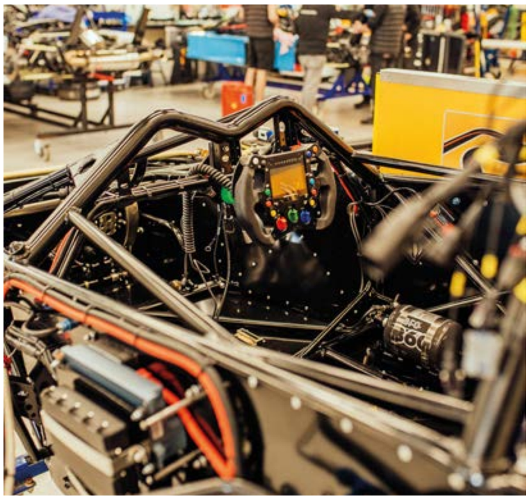


The Radical Precision Engineering arm of the company is responsible for much of the work on the engines and the chassis, with many components fabricated or machined in-house



The engine arm, Radical Precision Engines, adapts, develops and builds both motorcycle and road car-derived power units at the company's Peterborough, UK plant

The RPE Suzuki Hayabusa, in 1340cc and 1500cc form, can be found in both the entry-level SR1 and the evergreen SR3



Radical has kept its faith in spaceframe chassis since its inception, arguing that they make sense from both a cost and safety perspective

Radical SR1

The entry-level Radical is now into its second iteration, with the Generation 2 car sporting a new style body, improved aerodynamics and new electronics.

For a car aimed at track days and club racing, it's a pretty rapid machine, with a 0-60 time of 3.5 seconds and a top speed of 138mph. The 490kg car costs £45,995 (approx. $60,050 / €54,850) and is powered by a 182bhp, 1340cc, RPE-Suzuki four-cylinder engine, based on a motorcycle unit. It comes with the ubiquitous (for Radical) Nik-Link suspension, with Avo dampers, a six-speed, paddle-shift gearbox and Quaife limited slip differential.

'We have Radicals racing all over the world, and crash damage can be fixed by our dealers in market,' Pinkerton adds. 'If you live and race here in England, close to Motorsport Valley, that's one thing. But if you damage a carbon tub and you live in, say, Korea, or the far reaches of Canada, suddenly you're having to freight your car to a specialist who might even be in a different country. And the cost of repair is immense.'

That's not the only benefit a tube chassis can give, notes Pinkerton, a successful racer in his own right, having won the Radical SR1 Cup in 2018 and 2020. 'Our drivers also love the way our spaceframe chassis feels as it loads up through a corner, and the way in which it telegraphs information through the controls. It's very supple and confidence-inspiring as you find the limit.'

Maximum safety

Radical's chassis are built with CDS (cold drawn seamless) steel tube, while the safety critical sections are made from T45, a high strength steel alloy. There is also an aluminium honeycomb crash structure.

But with carbon seemingly ubiquitous in modern motorsport, some might still question the suitability of tube frames. Yet Radical insists they're simply the best way to get maximum safety for this type of car.

'In our category of racing, they're incredibly safe,' insists Pinkerton. 'If the vehicle was significantly heavier, faster or smaller – like an open-wheeler – then a carbon tub would be applicable for safety. But for our type of racing, and with the design of our cars, we think the safety differences are negligible because tubular spaceframes are much better at dissipating energy. A carbon tub may be stiffer, but a greater proportion of that impact loading is then transmitted through to the driver, which then has its own consequences. And, of course, carbon tubs are more difficult and far costlier to repair.

'We design our chassis to absorb and dissipate energy throughout the car, a crumple zone if you will,' adds Pinkerton. 'The cars are very light, which results in far less impact momentum. And we have a lot more space around the driver for that energy to be absorbed and dissipated.

'The most crucial thing in designing these chassis is to understand the load paths – where loads are transmitted through the chassis while racing and where they go during a crash – which ensures the integrity of the crumple zones, to make sure the driver safety zone isn't breached.'

One-stop shop

Another common feature on Radicals is the Nik-Link suspension, which was originally designed so it might be packaged in the sleek front end of the Clubsport. Radical has always made great looking cars, and clever engineering solutions have sometimes been used to accommodate aesthetic preferences.

'Nik-Link takes its name from Nick Walford, our chief engineer, who's been with the company since year one and designed the system,' says Pinkerton. 'It's a cost-effective roll bar solution that Colin Chapman himself would surely have been impressed by. It sits horizontally across the chassis and uses the torsional stiffness of a steel tube to counter roll. It deletes the requirement for drop links, is incredibly well packaged, very light and extremely cost effective.'

Radical uses SolidWorks CAD for its design engineering processes and for the majority of its Finite Element Analysis (FEA) work, though it does source externally for more complex situations when required.

The cars also boast a fair degree of aero, with even the entry-level SR1 generating decent downforce numbers, and this is developed with CFD and on-track testing.

'We use strain gauges to measure loads through the pushrods and pitot tubes to measure air speed across surfaces of the car,' explains Pinkerton. 'We correlate that back into CFD and adjust the design as required.'

What is clear from much of the above is that Radical is pretty much a one-stop shop when it comes to racecar construction. However, the company is also split into its own component parts, with Radical Sportscars responsible for the design and manufacture of the cars themselves, Radical Precision Engineering the machine work and fabrication (also offering external contract engineering services) and Radical Performance Engines the manufacturer's in-house powertrain specialist.

External services

RPE does more than supply motors for Radicals, though, it also offers its services and expertise to other automotive and motorsport concerns, race teams and series.

For example, right now the RPE team is busy fitting its own 2.7-litre V8 – the engine designed for the Radical SR8 – into an original works MG Metro 6R4 Group B rally car.

'The owner couldn't find a cost-effective solution to replace the original engine, which is becoming increasingly rare, and he'd always loved our Macroblock V8, so he asked us to find a way of installing it in the 6R4,' explains Pinkerton. 'We've used the original drivetrain and diff', but designed a new bellhousing to mount the V8 to the gearbox. As the original bellhousing held some of the forward gears, it was quite a complex task.

RPE does more than supply motors for Radicals, it also offers its services and expertise to other automotive and motorsport concerns

The SR10 (and also the latest incarnation of the SR3 model) boasts cockpit electronics and data logging capabilities that would not be out of place in a Le Mans Prototype – something customers now demand, says Radical

TECH SPEC: Radical SR10

Engine: RPE-Ford EcoBoost; 2261cc; custom Garrett turbocharger; direct injection; twin-independent variable cam timing; drive-by-wire throttle; forged motorsport pistons; bespoke dry sump system; Life Racing ECU; high flow racing exhaust system

Power: 425bhp (at flywheel)

Torque: 380ft.lbs

Transmission: six-speed Hewland sequential transaxle; Radical-developed, paddle-activated gearshift system with auto-blipper; automatic torque-biasing limited slip differential

Chassis: Radical spaceframe constructed with CDS steel tube with T45 safety devices; aluminium honeycomb crash structure

Body: High downforce, lightweight glass fibre

Suspension: Fully adjustable Nik-Link system; front and rear unequal length top and bottom wishbones; front and rear adjustable pushrods; lightweight cast aluminium uprights; interchangeable roll bars; Intrax triple-adjustable dampers

Brakes: four-piston calipers; 315mm x 35mm front and rear discs

Cockpit: Twin or single-seat options; AiM Formula Wheel with integral LCD display; lightweight shift paddles and on-wheel switching (functions include LCD rev counter, gear indicator, shift light and engine / gearbox strategy dial controls)

Electronics: Solid-state AiM Technologies Power Distribution Module (PDM) with Controller Area Network (CAN) linked wiring and telemetry; data integration allowing additional data logging, including tyre pressure and temperature monitoring and laser ride height logging

Safety: FIA-spec, foam-filled, 77-litre fuel cell; electronic fire extinguisher system

Wheels: Centre-lock cast aluminium – 8 × 15in front, 10.5 × 16in rear

Dimensions: Length: 4077mm; width: 1799mm; height: 1093mm

Weight: 725kg

Price: £117,900 (approx. $153,950 / €140,615)

Radical SR3

This car, in its various guises, has been around since 2002, but the most up-to-date version, the SR3 XX, has benefited from some close cooperation with Radical's long-term data partner, AiM Technologies. Consequently, it boasts a state-of-the-art data package and the sort of steering wheel technology you would usually associate with an LMP car.

Beyond the trick electronics, the £71,900 (approx. $93,900 / €85,750) car packs either a 1500cc (226bhp) or a 1340cc (195bhp) RPE-Suzuki four-cylinder motor, the former capable of 0-60mph in 3.1 seconds and a top speed of 147mph.

The SR3 also has Radical's Nik-Link suspension, a six-speed sequential 'box and Quaife LSD, plus an aero package that includes a dramatic, high-downforce bi-plane rear wing and diffuser.

RADICAL
RADICAL
HEWLAND
SR10

FRONT
LifeRacing
THIS SIDE UP

'We also re-designed our lower crankcase to mount the differential to the engine, and re-designed the sump because the drivetrain runs through it.'

The Peterborough base where all this ingenious activity takes place contains design and engineering offices, an engine shop and test lab, build hall, machine and fabrication shop, dynos, race team, and the administration and management offices. Currently, 130 people work on site, with a further three people employed in the US – a major market for Radical, with over 75 per cent of its racecars sold there.

US market

'At the moment we're working on further bolstering the dealer network, and expanding our presence in the USA,' says Anwyll. 'The Radical Cup North America uses bucket list tracks, as well as supporting IndyCar at two events this year. The series is enjoying its largest ever grids, which is a fantastic sign of how the brand, and customer base, are growing over there.'

That said, Anwyll is very aware the US market is different from the UK and Europe. 'The expansion of the North American market has been crucial to our success over the past few years, and it is rooted in how our American customers use their cars. Culturally, the two markets [UK and US] are different. Americans have always loved their motorsport and they've got the space over there to properly enjoy it. Dirt bikes, ATVs, off-roading, karting, recreational flying, it's all big.

'Over the past decade, motorsport country clubs have boomed. These are big properties where an entrepreneur will build a racetrack, pit garages and a group of condos and you can buy a membership there. You can drive the track whenever you like. You can even build a house and live there if you want to.

'Radicals are perfect for this kind of country club use case scenario. They're approachable to drive if you're still learning, yet they truly deliver if you've got the skills.

'We have American customers who'll put more hours on their cars in a month than our European ones will put on in a year. They'll take a week off work, go to their country club and just pound laps for five days straight.'

The Radical franchise

The company's reach goes far beyond the United States, though, as Daniel Redpath, Radical's group sales and marketing director explains: 'Our current network of 32 Radical dealers is the largest franchise in motorsport, and our representation stretches across the UK and Europe, throughout North America, the Middle East, Asia, and into Australia and New Zealand.

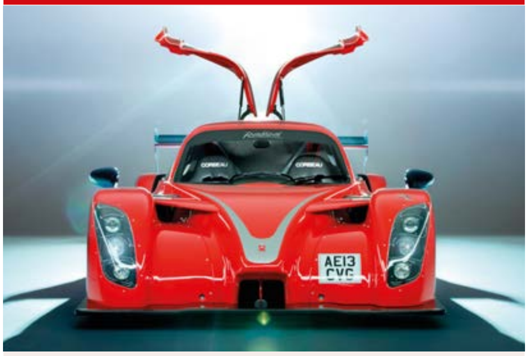
'As a company, we operate the Radical Challenge and SR1 Cup here in the UK and the Radical Cup North America, and we support official Radical championships run by our dealers in Australia, Canada, the UAE, Scandinavia, Spain, Romania and Korea.'

