MUSTANG Ford Performance launches new GT3 car for global competition

UK £5.95 / US $14.50
August 2023 / Vol 33 No 8

Inside the world of modern motorsport technology

Racecar engineering™

Ferrari wins Le Mans

How the Prancing Horse conquered Toyota

- **Full race analysis**
  Team and driver performances examined in Hypercar, LMP2 and GTE
- **Hydrogen prototypes**
  New class to compete for overall victory at enduro classic

Red Bull powertrains

Behind the scenes as grand prix team gears up for 2026 change

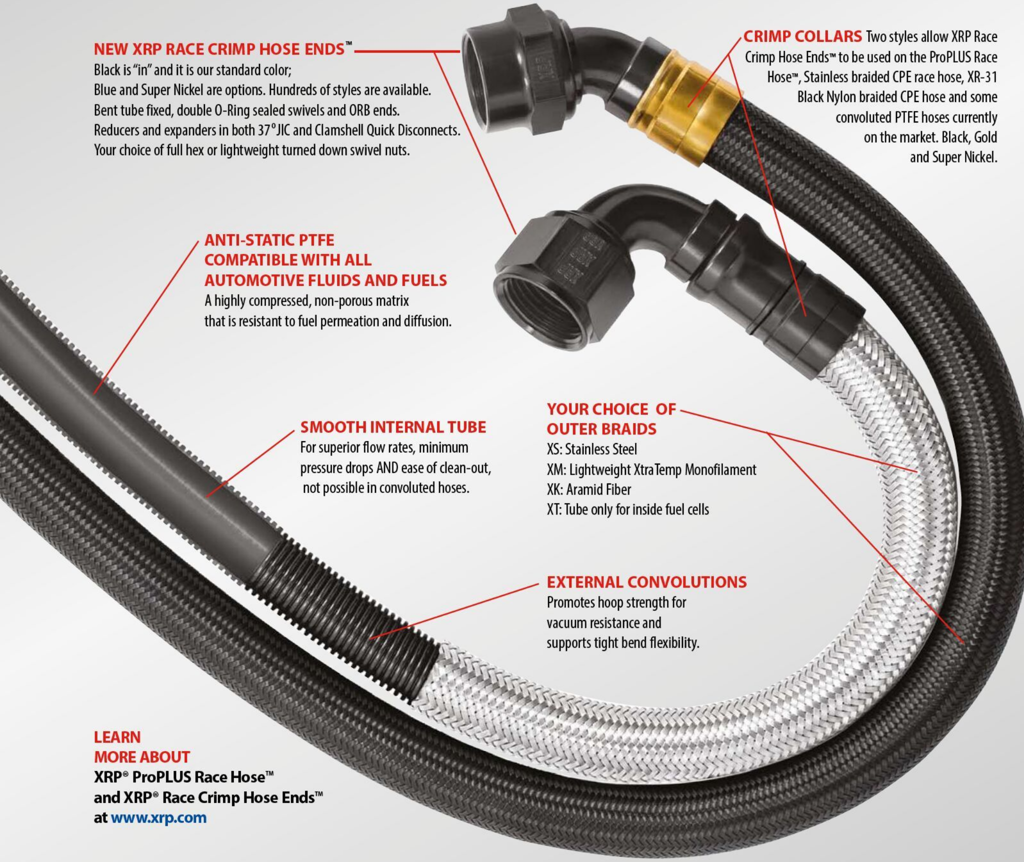
Hardware-in-the-loop

We investigate the latest advances in racecar simulation technology

THE EVOLUTION IN LIGHTWEIGHT FLUID HORSEPOWER™

XRP® ProPLUS Race Hose™ and XRP® Race Crimp Hose Ends™

A full PTFE smooth-bore hose, manufactured using a patented process that creates convolutions only on the outside of the tube wall, where they belong for increased flexibility, not on the inside where they can impede flow. This smooth-bore race hose and crimp-on hose end system is sized to compete directly with convoluted hose on both inside diameter and weight while allowing for a tighter bend radius and greater flow per size. Ten sizes from -4 PLUS through -20. Additional "PLUS" sizes allow for even larger inside hose diameters as an option.



NEW XRP RACE CRIMP HOSE ENDS™
Black is "in" and it is our standard color;
Blue and Super Nickel are options. Hundreds of styles are available.
Bent tube fixed, double O-Ring sealed swivels and ORB ends.
Reducers and expanders in both 37°JIC and Clamshell Quick Disconnects.
Your choice of full hex or lightweight turned down swivel nuts.