Redpath sees the growing dealer base as one of the secrets to the company's recent success. 'We've put a great deal of effort into expanding our global dealer network. They're the true jewel in the Radical crown. We've added 12 new dealers in the last two years who are all working exceptionally hard in helping us penetrate new and emerging markets.

'Anywhere that has an established motorsport scene is a potential market for us'

Daniel Redpath, group sales and marketing director at Radical Sportscars

Radical RXC 600R



The RXC comes in four guises: Spyder; GT3 (homologated for that category); GT Road (part of a long tradition of street driven Radicals) and the RXC 600R. The latter is marketed as a 'high performance track day and race car for the gentleman driver' and, with 650bhp on tap, this 1130kg projectile can reach 60mph in 2.7 seconds and go on to a top speed of 180mph.

The engine is a 3.5-litre, twin-turbocharged, Ford EcoBoost V6, mated to a bespoke, six-speed Hewland sequential gearbox.

The car's design is based on a modern LMP car, so comes with a roof, and costs £147,500 (approx. $192,600 / €175,900).

'We see potential for expansion throughout South America, India and in South Africa, which are three regions we're exploring. Anywhere that has an established motorsport scene is a potential market for us.'

Radical surely is a worldwide motorsport phenomenon. But, while its range of cars and its sales are impressive, it admits it's also following a proven philosophy. Which begs the question: is Radical *still* radical?

'Absolutely! Now more so than ever,' says Redpath. 'The very things that drove us in the early days – the desire to produce lightweight, fast and manageable racecars for enthusiast club racers – hasn't changed. If anything, the concept is more relevant today than ever.

'Road and racecars are getting bigger, heavier and more complex. We have track day drivers with modern supercars who are throwing a set of [Michelin] Pilot Sport 4s and brake pads on their cars every track day, and a set of carbon discs every year, at huge cost. And we have racers afraid to race for fear of damaging their cars and spending an entire season's budget in one incident.

'And then they drive our cars and are blown away. They can go significantly faster, they can race harder, for longer, and can push themselves in a true racecar that doesn't let complexity and needless waste get in the way.

'As the automotive and motorsport landscapes continue to progress, we arguably get even *more* radical.'

Which is perhaps the point. Radical stays radical by keeping things simple and doing what it's always done best. When that approach results in cars like the SR10, you can only hope that this company is around, doing its thing, for another 25 years.

While it is looking to expand all the time, Radical currently has 32 dealerships all over the world and runs championships for its cars in many of those markets. Here SR3s are pictured in action at Spa Francorchamps, Belgium

Optimal thinking

Theory and good practices on suspension kinematics design, part one

BY CLAUDE ROUELLE

XPB

For years, WRC teams have been exploiting short wheelbase cars by turning small hatchbacks into very competent off-road racers

'Give me a lever long enough, and a fulcrum on which to place it, and I shall move the world,' said Archimedes.

We have learnt in our engineering courses that a force is defined by an application point, a direction and an intensity. So worry first about the force application point, and its direction, before you consider its intensity.

Now apply this thinking to racecars. Sometimes, when a car cannot get into 'the zone' of performance, even after having changed ride heights, springs, ARBs, dampers, camber, caster, toe, tyre pressure… you name it, changing some inboard or outboard suspension pick-up point coordinates by a few millimeters can make the car more controllable for the driver, and more sensitive to set-up changes.

What will follow over the next few OptimumG columns is a proposed approach for suspension kinematics design in 12 steps, which we will then look at individually:

1. Wheelbase and tracks
2. Scrub radius and mechanical trail
3. Caster angle and KPI angle
4. Outboard pick-up points
5. Front view VSAL, front view IC height, roll centre height
6. Side view VSAL, side view IC height, pitch centre height
7. Inboard wishbone pick-up points
8. Steering rack position, inboard and outboard toe link position
9. Spring motion ratio
10. ARB motion ratio
11. Integration with vehicle design
12. Suspension kinematics optimisation and conclusions

Tracks and wheelbase

For most passenger cars, the wheelbase and the tracks are largely defined by the segment the car manufacturer wants to compete in and the consequent packaging of all parts.

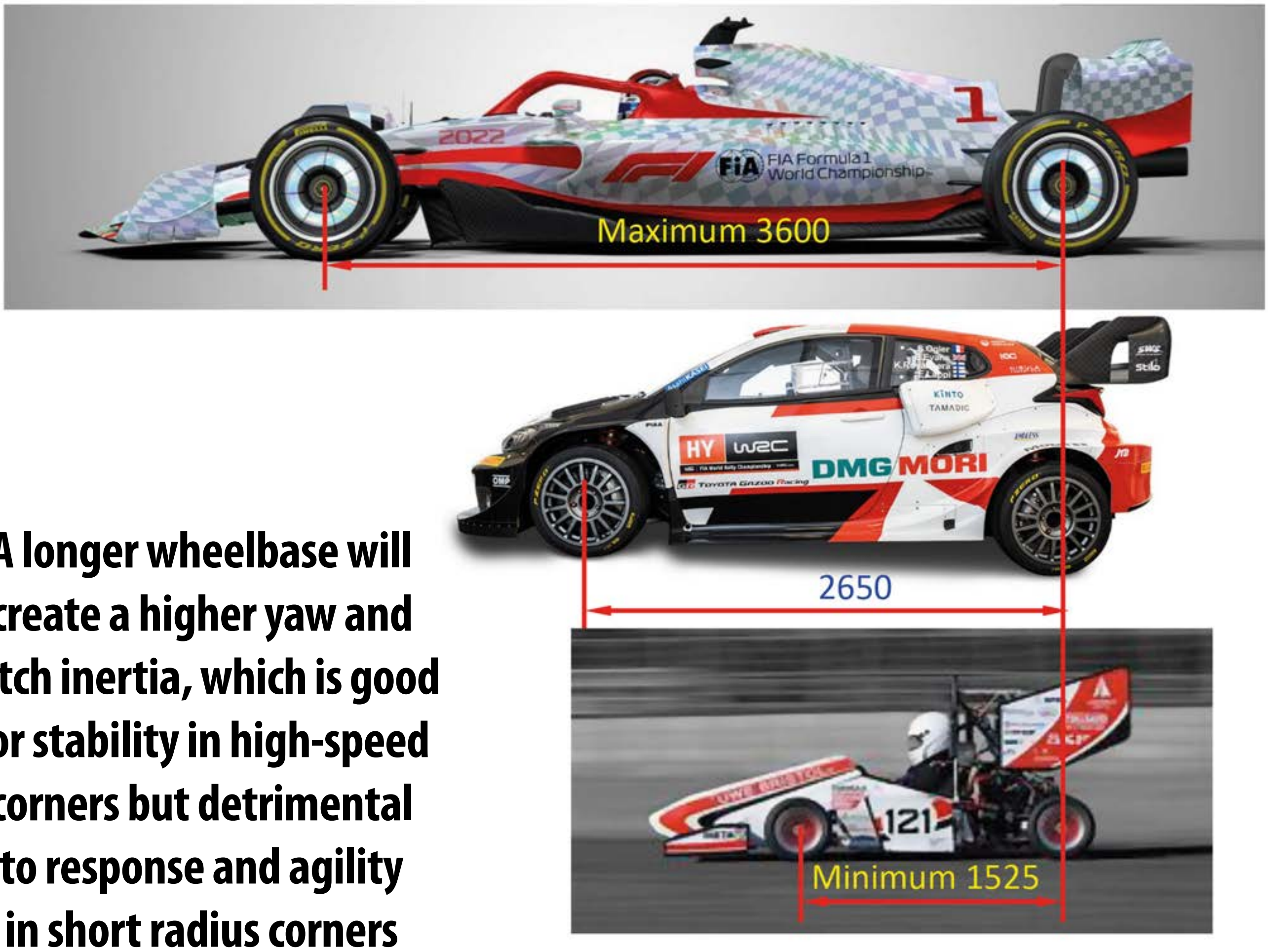
For racecars, however, things are different. Several additional factors must be considered: inertia, type of circuit the car will be running on, driver skill, tyre characteristic, rules, weight target, downforce target and risk of roll over.

Figure 1 shows various racecar wheelbases. We know that in Formula 1, for example, the biggest part of the downforce is generated by the underwing. If well designed, the longer the underwing, the more downforce. However, a longer car will necessarily be heavier, so a compromise has to be found between how much you gain in downforce against how much you are prepared to give away in weight. With a new standard part for 2022, several F1 teams are finding themselves unable to reach the minimum weight.

Also, a longer wheelbase will create a higher yaw and pitch inertia, which is good for stability in high-speed corners but detrimental to response and agility in

A compromise has to be found between how much you gain in downforce vs how much you are prepared to give away in weight

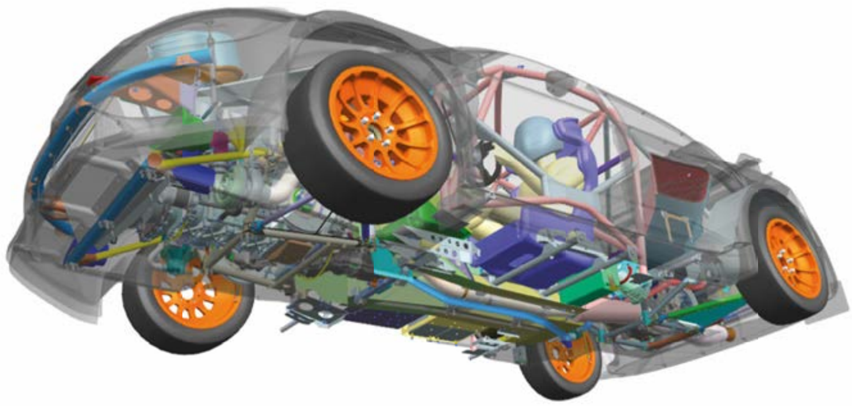
Fig 1: Different wheelbases for different reasons



A longer wheelbase will create a higher yaw and pitch inertia, which is good for stability in high-speed corners but detrimental to response and agility in short radius corners


Francis Bradfield

The BTCC uses ballast to help maintain a competitive field


Prodrive

In series where ballast position is not mandated, engineers will use it in different places depending on track

short radius corners, such as in the streets of Monaco. Because of the parallel axis theorem (also called Huygens or Steiner in different countries), the longer the distance (in fact the *square* of that distance) between each car part c of g and the car c of g, the higher the inertia. In fact, non-suspended masses and wings will create more yaw and pitch inertia than the engine and gearbox. Roll inertia plays a role in performance too, but to a lesser extent because a car width is always shorter than its length.

In some racing series, cars are built under the minimum weight, and ballast must be added. Even with an imposed weight distribution, putting ballast in the nose and near the gearbox will help stability in large radius corners, while putting them near the car's c of g will help response in small radius corners.

The type of circuit helps engineers decide on which side the compromise is made.

In Formula 1, most of the drivers have very similar skills, but in some racing series there could be a large driver skill spectrum.

Stewart Mitchell

In a relatively low speed competition like Formula Student where inertia is high, response is the most critical factor, so wheelbase and track are kept deliberately small for maximum agility

I do not understand why a Formula Student team would design a car with a wheelbase much longer than the 1525mm minimum imposed by the rules

If we look at the man / machine control loop, a professional driver that has excellent sensing, as well as quick and proportioned reactions, could drive a car with less yaw inertia, while an amateur driver will want a less responsive but more stable ('calm') car.

Tyre influence

The tyres' grip will influence the yaw inertia target, too. On a wet surface, the difference between the 'ideal' inertias in slow and fast corners will be bigger than on a dry surface.

With the many hairpins encountered in a special stage, it is obvious a World Rally Car could not be run with a 3.6m wheelbase. WRC engineers, therefore, have the chance to distribute their ballast in different positions, and often locating it close to the centre of the car gives the best results.

The extreme case is Formula Student. For the type of circuits and corners used in this competition, *if* well designed, and *if* with good drivers, a Formula Student *always* has too much inertia. Because of the low-speed corners, though, stability is rarely a problem. Lack of response is. The best proof of this is that go-karts are lighter, smaller and have way less inertia, yet good drivers can still manoeuvre them in all corners.

There is also no minimum weight in Formula Student, and we all know the best way to get a light car is to design a small car. I do not understand, therefore, why any Formula Student team would design a car with a wheelbase much longer than the 1525mm minimum imposed by the rules.

If we consider the risk of possible roll over, larger tracks are obviously better. However, I have seen Formula Student cars with tracks as little as 900mm. These cars did not overturn because they were light (less mass = less load transfer), had a low c of g and, even at low speed, produced enough downforce to counteract the load transfer. The attendent gain in agility was consequent, and the risk of high overturning moment was low.

In the next article, we will discuss the importance of upright design, especially the front one, and the influence steering has on corner load variation, camber variation, ride height variation and steering torque.

Slip Angle is a summary of Claude Rouelle's OptimumG seminars.

Public, on site, and online OptimumG seminars are held worldwide throughout the year. The Advanced Vehicle Dynamics and the Data Driven Performance Engineering seminars present several theories and best practices that can be used by engineers when making decisions on how to improve vehicle performance. OptimumG engineers can also be found around the world working as consultants for top level teams.

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OPTIMUM G

C-rate expectations

Racecar *charts the latest developments in high performance battery technology*

By LAWRENCE BUTCHER

C-rate refers to the rate of charge, or discharge, of a battery relative to its capacity. While some series are open and willing to share figures, others remain tight lipped. ERA Championship shown

Like it or not, traction batteries – those which help propel a vehicle, rather than just power its electronics – are an ever-growing part of the motorsport landscape. From the fully electric drivetrains found in Formula E and Extreme E, to the hybrid systems of Formula 1, the WEC, WRC and BTCC, to name but a few. Consequently, development of motorsport-specific battery systems is on the rise.

All this should come as little surprise, given the momentum behind both the political and industrial drive towards electric vehicles (EVs), with manufacturers keen to bestow some degree of environmental credence on their motorsport activities. It is also the case that increasing electrification provides racing with an opportunity to retain technological relevance as a proving ground for next generation technologies.

It would be easy to dismiss this last facet, but there are already many examples of electrification technology forged in competition aiding development in other areas. Take Formula E as an example. While battery technology is fixed, manufacturers are open about the fact they learn lessons related to energy management and software development, and deploy that knowledge within their road car programmes.

Meanwhile, companies such as Williams Advanced Engineering, recently acquired by Australian mining behemoth, Fortescue, will soon see its motorsport-developed battery technology deployed in mining applications, thanks in part to experience gained developing battery systems in Extreme E.

In the passenger car segment, Tesla rival, Lucid, has an engineering team peppered with motorsport engineers, and has used this experience to push the efficiency and performance of its debut model, the Air, to levels previously unseen in production cars.

The key areas of development when it comes to motorsport, or any vehicle, batteries can be broken down as follows: battery cell design and chemistry, pack construction, cooling and battery management. Each is dictated by the overall demands of the vehicle's powertrain and packaging. The needs of a WRC hybrid, for example, are quite different to those of a Formula E car.

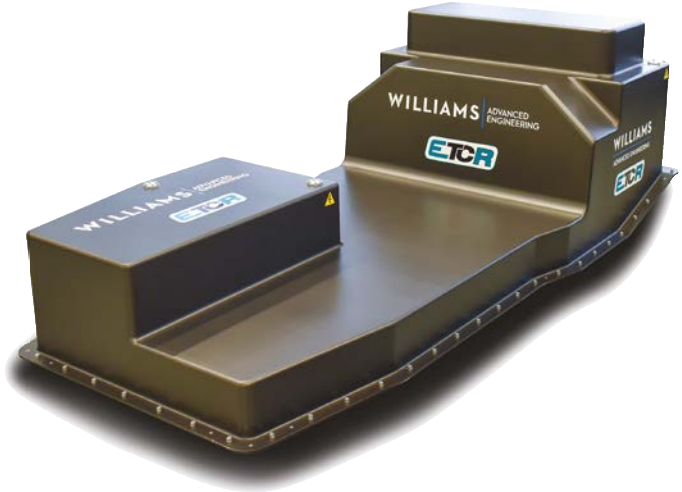
For the purposes of this article, we will focus on cell design, chemistry and cooling, as the other two topics warrant their own in-depth investigation.

Cell types

Starting with the cells themselves, these are the building blocks of any battery system and come in three main types: cylindrical, prismatic and pouch. In the automotive world, cylindrical cells are the most commonly used variety. The 18650 size is widespread, but several manufacturers have developed different formats, such as Tesla with its 4690 form factor, produced in conjunction with Panasonic.

A cylindrical cell is made up of spiral wound layers of foil, comprising an anode, separator, cathode and liquid electrolyte, housed in a metal canister with a positive terminal at the top and negative at the bottom. There are a number of benefits to cylindrical cells, not least they are relatively easy to manufacture in volume. They are also durable, suit being assembled into packs and can resist internal pressure build up well.

ETCR Battery



Battery packs come in all shapes and sizes, depending on their application. Shown here are an LMDh pack (above) and an ETCR pack (right), both produced by Williams Advanced Engineering

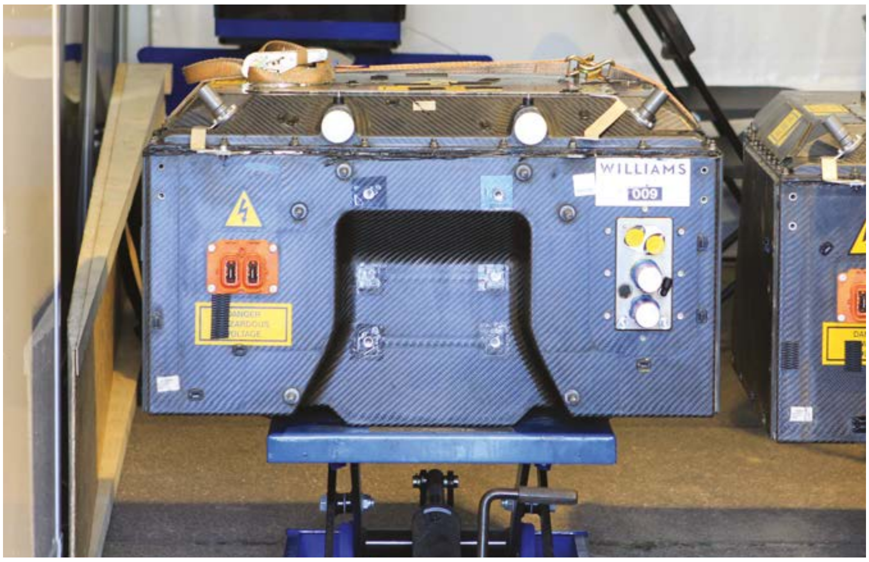
EVs are now an integral part of modern motorsport, and developments will help improve electric / hybrid road cars. ETCR shown

Increasing electrification provides racing with an opportunity to retain technological relevance as a proving ground for next generation technologies

Prismatic cells, meanwhile, see multiple positive and negative electrodes stacked together and housed in a flat canister. The shape of the container means they can be packaged together more tightly than cylindrical cells, but they tend to have a lower energy density and are more prone to issues such as swelling if internal pressures increase. They are also more costly to manufacture.

Finally, pouch cells. Here, the anode and cathode are placed within a soft, flexible foil pouch, with tabs protruding from the top to transfer current out. Pouch cells are the most space efficient form of cell, with around 90-95 per cent packaging efficiency, but their lack of structure means they need additional support within a pack. A useful benefit is that if they do experience thermal issues, pouch cells tend to bulge rather than explode, and also have low internal resistance, meaning they are attractive in high-power applications.

The type of cell used in a battery system will depend on a variety of factors, including, but not limited to, the chemistries available in that particular cell format, the packaging needs of an installation, its cooling provision and the target cost of the finished battery pack. On this last point, cylindrical cells, due to their more widespread availability, tend to be the most cost effective. Conversely, due to the need for less investment in tooling, bespoke chemistries tend to be provided in pouch format as these are often used for short production run applications and experimental purposes.



The chemistry used in the pack's construction also differs greatly, depending on the demands required of the vehicle's powertrain, as well as its packaging and cooling requirements. Shown is a WAE Formula E Gen 1 battery

A pure EV will require a relatively energy dense battery, a hybrid will tend to favour greater power density, allowing for rapid energy deployment and regeneration

Lithium-ion (Li-ion) batteries are still the most commonly used in motorsport, though new technologies are being explored all the time. FIA Electric GT shown

Regardless of format, lithium-ion (Li-ion) batteries – which will be the focus of this article – all operate on the same basis. As the battery charges and discharges, lithium-ions pass from the cathode to the anode (when charging) via an electrolyte, and vice versa when discharging.

Chemistry lesson

The internal construction of a battery cell consists of an anode and a cathode, separated by a thin layer of insulating material. The 'active' battery material, often referred to as the chemistry, is coated onto the surface of the electrodes. The selection and formulation of this chemistry is a key determinant as to whether a cell is energy or power dense, or a compromise between the two. In motorsport terms, it is generally power density that is in demand, though in pure EV applications energy density is also a concern.

High power density stems from the chemistry of the battery and the electrode design, as well as how effectively the cell can be cooled. Increasing the power of a battery hinges on reducing the resistance experienced by the ions as they travel between the electrodes. Of critical importance here is the thickness of the coating on the electrodes.

If charging or discharging a battery, ions need to move through the full thickness of the material, across the separator, and through the full thickness of the second material. The greater the distance, and the more material the ions must pass through, the more resistance there is in the battery.

Cell construction and internal chemistry determines the balance of power and energy densities. BTCC battery pack shown

This resistance causes heat build up and a drop in voltage (in addition to potentially causing instability in the cell). Unfortunately, creating a high-power battery is not as simple as putting a thin coating onto the electrodes. Resistance will be low, and power high, but the energy content will also be very low.

Where the balance falls in terms of energy and power density depends on the application in question. For example, while a pure EV will require a relatively energy dense battery, a hybrid will tend to favour greater power density, allowing for rapid energy deployment and regeneration.

Though F1 teams keep tight lipped about the C-rates of their batteries (the rate of charge or discharge, compared to the capacity of a battery), and energy deployment and regen' from and to the battery are capped, technology developed in the series is deployed elsewhere.

For example, Green GT, the developers of the eponymous hydrogen fuel cell racer and heavily involved in the ACO's MissionH24 project, uses a buffer battery between its car's fuel cell and motors. According to the company, it worked with a Formula 1 supplier to develop a battery pack capable of a C-rate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Cooling is a major consideration in all EV technologies, but particularly relevant in a series such as Extreme E that takes place in a wide variety of landscapes and climate zones

of 150, and a capacity of 2.4kWh (equating to it being able to discharge its total capacity in around 24 seconds).