CRIMP COLLARS Two styles allow XRP Race Crimp Hose Ends™ to be used on the ProPLUS Race Hose™, Stainless braided CPE race hose, XR-31 Black Nylon braided CPE hose and some convoluted PTFE hoses currently on the market. Black, Gold and Super Nickel.

ANTI-STATIC PTFE COMPATIBLE WITH ALL AUTOMOTIVE FLUIDS AND FUELS
A highly compressed, non-porous matrix that is resistant to fuel permeation and diffusion.

SMOOTH INTERNAL TUBE
For superior flow rates, minimum pressure drops AND ease of clean-out, not possible in convoluted hoses.

YOUR CHOICE OF OUTER BRAIDS
XS: Stainless Steel
XM: Lightweight XtraTemp Monofilament
XK: Aramid Fiber
XT: Tube only for inside fuel cells

EXTERNAL CONVOLUTIONS
Promotes hoop strength for vacuum resistance and supports tight bend flexibility.

LEARN MORE ABOUT
XRP® ProPLUS Race Hose™ and XRP® Race Crimp Hose Ends™ at www.xrp.com

Like us on Facebook/XRPinc

Follow us on Instagram #XRPracing

XRP, Inc. 5630 Imperial Hwy.
South Gate, CA 90280
Tel: 562.861.4765
Email: sales@xrp.com

In Europe JLS Motorsport
fax: 44 (0) 121 535 4833
Tel: 44 (0) 121 525 5800
Email: motorsport@lister.co.uk

XRP®

THE XTREME IN RACECAR PLUMBING

Ford Performance

Ford Performance's 1400bhp, all-electric Supervan 4.2 will be piloted up Pikes Peak by Romain Dumas. The vehicle is designed to 'showcase the extreme limits of electric power' and to 'demonstrate the immense potential of electric vehicles in motorsport', says Ford

Electric sense

An old idea revived for the modern world

The FIA has launched a new technical rule set for production electric vehicles that will allow them to compete in a variety of racing activities. The body has defined safety criteria around the cars, with the intention that they may be driven to the event, compete, and then return, provided they haven't crashed, broken down, or run out of charge.

It is, says the FIA, the first time it has attempted to produce a set of regulations for production EVs, and the hope is that manufacturers will now develop extensive customer programmes in line with what has been achieved with GT3 and GT4.

Talking to the FIA's Bernard Niclot, a passionate advocate of hydrogen in competition, who says he has 10 manufacturers interested in competing to win at Le Mans using this fuel, he made the point that if we were not facing a climate crisis, and an exhaustible supply of fossil fuel, we would not be considering hydrogen. We probably would not be considering electric either, as it too has drawbacks.

Right now

However, says Niclot, we *are* facing both challenges right now, and we therefore *must* do something.

So, while the ACO pushes hydrogen for long-distance racing, and Formula E pushes single-seat competition in towns with electric vehicles, this is designed for the customer, and meets with the FIA's manifesto brief to focus on club motorsport.

'The primary target recipients for the FIA ESV [Electric Sport Vehicle] regulations are FIA member clubs, in order to grow safe and sustainable motorsport for the future,' reads the FIA press release.

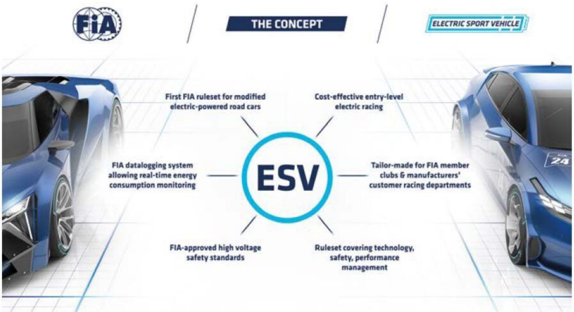
The rules broadly mirror the old Group N regulations, with minimal adaptations from the roadgoing production models. The electric class will be open to both Grand Touring cars and four-door, coupé-shaped sports sedans, with the maximum chassis height set at 1460mm.

The bodywork shape must remain broadly unchanged from the base model, with the exception of flared wheelarches for wider racing tyres and additional cooling ducts. Weight may be stripped from the car by replacing body panels with lightweight construction.

The class is destined for cars with a minimum production volume of 300 units over the first 24-month period from the homologation of the road car, says the FIA release. This will result in limited run, production specials not being eligible for the rule set. Minimum power will be 300kW, around 410bhp.