Current thinking

Battery cell manufacturers are constantly striving to create new chemistries that allow for both energy and power density and progress over the last decade has been impressive. This is best illustrated by Toyota's development of its previous generation LMP1, the TS040 and its successor, the TS050. Initially, lithium-ion battery technology was not sufficiently mature to support the high power demands of Toyota's hybrid system, so it instead opted to use super capacitors. This gave the power density required, but at the expense of energy storage. The resulting unit was bulky, albeit not overly heavy.

By 2016, battery chemistries, as well as management and cooling techniques, had advanced sufficiently for the team to adopt a lithium-ion based system, which it still uses to this day.

Currently, the most potent commercially available battery chemistries tend to be those that use lithium nickel manganese cobalt oxide (NMC) or nickel cobalt aluminium oxide (NCA) cathodes, which have both impressive power and energy density. The downside being they are costly to produce and relatively unstable, so require a greater level of management than some lower power chemistries (for example, lithium iron phosphate - LiPo).

The very best commercial NMC cylindrical cells available today have an energy density of around 300Wh/kg (Watt hour per kg), while cells are under development by the likes of CATL (Contemporary Amperex Technology Ltd) that pair NMC cathodes with silicon / graphite anodes and have a projected potential of 700Wh/kg.

Another chemistry that is still very much in the development stage, but seemingly nearing commercial reality, are lithium sulphur cells, which use a sulphur-based cathode. These have a theoretical energy density in the region of 2000-2500Wh/kg, with the added attraction that sulphur is a low-cost material. However, their development is hampered by problems relating to the movement of polysulphides between the electrodes, which degrades the performance of both the sulphur cathode and lithium anode.

The reality is that most experimental sulphur batteries have only reached around 300Wh/kg. However, work is underway on a number of fronts to circumvent these issues. One US-based company, Lyten, is using what it calls a 3D graphene-based architecture and sulphur 'caging' to prevent the migration of polysulphides, and is projecting energy densities up to around 900Wh/kg.

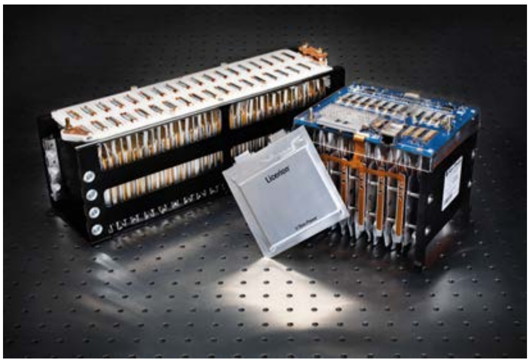
There are a host of other chemistries still in the research phase, some with greater potential than others, but all with hurdles still to cross before they become commercial realities. A good example being rechargeable

Another intriguing solution to the issue of balancing energy with power density is to mix cell or chemistry types within a system

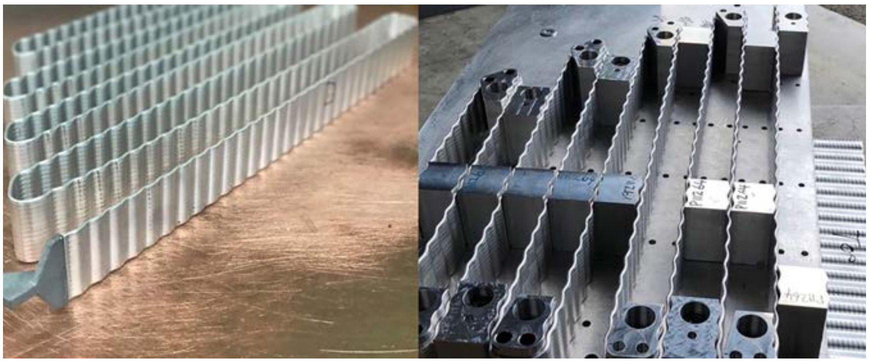
lithium-metal batteries. These have been available for years as single-use products, most commonly found as button cells for watches, but producing rechargeable versions has so far proved tricky.

One of the biggest problems with lithium-metal cells is the growth of lithium deposits from the anode, called dendrites, which pierce the electrode separator and short circuit the battery. This type of battery has the potential for impressive energy density, in excess of 500Wh/kg, and developers are working on a variety of solutions to the dendrite issue, such as protective coatings on the lithium anodes, additives for the liquid electrolytes and the addition of ceramic reinforcement in the separators.

Once such developer, Sion Power Corporation in the US, says it is close to commercialisation of its 400Wh/kg 'Liceron' lithium-metal cell. Similarly, another US manufacturer, Sakuu, is developing a 3D-printed, solid-state, lithium-metal battery that it hopes will achieve around 300Wh/kg,



Lithium-metal batteries, such as Liceron from Sion Power Corporation in the US, have the potential for impressive energy density numbers



Goodfabs

Battery packs prefer to be kept between 20 and 50degC, so the associated cooling package is critical. In some applications, liquid cooling channels, such as these produced by Goodfabs, will be wrapped around the pack

Cooling solutions can depend on the duration of the race. The WAE packs used in Extreme E, for example, are cooled prior to the races and then heat up naturally during use, but not to the point where they exceed their maximum operating temperature

with a higher degree of safety than current lithium technologies.

Another intriguing solution to the issue of balancing energy with power density is to mix cell or chemistry types within a system. This is the approach Ferrari has deployed in F1 and, seemingly, will be carried over to its road car project due in 2025. Here, one battery pack uses a chemistry that provides a high energy density, while another battery uses a high power density chemistry. This creates what is known as a blended battery pack, and means the size of each pack can be optimised to either low power / long duration, or high power / short duration use, with any excess capacity eliminated. A properly executed blended battery system can provide a significant weight saving over a single system (referred to as a uniform solution) as there is no need to oversize the individual batteries to account for both maximum energy and power density requirements.

Thermal management

Batteries present one of the most challenging cooling tasks in a racing EV or hybrid, owing to the relatively low temperatures that lithium-ion chemistries can withstand. While a SiC semiconductor can survive at up to several hundred degrees, and motors at up to 100degC, the upper limit for most batteries is about 60degC and ideally, they are happiest between around 20-50degC. Therefore, ensuring each of the individual cells can be cooled effectively is vital, both from a performance and safety perspective.

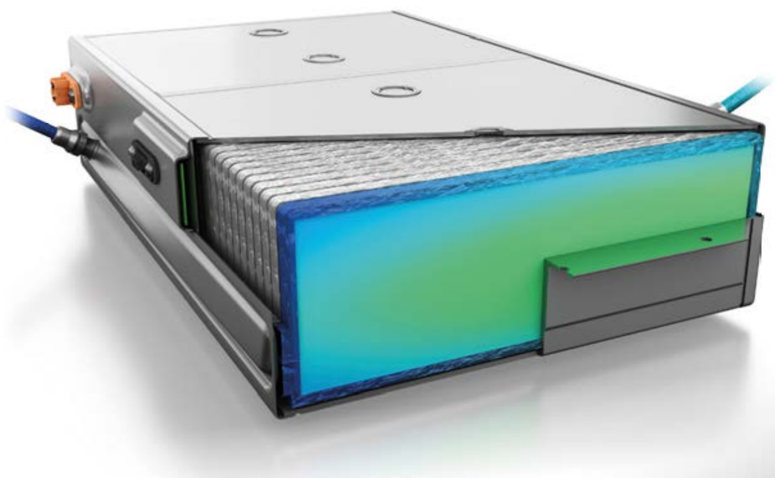
Most will have heard of the term thermal runaway, where if one cell malfunctions or overheats within a pack, it sets off a chain reaction in its surrounding cells. Effective cooling, combined with management of the cells at an individual level, are key to preventing catastrophic issues such as this.

On a more mundane level, running cells at the extremes of their temperature capabilities will lead to rapid degradation and a loss of performance (not least as internal resistance increases with temperature).

In some applications, where high power is only needed for a short period of time, it is possible to rely on air cooling, or even simply harnessing the thermal mass of the pack. This was the approach taken by Williams Advanced Engineering with the packs it supplied to Extreme E. These were cooled prior to each race using a chilled air system, and then heated up over the course of a race, but never exceeded their maximum operating temperature. WAE adopted this solution due to the simplicity of design it affords, which is beneficial when vehicles and batteries need to be serviced in a tent, for example. However, this approach was only possible in very specific applications and, generally speaking, some form of active cooling is required.

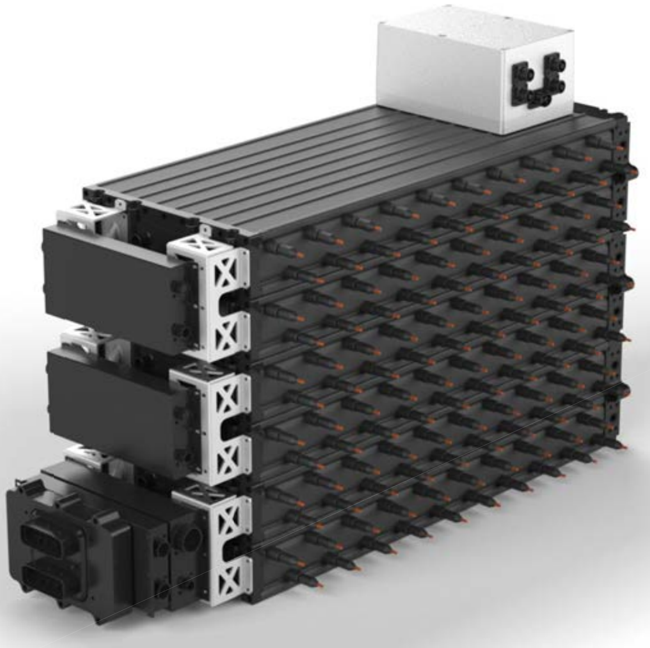
By and large, active systems rely on some form of liquid cooling, either indirectly or, increasingly, directly. The means of removing heat from the cells varies depending on battery architecture, such as whether cylindrical or pouch-type cells are used. For example, pouch cells can be cooled using heat-conducting strips running from each pouch to a cold plate at the bottom of a pack, so are cooled in much the same way as the power electronics in an inverter, via fluid running along the underside of the cold plate.

Most electric racing series employ some form of indirect cooling system for its battery packs, though direct cooling is becoming more commonplace



The current ultimate battery cooling solution is total immersion, shown by this Mahle battery cell. It allows for higher cell loading without the associated thermal risk

Another option is direct fluid cooling, as used by Taiwanese company, Xing Mobility, on the battery systems in the Miss R off-road supercar



This is the approach used by Delta Cosworth with the pouch cells deployed in its 48V BTCC hybrid batteries. Further cooling plates can then be added between pouches to increase the rate of heat removal.

If greater cooling effect still is required, without moving to direct fluid cooling of the cells, the next step is to use cooling channels directly abutting the cells, which incorporate many small fluid channels in a single extruded section (known as micro port extrusions, or MPEs), formed to the shape of the cells. Some of the latest developments in this area have seen the use of additive manufactured (AM) cooling channels replacing extruded parts.

There are several advantages to using AM manufacturing methods, particularly in the case of small batch production runs that are prevalent in motorsport. Rather than having to produce bespoke tooling to create MPEs, AM parts can be printed as required. Furthermore, whereas an extruded channel will be of uniform geometry and size along its entire length, AM allows for variations in the shape and size of channels to better match the cooling demands of a specific pack, or the packaging requirements of the racecar.

Current AM technology, when properly validated, can create impermeable wall thicknesses down to 0.2mm. When combined with the ability to shape channels to match cell geometry and CFD simulation of coolant flow and temperature distribution, very efficient cooling can be achieved.

Some of the latest developments in battery technology have centred around total immersion cooling of cells. This method is most often applied to cylindrical cells and has the potential to allow for exceptionally high loading of cells without thermal issues. Of course, given the direct contact of the coolant with the cells, non-conductive dielectric fluid must be used, and suppliers such as 3M (with its range of Novec cooling fluids) have been developing products aimed at battery and electronics cooling for some time.

Direct fluid cooling of hi-po battery packs is currently being used in WRC and World Rallycross, but technology is developing at pace

For now, though, water remains one of the most efficient cooling mediums, and dielectrics are still some way off competing with it, though recent improvements in fluids' specific heat capacity, coupled with the lack of thermal resistance when used directly on a cell, make them an attractive option.

There are several examples of direct fluid cooling of high-performance battery packs out in the wild, most notably those supplied by Kreisel to both the WRC and World Rallycross, and those used by Taiwan-based Xing Mobility for a variety of applications, including its Miss R off-road supercar. One of the most useful aspects of immersion cooling is that it helps ensure an even temperature distribution across the battery pack, reducing the chances of hotspots developing. Furthermore, in a worst-case scenario, if a cell is punctured or suffers a catastrophic failure, the dielectric fluid will help extinguish and contain any combustion.

Battery technology is continuing to develop at pace and, inevitably, some solutions found in the upper echelons of motorsport, currently kept under tight wraps, will start to trickle down into other series.

Next generation technologies, such as solid-state batteries, are also drawing nearer, driven by significant investment from both automotive OEMs and the wider electronics industry. Once proven, they will surely find their way into racing. And, as high-performance cells become more readily available, along with specialists supplying the parts for cost-effective bespoke packs, the bar to entry of EV technology into more areas of racing will continue to fall.

The porpoise effect

It's nothing new, but what exactly is it, and how do you deal with it?

By DANNY NOWLAN

XPB Images

Porpoising has been one of the main topics of conversation amongst professionals and lay persons since the new generation F1 cars hit the track earlier this year, but Danny's seen it all before

Motorsport-wise, one of the key problems that has emerged from early season testing of the new generation Formula 1 cars is so-called porpoising. Given that myself and ChassisSim customers have dealt with this to some degree over the years, I've had a wry giggle at the number of lay punters out there who think this is a new thing.

Porpoising has been around for a good while now, and is one of the things that's always lurking around the corner if you run a high-downforce racecar. In this article we'll discuss what it is and, more importantly, how you can deal with it.

First things first. If you insist on running a high-downforce racecar that is passive, the risk of porpoising is the price you pay. It doesn't matter whether you're running ground effect tunnels or flat bottoms, if you have either very badly conditioned aerodynamics, or a badly tuned spring / damper package, it will make its presence felt at some point.

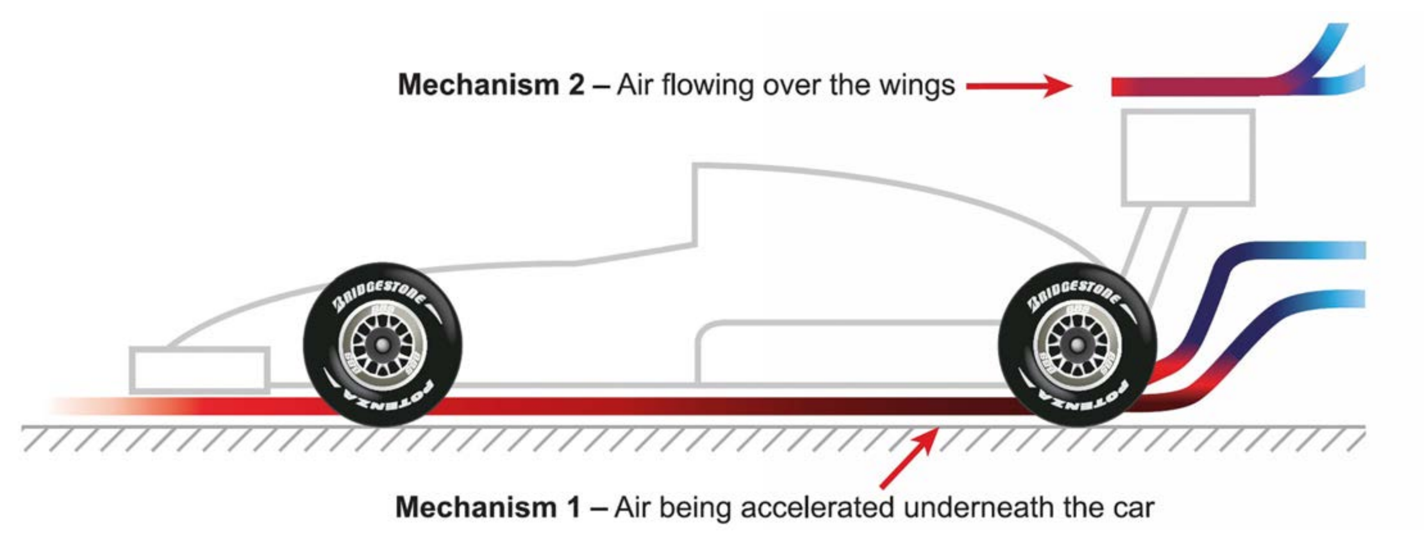
What porpoising refers to is low-to-high frequency oscillation in the pitch mode of the sprung mass of the vehicle. To illustrate this, **Figure 1** shows how downforce is generated on a racecar.

The two ways you generate downforce are by accelerating air under the car or over the rear wings. The latter is tied quite closer to the former, but we are nitpicking.

When a car is prone to porpoising, from an aerodynamic perspective you have two culprits. Either the front wing / splitter

Porpoising… is low-to-high frequency oscillation in the pitch mode of the sprung mass of the vehicle

Fig 1: How downforce is generated on a racecar



From a mathematical perspective, what drives this is the aerodynamics having a fundamentally destabilising moment on the car

Equation 1

$$A=\begin{bmatrix}
\frac{-(c_f+c_r)}{m_s} & \frac{-(k_f+k_r)+\frac{\partial F}{\partial z}}{m_s} & \frac{(a\cdot c_f-b\cdot c_r)}{m_s} & \frac{(a\cdot k_f-b\cdot k_r)+\frac{\partial F}{\partial \theta}}{m_s} & \frac{c_f}{m_s} & \frac{k_f}{m_s} & \frac{c_r}{m_s} & \frac{k_r}{m_s}\\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
\frac{(a\cdot c_f-b\cdot c_r)}{I_y} & \frac{(a\cdot k_f-b\cdot k_r)+\frac{\partial M}{\partial z}}{I_y} & \frac{(-a^2\cdot c_f-b^2\cdot c_r)}{I_y} & \frac{(-a^2\cdot k_f-b^2\cdot k_r)+\frac{\delta M}{\delta \theta}}{I_y} & \frac{-a\cdot c_f}{I_y} & \frac{-a\cdot k_f}{I_y} & \frac{b\cdot c_r}{I_y} & \frac{b\cdot k_r}{I_y}\\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0\\
\frac{c_f}{m_{tf}} & \frac{k_f}{m_{tf}} & \frac{-a\cdot c_f}{m_{tf}} & \frac{-a\cdot k_f}{m_{tf}} & \frac{-(c_f+c_{tf})}{m_{tf}} & \frac{-(k_f+k_{tf})}{m_{tf}} & 0 & 0\\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0\\
\frac{c_r}{m_{tr}} & \frac{k_r}{m_{tr}} & \frac{b\cdot c_r}{m_{tr}} & \frac{b\cdot k_r}{m_{tr}} & 0 & 0 & \frac{-(c_r+c_{tr})}{m_{tr}} & \frac{-(k_r+k_{tr})}{m_{tr}}\\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0
\end{bmatrix}$$

stalls, or chokes the floor to the under floor. Alternatively, the rear gets too low and that stalls the diffuser. What happens in both cases is that when either the front or rear gets critically low, the discontinuity that occurs kicks in and sends the relevant end back up. Downforce then kicks in and pushes the relevant end back down again. This up / down motion can set up a high-frequency pitch oscillation that can be deleterious to both the car itself and performance. During my career I've seen both effects make their presence felt, so it's not limited to one situation or the other.

There are some other interactions what will induce porpoising as well. Typically, a badly conditioned spring / damper package. The worst offender I tend to see is a third spring arrangement that hits a bump rubber that's effectively a brick. This then sets up an oscillation that is very difficult to manage.

Another popular culprit is when you have a large amount of downforce combined with a massive aero balance. Both of these on their own are bad enough, but combine them and you are quickly in a world of hurt.

From a mathematical perspective, what drives this is the aerodynamics having a fundamentally destabilising moment on the car. This is summarised in **equation 1**, taken from my book, The dynamics of the race car.

Now, I'm not going into all the terms of this equation because it would distract us from the purpose of this article. However, I want to bring your attention to two things. Firstly, the spring and damper settings described by the k and c terms have a fundamentally stabilising effect on the sprung mass, particularly in pitch. The aero terms are described by the derivatives of F and M respectively, and fundamentally destabilise the sprung mass. How big these terms are will dictate what you can and cannot do about it.

Problem solving

The first step to solving this problem is having an aero map validated from race data. This is a do not pass go, don't collect your \$200 point. If you haven't got that, you need it, and it should look something like **Figure 2**.

Without something like **Figure 2**, you are not in the game. That's the very reason we at ChassisSim went to a great deal of trouble to develop and evolve the aero modelling toolbox. I also hammer this point home in the ChassisSim bootcamps, and the seminars I give, because it gets results. Simple as that.

Once you have this, you have the tools at your disposal to start addressing the problem.

Before we begin, though, there is a common misconception that, unless you have inerters / mass dampers and front and rear interconnected springs, you can't deal with this. I can tell you from personal experience that is nonsense, but the best way to dispel a myth is by example.

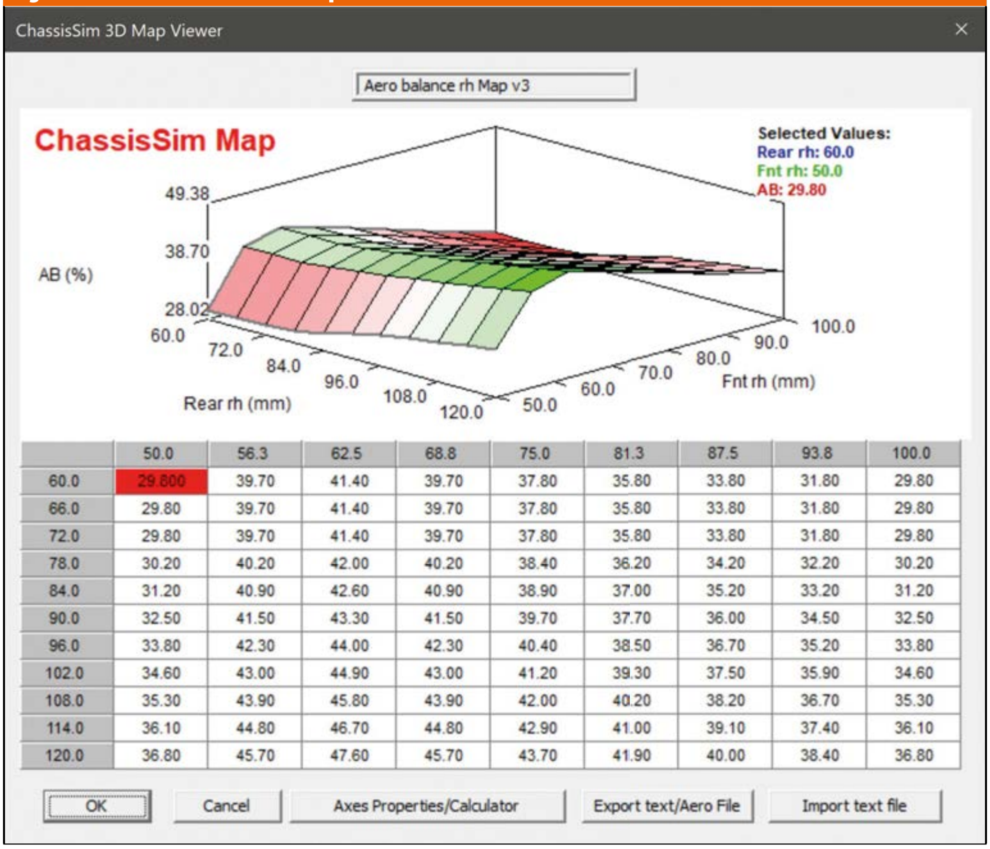
Lead by example

To illustrate this, I have recently been working on a hillclimb car called an Empire Wraith, as shown in **Figure 3**.