The good old ways

This is an attempt to bring electric racing to the masses and, by not creating a specific series for it, I think it's actually a good idea. A return to the 'old ways' is a good thing in many walks of racing, and the revival of Group N – essentially production cars that have been tickled up for competition – is certainly one of those.



The new rule set is designed to encourage FIA members to go racing, safely and sustainably, in production EVs

The FIA will use what it has learned in other high-voltage racing to make this as safe as it can be, though it's not without its challenges.

One of the big areas of concern is going to be marshalling these cars, and in the event of an accident. With hybrids starting to race in more series, the training for those keeping the fans and driver crews safe following an accident involving an EV should be keeping pace.

Using a production-based car on a hillclimb will certainly need some thought in that area.

Another will be charging facilities on event. I can't imagine that a location such as Shelsley Walsh, or Thruxton, or Pembrey in Wales, will have enough juice to power up a raft of competing vehicles. I might be wrong, but this seems to be quite a reach.

It also mirrors what's happening in real life, with ambition for electric far outstripping the facilities needed to make it work. But, as Niclot says, we have to start somewhere.

'The FIA ESV rule set very much responds to the demands of the market,' says FIA GT Commission president, Lutz Leif Linden. 'Having this set of technical regulations will allow the manufacturers' customer racing departments to offer competition-ready variants of their electric cars, which should be a considerable source of revenue to them, much like GT3 is.

'It can even open the door for them to create their own one-make series. The fact that the regulations are inclusive and accommodate four-door cars reflects the latest trends on the road car market. We already see several manufacturers having sporty, four-door grand coupés in their line ups.'

Performance will be balanced using the same Performance Factor method currently in force at hillclimb events. The system creates a value for each car based on figures representing weight, power unit and aerodynamic performance, along with transmission and chassis parameters that allow different cars to compete against each other in groups based on their relative performance levels.

This is a good start, a sensible regulation set that uses knowledge of successful past formulae and applies them to modern day racing and thinking. It now just remains to be seen how many will actually take up the option to buy and race electric cars, and how much it will cost, both in purchase price to the customer and for the events to install the necessary charging points and train up marshals. Ⓡ

This is an attempt to bring electric racing to the masses and, by not creating a specific series for it, I think it's actually a good idea

The show must go on

New safety car regulations and a last-minute change to the BoP altered the dynamics of the greatest 24-hour race of them all