What made my job a lot easier in this instance is the aerodynamics of the car were done by Willem Toet. The car is a masterpiece of the art, with very well conditioned aerodynamics. That said, there were still issues in terms of the stability of the platform, which is where I was called. I should also add, in terms of suspension for this car you are dealing with a front monoshock and twin main springs. The accompanying damper package was nothing special, so it was just a matter of harmonising the components.

The first step in bringing this project together was the ChassisSim shaker rig toolbox. A typical output of which is shown in **Figure 4**.

Fig 2: A suitable aero balance map derived from race data



	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0
60.0	29.800	39.70	41.40	39.70	37.80	35.80	33.80	31.80	29.80
66.0	29.80	39.70	41.40	39.70	37.80	35.80	33.80	31.80	29.80
72.0	29.80	39.70	41.40	39.70	37.80	35.80	33.80	31.80	29.80
78.0	30.20	40.20	42.00	40.20	38.40	36.20	34.20	32.20	30.20
84.0	31.20	40.90	42.60	40.90	38.90	37.00	35.20	33.20	31.20
90.0	32.50	41.50	43.30	41.50	39.70	37.70	36.00	34.50	32.50
96.0	33.80	42.30	44.00	42.30	40.40	38.50	36.70	35.20	33.80
102.0	34.60	43.00	44.90	43.00	41.20	39.30	37.50	35.90	34.60
108.0	35.30	43.90	45.80	43.90	42.00	40.20	38.20	36.70	35.30
114.0	36.10	44.80	46.70	44.80	42.90	41.00	39.10	37.40	36.10
120.0	36.80	45.70	47.60	45.70	43.70	41.90	40.00	38.40	36.80

The mechanics of how to drive and use this I have covered many times before, so the quick 'elevator speech' version is the contact path load (CPL) variation is a direct measure of your mechanical grip. You are then watching the heave mode (the variation of vertical load of the chassis) and the cross pitch mode, which is the pitch response when you have a heave input. The telltale sign that you have a porpoising problem, or at the very least have pitching that needs to be controlled, is when the cross pitch mode is very high. This is exactly what we see with this car, illustrated by the black trace in **Figure 4**. Fortunately, for this car, the latter was the case.

Fig 3: The Empire Wraith hillclimb car

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While porpoising is certainly a problem that needs to be taken seriously, it can be dealt with, or at least mitigated, using off-the-shelf components

An additional challenge faced in this example was that, in addition to its high downforce levels (a CLA well north of three, in a very light car), the car was running on some exceptionally bumpy circuits, which meant you couldn't go to insane spring rates.

We therefore had to be very creative with the damping. Here, the ChassisSim dual rate damper model is your friend, and this is illustrated in **Figure 5**.

The important thing to understand here is the low speed section controls the sprung mass and the high speed filters out the bumps. With this car, we needed to pay very close attention to the bypasses, and the relations between the low speed and high speed damper rates. In particular, since we had to go to a softer spring rate, we needed damping ratios north of 0.7 in the low speed. Compromises like these are the dance you need to engage in and, while the dual rate damper model is far from perfect, it's a powerful tool to help you sort through the options.

And the tuning process you have to go through will be very enlightening. The spreadsheet of this is shown in **Figure 6**.

Since this is a live racecar, I have redacted the specific set-up information, but the take away is right down the bottom. Note the increase in the rear spring rate and the reduction in the CPL and cross pitch mode. This is what happens when you have a proper aero map (in this case generated from CFD) that has an effect on the shaker rig calculations. This should lay to rest one of the primary criticisms of shaker rigs – that you always soften the car. This was not the case here.

Of course, the ultimate proof is in the pudding so, if you want to see the result, the last 20 seconds of this YouTube video speaks volumes: youtu.be/DTWh9XyL1yU You will note how stable the platform is.

Summary

The point of this case study is to show how far down the road you can get toward addressing porpoising using straightforward suspension elements. To summarise, here's a quick porpoising cheat sheet:

- Know the car's resonant frequency, so you can stay away from it.
- Don't worry (within reason) about being aggressive with damping.
- Don't fall into the trap of no bump and plenty of rebound. That is the last thing you need if you are suffering porpoising effects.
- When the bump rubber engages, make sure it is continuous and smooth.
- Finally, a tool like the ChassisSim shaker rig toolbox is invaluable.

In conclusion, while porpoising is certainly a problem that needs to be taken seriously, it can be dealt with, or at least mitigated, using off-the-shelf components.

Fig 4: ChassisSim shaker rig toolbox

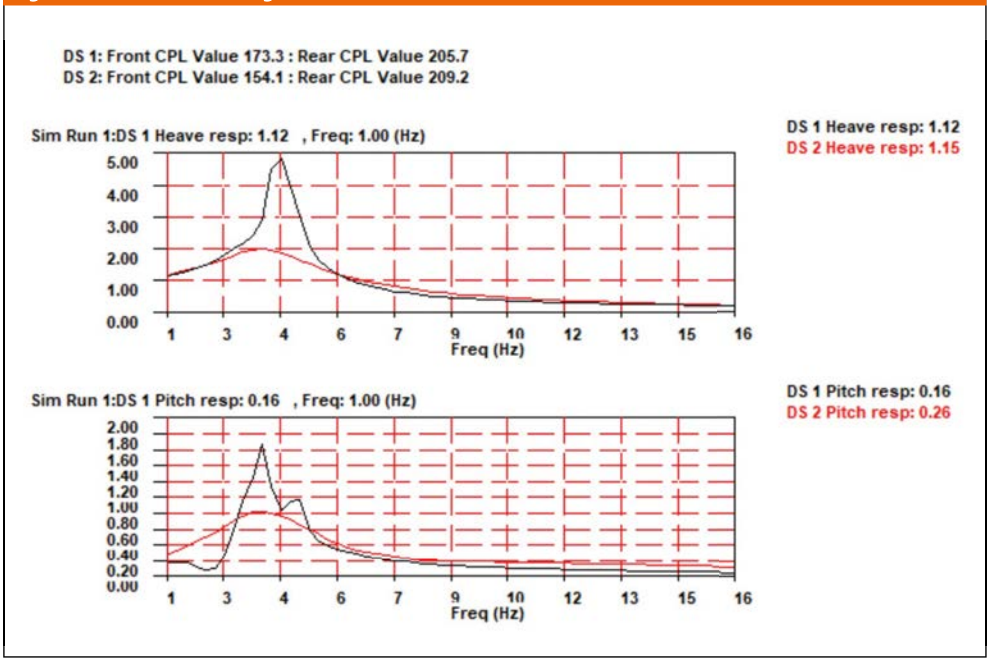
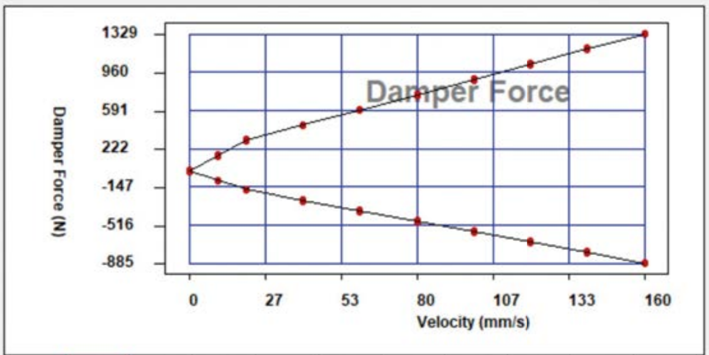


Fig 5: The ChassisSim dual rate damper model



vel	0	10	20	40	60	80	100	120	140	160
Bump	0	150	300	447	594	741	888	1035	1183	1329
Rebound	0	-88	-176	-278	-379	-480	-581	-683	-784	-885

Dual Rate Damper Spec
Units - SI - 0 - Imperial 1: 0
Use Dual Rate Damper Spec 1 - Yes, 0 - No: 1
Bump
LS Rate: 15000
HS Rate: 7350
Bypass: 20
Rebound
LS Rate: 8820
HS Rate: 5063
Bypass: 20

Fig 6: Tuning process for the dampers

	Setup	Heave Res freq	Heave Resp	Cross Pitch	CPL Fnt	CPL Rear	Comments
1	Setup	Heave Res freq	Heave Resp	Cross Pitch	CPL Fnt	CPL Rear	Comments
2							
3	Baseline	4	1.64	1.29	145.2	214.5	Problem is at the rear - Rear high speed oscillation
4	Rear LSR [redacted], HSR [redacted]	4	1.57	1.33	145.4	219	Made things worse
5	Rear LSR [redacted], HSR [redacted] bypass [redacted]	4	1.58	1.33	145.3	217.2	Slightly better but this is a dead end
6	Front Damp LSB [redacted], LSR [redacted]	4	1.64	1.23	146.5	216.3	Cross pitch mode definitely better but nothing spec
7	Front Damp LSB [redacted], HSB [redacted], LSR [redacted], HSR [redacted] bypass [redacted]	4.2	1.66	1.13	147.6	216.9	CPL is worse but the cross ptich is defintely much
8	Non linear front damper option 1	4.1	1.67	1.12	147.7	216.9	Cross pitch slighlty better but not a step forward
9	Front Damp LSB [redacted], HSB [redacted] LSR [redacted], HSR [redacted] bypass [redacted]mm - Bline - 100 lbf/in	4.1	1.57	1.16	147.7	217.2	Hell no - step backwards.
10	Front Damp LSB [redacted], HSB [redacted] LSR [redacted], HSR [redacted] bypass [redacted]mm - Bline - 50 lbf/in	4.1	1.66	1.1	147.6	216.6	This is a minor step forward - try on the LTS
11	Front Damp LSB [redacted] HSB [redacted] LSR [redacted] HSR [redacted] bypass [redacted]mm - Bline + 100 lbf/in	4.1	1.64	1.03	147.6	215.8	Cross Pitch is a big step and the rear CPL is comir
12	Front Damp LSB [redacted] HSB [redacted] LSR [redacted] HSR [redacted] bypass [redacted]mm - Bline + 200 lbf/in	4.1	1.63	0.96	147.6	214.9	Cross Pitch is another step, rear CPL - Try on the
13	Damp 1 - Ft spring [redacted]N/mm, Rear Spring [redacted]	4.2	1.64	1.12	147.6	216.3	Stick with what we have!
14							

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IndyCar delays hybrid introduction

The IndyCar series has taken the decision to delay the introduction of its hybrid powertrain until 2024 following supply chain issues. The series had planned to introduce the hybrid system in 2022, but that has been pushed back after Covid-related delays.

Following a discussion with teams and suppliers it has been agreed to retain the 2.2-litre, twin-turbo V6 engines for the 2023 season, while the 2.4-litre engines are developed for a further year through its suppliers, Honda and Chevrolet.

Some elements of the engine and hybrid system are unique to IndyCar and so, although the long lead time components are already in build, ready for testing later this year, the decision had to be taken early regarding the timing of the new engines.

'We are pleased with the pace of the technical development of the 2.4-litre, twin-turbocharged V6 hybrid as we prepare it for competition,' said IndyCar president, Jay Frye. 'We are very encouraged by the progress our team and our partners have made, but an immediate decision needed to be made to ensure we are prepared for the 2023 season utilising our current 2.2-litre engine package.'

The first on-track testing of the new engines took place at Sebring at the end of March, while development testing and work to incorporate the hybrid component will continue throughout the year.

The new engines and hybrid combination will produce around 900bhp, up from some 700bhp in the current regulations. Dallara's DW12 chassis will also be retained for a further season, which will help reduce the cost to the teams.

Russian sanctions in effect

The FIA has issued a ban on all Russian teams competing in its competitions following the invasion of Ukraine. Furthermore, it has banned all Russian drivers from racing under their homeland flag, insisting they race in a neutral capacity under the FIA flag instead.

At a special meeting of the World Motorsport Council, the FIA condemned the Russian invasion of Ukraine, and undertook measures to reduce the Russian influence on its board. Representatives of Russian and Belarusian FIA members were told to step aside from their roles and responsibilities, while the FIA also confirmed no grants would be awarded to those members.

Some of the results of these measures are the cancellation of the Russian Grand Prix, the Haas team splitting with its Uralkali sponsorship and terminating its contract with Nakita Mazapin and the G-Drive Racing team withdrawing from the WEC and European Le Mans Series.

There will also be no FIA-sanctioned events in either Russia or Belarus until further notice.

Nakita Mazapin will no longer race with the Haas team after a lacklustre 2021 season

SEEN: FERRARI 296 GT3

Ferrari has unveiled the first sketches of its new GT3 challenger, the 296 GT3. It will replace the 488 that has recorded 429 race wins from 770 starts and helped the Italian manufacturer to 107 titles around the world.

The car is the first the company has designed to the new GT3 regulations, which have provided manufacturers with the opportunity to make more changes to the base model car, compared to its predecessors.

The 296 GT3 will be built by French company, ORECA, in Signes, near the Paul Ricard circuit in southern France, and by regulation, more than 20 cars must be sold in the first two years of production. ORECA is therefore ramping up its production capability in order to achieve the target.

The design of the new car has, according to the press release, 'preserved the link to the production model, which from its very conception is inspired by cars such as the 1963 250LM', further confirming the freedom the racecar will have compared to the regular production model.

The 296 GT3 will be powered by a Ferrari-supplied, six-cylinder engine, and will not be fitted with a hybrid system.

It will start testing 'soon', according to ORECA's technical director, Remi Taffin, with a programme that starts in Europe and will then continue at race tracks around the world, including Sebring in the USA. The car is expected to make its race debut in both factory and customer hands at the Daytona 24 Hours in January 2023.

Peugeot Hypercar delayed

Peugeot has confirmed it will delay the introduction of its 9X8 Le Mans Hypercar until after this year's 24 Hours of Le Mans race.

The French manufacturer based its design and development programme around the 2022 / '23 winter season that was due to start in July 2022, but tried to bring forward its test programme to accommodate a return to a more traditional schedule.

The 9X8 was confirmed to miss the Sebring 12 Hours in March, but the team was hoping to have the car ready in time for the second round at Spa in May. From there, the FIA and ACO technical teams could balance the car against the Toyota, Glickenhaus and Alpine entries ahead of Le Mans.

It now looks likely the team will make its debut at the fourth round of the season at Monza in July.

'This will afford us the time we need to achieve the necessary level of reliability,' said Olivier Jansonnie, technical director of Peugeot Sport. 'For obvious reasons with regard to Balance of Performance adjustments, it would not have been possible to enter the Le Mans 24 Hours without contesting the preceding WEC race, the 6 Hours of Spa-Francorchamps on May 7. This way, our planning will enable us to put the full weight of our teams and resources behind our own test sessions, without the disruption of racing at Spa-Francorchamps and Le Mans.'

Multiple sources have suggested that reliability is not yet there for the car to compete and that the work needed to make the car race-worthy may be more extensive than first estimated. One rumour in the Sebring paddock was that the car has already been homologated and may need to use its 'joker' package.

Peugeot still maintains the rear wing-less 9X8 is ready to race, but concerns about reliability are keeping it off the grid at La Sarthe this year

IN BRIEF

The acquisition of **Williams Advanced Engineering** by Australian firm, **Fortescue**, has now been completed and, to mark the occasion, the organisation confirmed the world's first zero-emission 'Infinity Train'. The regenerating battery electric iron ore project will use gravitational energy to recharge its battery electric systems without any additional charging requirements.

The **FIA** has homologated a new advanced debris fence system developed by Swiss company, **Geobrugg**, for use at Grade 1 circuits. The new development allows the steel posts to be separated by six metres, instead of four, while still meeting the safety requirements of the FIA.

BWR Motorsports GmbH has developed a kit to measure dynamic mechanical analysis (DMA) at a race track. The portable testing kit, **MOTITE**, allows teams to measure tyre grip levels and rank the tyres on track. The software outputs an immediate grip level and enables measurements to be carried out directly on the tyre.

Audi's LMDh programme has been put on hold and likely cancelled, according to paddock rumour at Sebring.

Supplier, Multimatic, confirmed in January that it has delivered the first two chassis to Audi but, should the murmurings be confirmed, it means Audi's GT3 teams will not be able to race in the World Endurance Championship.

Le Mans Hypercars to race in US as tech agreement secured

The ACO, IMSA and the FIA have confirmed that the hurdles to control the four-wheel drive cars compared to LMDh have been overcome, and IMSA has therefore opened the door to LMH cars in its race series.

Previously, the American organisation had refused to confirm it would allow the cars to compete until it had seen track validation of the performance balancing between the two and four-wheel-drive cars. However, at Sebring, the organisers said final details have been agreed by all manufacturers and provided a timeframe for the LMH cars to compete in its season opener at the Daytona 24 Hours in January 2023.

Teams wishing to enter, including Toyota, Peugeot and especially Jim Glickenhaus' team, would have to notify IMSA by 1 September, and then take part in two sanctioned tests at Road Atlanta, the first in October and another in December after wind tunnel testing at the Windshear facility.

There have been a number of technical issues to resolve, not least the performance advantage the 4WD cars have in the braking and turn-in phases of corners.

'We have defined a limited amount the diff' can open, and so we have allowed to all competitors the cockpit-adjustable roll bars,' said the ACO's technical director, Thierry Bouvet. 'Convergence is mainly around four points. The first is that all cars will have the same performance window, the same evaluation and the same processes.

'The second is tyres. The LMH manufacturers have the choice of [31in wide tyres front and rear] or 29 / 34. From 2023 onwards, only for new homologation cars, they will have to run 29 / 34.

'Then we had the four-wheel-drive system and that was deeply looked into from a simulation standpoint. We had to de-couple the braking and acceleration phases and that showed it's always linked to the dimension of the tyre. So that's what we have been able to put in place.

'We feel we have a very good base, and all manufacturers involved are pleased with the rules that we have now.'

Interview – Danielle Shepherd

Mystery machine

There was something strange about the no.02 Chip Ganassi Racing Cadillac at the Sebring 12 Hours – it was comfortably fastest in all conditions. Race engineer, Danielle Shepherd, explains all

BY ANDREW COTTON

The second round of IMSA's WeatherTech Sportscar Championship was the 12 Hours of Sebring, held in March during Spring Break. College students from across the country come together to party and, in doing so, many of them head to mid-Florida to watch Sportscar racing at its finest.

One of the key features of the 12-hour race is the changing temperature, and one of the main points of interest is how the cars perform in the different conditions, when the heat of the day is replaced by much cooler air as the sun sets, until the race finishes in darkness.

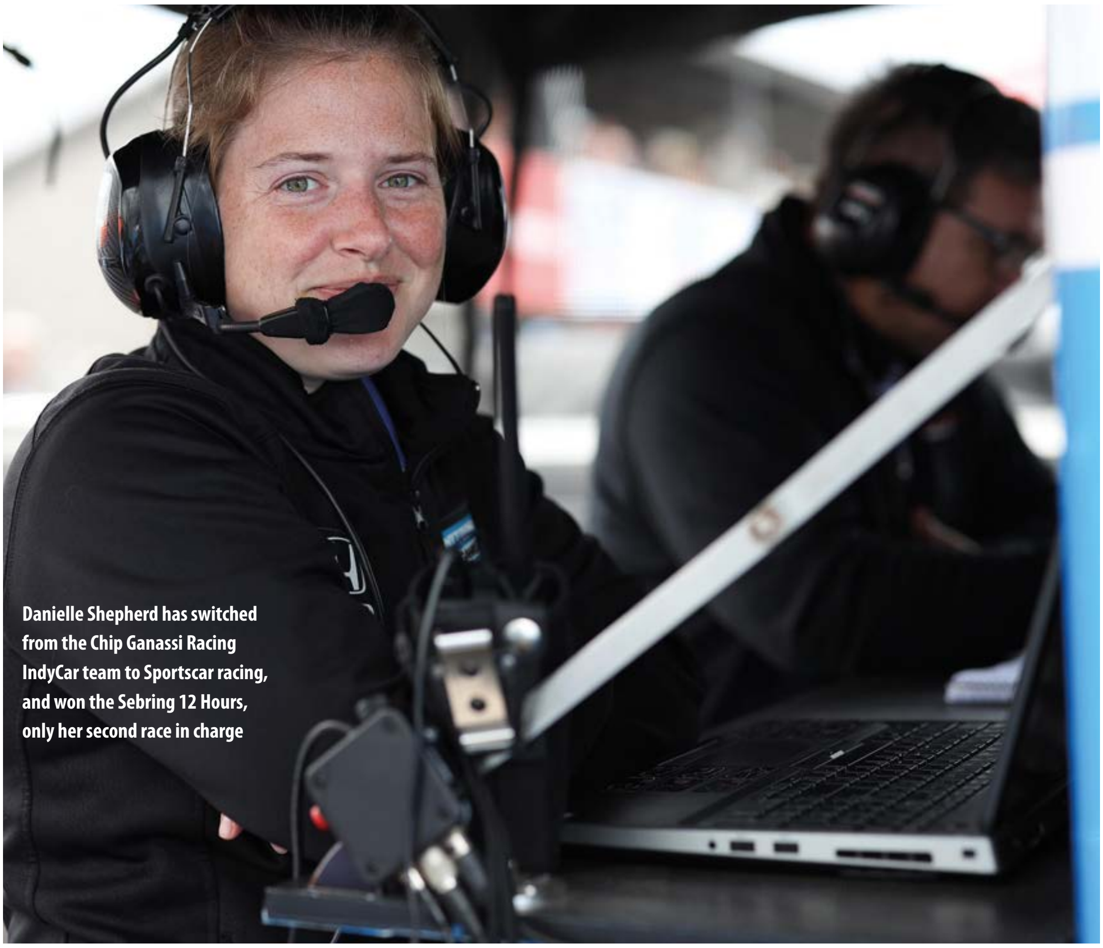
For the two manufacturers competing in the series, Cadillac and Acura, the strengths of the cars differ wildly. The Cadillac has an advantage over the bumps, with good ride control, and is able to use the kerbs better too for the same reason. By contrast, the Acuras are more sensitive to ride, and instead rely on aero to work.