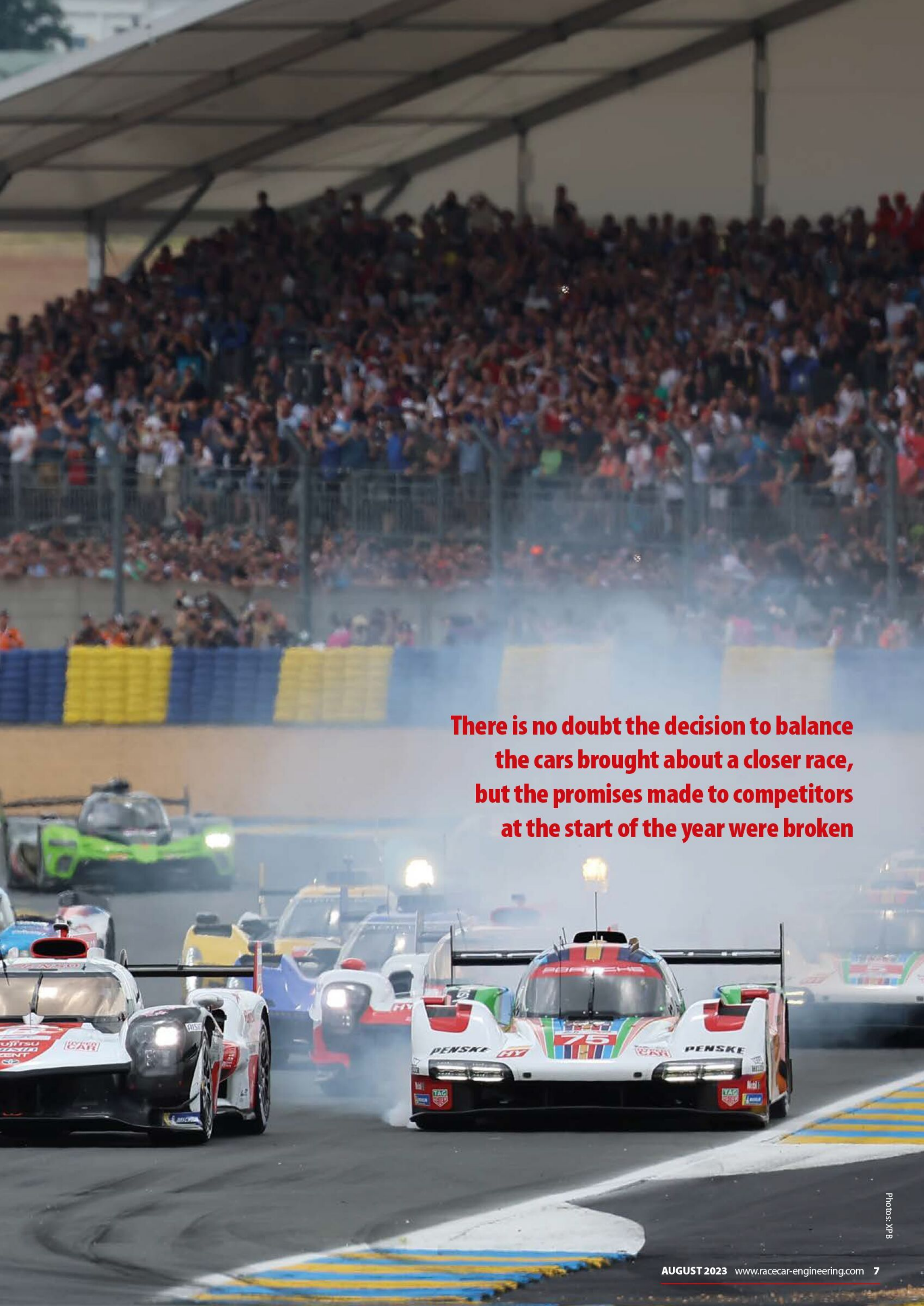
By ANDREW COTTON

Analysis by PAUL TRUSWELL

Ferrari overcame all the odds to take victory at the centenary of the first running of the 24-hours of Le Mans. James Calado, Alessandro Pier Guidi and Antonio Giovinazzi took a narrow win over Toyota, crossing the line just over a minute ahead of the chasing GR010.

It was a win that was unexpected, given Toyota's dominance of the first three races of the FIA World Endurance Championship, taking victory at each. The Japanese brand came to Le Mans on the back of five successive wins, and was perfectly prepared.

However, the team was hit with a Balance of Performance change, with 37kg added to the GR010, and 4MJ of power added per stint. In the end, that proved telling. Ferrari, which also had a BoP change that was less severe, ran close to the race performance of the Toyota, and hardly put a foot wrong all race.



There is no doubt the decision to balance the cars brought about a closer race, but the promises made to competitors at the start of the year were broken

Photos: XPB

A time loss due to a spin into the gravel on Saturday night was negated by a safety car event when Pier Guidi was on board, and two slow pit stops due to the Italian needing to re-set the power system to fire up the V6 engine delayed the car. However, the Ferrari team also benefited from a large slice of luck when the chasing Toyota, driven by Ryo Hirakawa, crashed while in pursuit during a phase of the race the Japanese manufacturer believed would be favourable to the GR010.

The Japanese driver had been given the instruction to drive flat out, but was caught out by a locking rear axle, an issue that co-driver, Brendon Hartley, had successfully managed during his previous stint. Hirakawa consequently hit the barriers front and rear, damaging the car at both ends.

It was the unfortunate Japanese driver who was also behind the wheel earlier on Sunday morning when he hit a squirrel, damaging the underside of the nose, and causing understeer. That, too, came at a time when the Toyota team believed its car to be faster than the Ferrari.

Triumphant return

Ifs and buts don't win races, though, and at the chequered flag it was Ferrari celebrating a triumphant return to top-level prototype racing after a 50-year hiatus from the race.

The 499P received everything it needed to compete against Toyota, including tyre warmers that helped it to make strategic options during the night and in transitional phases between wet and dry weather.

There's no doubt it benefited from that last minute Balance of Performance change that brought it closer to Toyota, but the car proved to be lighter on its tyres than expected, and was more reliable, too.

Battle of attrition

What was interesting about the battle for the podium, between Ferrari, Toyota and Cadillac, was that each of the manufacturers lost their fastest cars, through no fault of their own. The no.50 Ferrari lost time with a holed radiator that cools the ERS. The no.7 Toyota crashed out, Kamui Kobayashi decelerating for a slow zone when he was hit from behind by at least one car, puncturing both of his rear tyres and breaking a rear driveshaft.

The no.3 Cadillac was supposed to be the quickest of the three, certainly in qualifying, but, like Kobayashi, Sebastien Bourdais was also hit from behind entering a slow zone.