Prior to the start of the race, the Acura teams were hoping the better mechanical grip of the Cadillac, that would help it in the heat of the day, would give way to aero dominance in the cooler night temperatures.

What happened, instead, was that the no.02 Cadillac, driven by Earl Bamber, Neel Jani and Alex Lynn, proved strong throughout the whole duration of the race.

The Chip Ganassi Racing Cadillac was simply untouchable in all conditions. Not only could it catch and pass other competitors, a feature of the race that no other car could easily do, but, in the cooler evening temperatures, Bamber in particular was able to extend his lead.

Actually, that is only partly true. Bamber was able to catch and pass the Cadillac of Richard Westbrook in the evening temperatures, but he then hit a

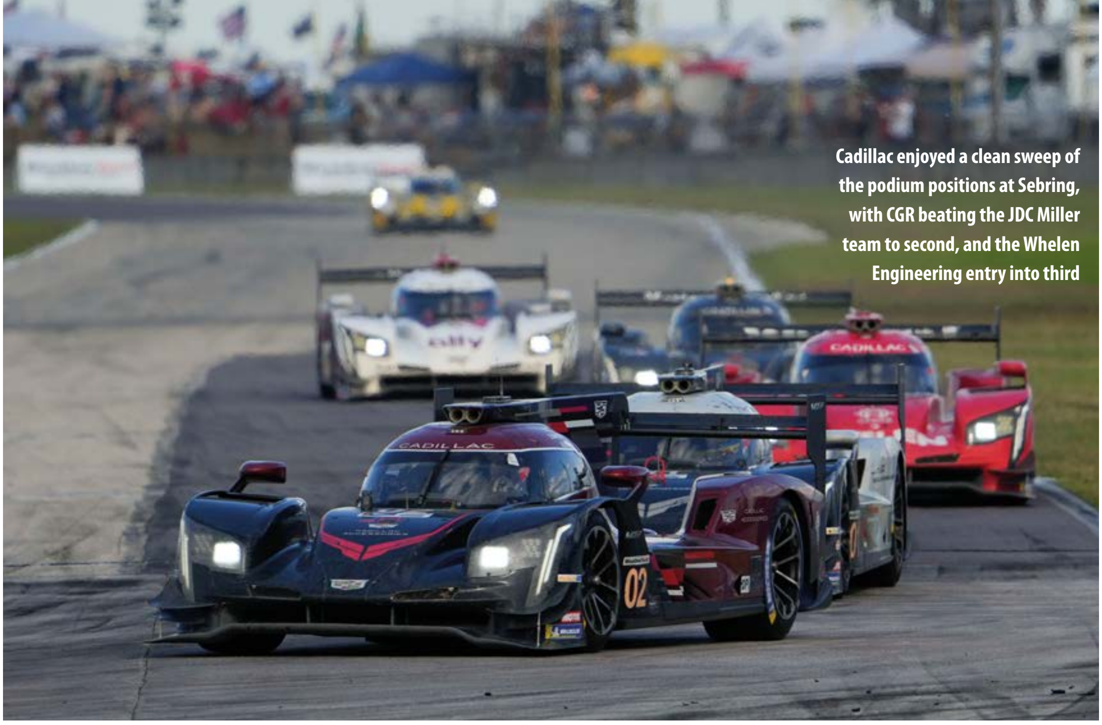


Danielle Shepherd has switched from the Chip Ganassi Racing IndyCar team to Sportscar racing, and won the Sebring 12 Hours, only her second race in charge

'If we could get into clear air we would be away, and so we did an aggressive stop to undercut'

Earl Bamber, driver 02 Chip Ganassi Racing Cadillac

Neel Jani, Alex Lynn and Earl Bamber celebrate their dominant performance with team owner, Chip Ganassi (right)



Cadillac enjoyed a clean sweep of the podium positions at Sebring, with CGR beating the JDC Miller team to second, and the Whelen Engineering entry into third

Pit strategy provided a crucial opportunity for the Cadillac to get ahead into clear air, where it was able to exert some authority

Ferrari and had to recover the lost time, and then pass again.

That he did so was testament to the superiority of the car in race conditions. The question on everyone's lips post-race, then, was what was that car's secret?

Restricted opportunitites

Set-up options have been deliberately limited by prescribed tyre pressures and cambers this year in order to protect the spec Michelin tyres used in the series, following a number of failures in high-speed races, notably the Daytona 24 Hours in 2021. Meanwhile, Balance of Performance and tightly controlled homologation periods have reduced the need to test or develop the cars.

The restrictions have reduced the opportunity to have a dominant car, so what was different at Sebring this year?

'I said to our race engineer that if we could get into clear air we would be away, and so we did an aggressive stop to undercut,' said Bamber. 'We saw an opportunity to do that and took it, and as soon as we had the lead we were away.'

Once ahead of the chasing pack, the car was increasingly fast over the final quarter of the race. The other teams knew it would take a major mechanical or driver error to stop the 02 car from winning. Neither happened, despite Bamber's self-confessed mistakes behind the wheel.

'The 01 car was also strong there last year, even though they were not able to capitalise due to a collision at the end of the race, so we had a strong baseline to start off with,' said Danielle Shepherd, race engineer for the 02 car, who only this year made the switch from the Chip Ganassi Racing (CGR) IndyCar team.

'While we were focusing on the night [in terms of setting the car up], we were trying not to compromise the daytime running, and it was just a balance.

'I was adjusting tyre pressures to try to keep in the range and the car balanced, so [the secret] was adjustments from my side and a solid baseline car that we started with to try to keep it in the window the whole way.'

The temperature gradient during this year's race was unusual, in that they climbed steadily from early morning to late afternoon, but then didn't drop far enough in the evening to help give the Acuras the chance to come into contention.

'It stayed pretty warm for the whole time,' notes Shepherd, 'but the track did cool off towards the end. We had tried to set ourselves up so we were ready to go [for the final sprint to the flag].

'The way Sebring is, we were trying to maintain our position during the day to capitalise at night. That was our philosophy because we are racing for the win when there are slightly cooler conditions.'

With the tyre pressures and camber settings so restricted, it is an engineering target to race as close to the limits as possible. Lower pressures and higher cambers are key to grip levels, but Shepherd was not willing to divulge any secrets on that front.

'The limitations are limitations and we have to respect them. They are enforcing them now, so we are trying our best to abide by the rules,' she says, before adding, 'but, given the opportunity, I would rather like more grip!'

Opportunity knocks

For Shepherd, the win is definitely a feather in her cap. Having worked her way through the ranks of Chip Ganassi Racing since 2016, first as a data engineer, and then as part of the engineering team working on Scott Dixon's title-winning IndyCar in 2018, and Alex Palou's Championship-winning entry in 2021, the result at Sebring at the helm of the race engineering team was a career milestone.

'It has always been my goal to be a lead engineer,' Shepherd commented, 'and so when the opportunity came, and I told them I was interested in doing it, they thought I was the right person for the job.'

Shepherd now hopes she can build on that and promote other women in engineeering.

'Chip Ganassi Racing is partnering with PNC to host positions for females in any range of motorsports, so it would be great to have some other women here that I can show the ropes, and help them to get interested in motorsport and interested in this internship.'

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News distribution
Seymour International Ltd, 2 East Poultry Avenue, London EC1A 9PT
Tel +44 (0) 20 7429 4000
Fax +44 (0) 20 7429 4001
Email info@seymour.co.uk

Printed by William Gibbons
Printed in England
ISSN No 0961-1096
USPS No 007-969

THE CHELSEA MAGAZINE COMPANY LTD
www.racecar-engineering.com

Paddock talk

There's good news, and there's bad news…

They always say the devil is in the detail, and there was a mixed bag of news in the Sebring paddock. There was a briefing on Wednesday night regarding the progression of the top Prototype category – named GTP in the US and Hypercar in the World Endurance Championship – that was extremely positive. Technical partners, Williams Advanced Engineering, Bosch and Xtrac, were complimentary about the push from the manufacturers and the organising bodies to make a success of the spec hybrid system in this early development phase.

For the first time ever, it seems manufacturers are willing to donate parts to other manufacturers in order to get the system prepared for distribution (read: Acura giving up some of the parts it needed to Porsche in order that the German manufacturer could complete a 2500km test of the system at Barcelona in March).

It was, as WAE put it, similar to the mood at the start of Formula E, when the manufacturers involved needed electric racing to be a success from the start.

Of course, once the gloves were off, the *entente cordiale* went out the window, as it should be in racing, and IMSA and the FIA / ACO made the point that they didn't expect this to last in LMDh either. However, right now, there is a clear common goal, including the minor details such as the sharing of test schedules that was universally welcomed.

Costs were far higher than expected due to a wide combination of factors

One key announcement was that the LMH cars will be eligible to compete in IMSA's series. Good news for Toyota, Ferrari, Glickenhaus and Peugeot. The fear that four-wheel-drive systems will be superior in some way have been allayed with a series of measures agreed by all, including reducing the impact of a front differential in order that all cars may have cockpit-adjustable roll bars, a feature that at Daytona in January was only for the LMDh cars.

Audi on ice

Among all the good news, however, there was confirmation that Audi has put on ice its plans to race in the top class. Having gone quiet over the past few months in the technical working groups, this was not a big surprise. Audi hinted that its decision was not to do with its Formula 1 ambitions, and that could easily be understood.

In the past, Audi and Porsche, both VAG companies, were allowed to race each other if they used different technologies. Porsche therfore ran a petrol-powered battery hybrid, while Audi raced a diesel, initially with a flywheel hybrid system.

Under cost-cutting measures, LMDh cars are significantly cheaper than the old LMP1s, but there still seemed little sense in the two manufacturers racing each other with exactly the same chassis, engine, suspension and hybrid system. The only difference would be bodywork styling, and even that would be negated by BoP. One potential knock-on effect is that manufacturers could only have their customers race in GT in the WEC if their cars raced in the top class, bad news for Audi's customers.

The Audi announcement certainly had a knock-on effect on Lamborghini, another VAG company with ambitions to race in the top class. The Italian manufacturer has stated often and loudly its intention to run an LMDh programme, and the assumption was that it would take the same chassis and engine developed by Porsche. However, they weren't planning to enter until 2024.

If the two Audi chassis are available, it could be that they take on the chassis originally destined for Audi. Or, they could pursue their own programme, and have been linked to Ligier.

Lamborghini CEO, Stephan Winkelman, was at Sebring, but was not in a position to confirm anything yet as nothing was set in stone. Sparkling water and double espresso were his (very welcome) contribution to this column instead.

Challenging times

A further fly in the ointment is the rapidly escalating costs of travel, coupled with an increasing scarcity of raw materials to develop parts. Toyota said it had not yet encountered a shortage of carbon fibre, but metallic parts were a challenge due in part to the war in Ukraine.

Even transport to Sebring was made more challenging as Russian carriers were not allowed to transport cars to the US. Costs were far higher than expected due to a wide combination of factors, and one supplier to the championship was particularly affected as it had not yet been able to ramp supply of its product back up post Covid, so had to air freight back to Europe at eye-watering prices.

These are uncertain times in racing, and in vehicle production. The decision by the manufacturers involved in the new LMDh rule set to work together and deliver a hybrid system, and LMDh cars, in time for the Daytona 24 Hours in January 2023 is probably more welcome now than ever before, but all a little trivial compared to the horrors we are witnessing in Ukraine. Motor racing is a selfish business.

ANDREW COTTON Editor


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