The race itself had a very different pattern compared to what has been seen before. The new safety car regulations meant that, when the weather was at its worst, manufacturers took the safest option, knowing that any time loss would be mitigated by the new regulations. These new regulations also brought other competitors into play, including the Hertz Team JOTA that started from the back of the grid, and by Saturday night was leading the race overall.

For Toyota's technical director Pascal Vasselon, this was an Americanisation of the race, and certainly in the early stages there was no pattern to the order. The Frenchman grew to embrace the regulation as it meant almost half an hour rest for those on the pit wall when the safety car was called, and then the merging of classes took yet more time.

There were just three safety car periods all race, totalling three hours and one minute. The second half of the race was controlled using more full course yellow procedures, five of them totalling 34 minutes. That left more than 20 hours of green flag running, with 136 laps slowed due to slow zones, compared to 58 laps run behind the safety car or under full course yellow. With such a high level of green flag running, it is hard to argue with the result.

Ferrari had the faster car at times, Toyota at others, the remaining competitors were not really in the game. They showed flashes of speed, but were not consistent enough to mount a genuine challenge.

Conservative approach

The new safety car regulations meant that many of the prototype teams took a conservative approach to the first half of the race. Before, under the old regulations, catching one of the three safety cars that govern the 13.6km circuit could mean the difference between winning and losing the race. Cars would therefore work to build as much of a gap as possible over those behind in the hope that they could catch a different safety car and extend their lead further.

What that meant was all cars fought hard to show speed from the start. European-style racing normally focusses on the first lap, while American-style racing focusses on the last

Some might say the late BoP change handed Ferrari the win, but the 499P proved equal to the Toyota on pace, and was less demanding of its tyres than expected

lap. This explains Toyota's view that the new regulations represent an Americanisation of the safety car rules, and certainly it played havoc with the running order, and pace of the cars, in the first half of the race.

This year the rules changed and, while the field was initially held behind the three safety cars, before the race went green they would be gathered behind one, and then each class would be grouped together before racing could begin again.

'You always have the safety car that puts you back, unless you are a lap down,' confirmed Calado after the race. 'It was more looking after the car, don't take risk. The number of times I could have made moves, but backed off, and I think that was good because it is a different approach than in GT.

'It takes a while to accept that you don't always want to make the move, we kept the car in good condition.'

Reduced pace

It meant that the cars ran to a conservative pace in the changeable conditions on Saturday and performance analysis didn't really come into it. Rain showers soaked parts of the track and led to accidents for many of the front runners in various classes. The reduced race pace allowed the Peugeots to perform better than anyone had expected, and they led the race on Saturday for three hours in the difficult conditions.

The lower hybrid activation speed meant the Peugeot 9X8 had four-wheel drive for more of the lap than its competitors, and the smaller rear wheels benefited the car in the wet conditions. Peugeot also made the right calls on tyres, but the leading Peugeot crashed, when Gustavo Menezes strayed onto the wet part of the track at the first chicane and hit the tyres on Saturday night.

The French cars then dropped back when the weather dried out and the pace picked up in the second half of the race, finishing the race suffering from power steering issues, while one car suffered an engine failure.

Peugeot certainly had a better showing at the race than expected, the 9X8 proving reliable for the first 21 hours, with the pace to stay with the front runners when the track was wet. It was a good reflection on the team, and the amount of work that has gone into the programme over the last year, but also showed how far the team still has to go if it wants to compete on an equal footing with Ferrari, Toyota and Cadillac.

After a multitude of technical failures in practice and qualifying, where both cars missed out on Hyperpole, the team was expecting trouble during the race.

'We didn't have the pace some of the others had, we knew that from the test day, but we tried to make some clever moves on the strategy, and it was a good start of the race,' said Peugeot's technical director, Olivier Jansonnie. 'The drivers were very focused but, when you take some risks, you have incidents. We tried to keep the drivers on slick tyres for longer in the wet conditions, which worked pretty well in the end. On occasion, though, it was too much.

'The surprise, initially, was the reliability of the car. It was relatively smooth until 21 hours into the race, and then we went into survival mode. I am proud of the team. They pushed to keep the car on the track, fixed it when we needed to, and even when we knew we couldn't do anything with the engine of the 94 car, we parked it, fixed it and then ran it for the last lap.

'With the 93 car we had bodywork failure, the front splitter, and then we had the issue with the power steering. 94 was mostly

Peugeot certainly had a better showing at the race than expected, the 9X8 proving reliable for the first 21 hours, with the pace to stay with the front runners when the track was wet

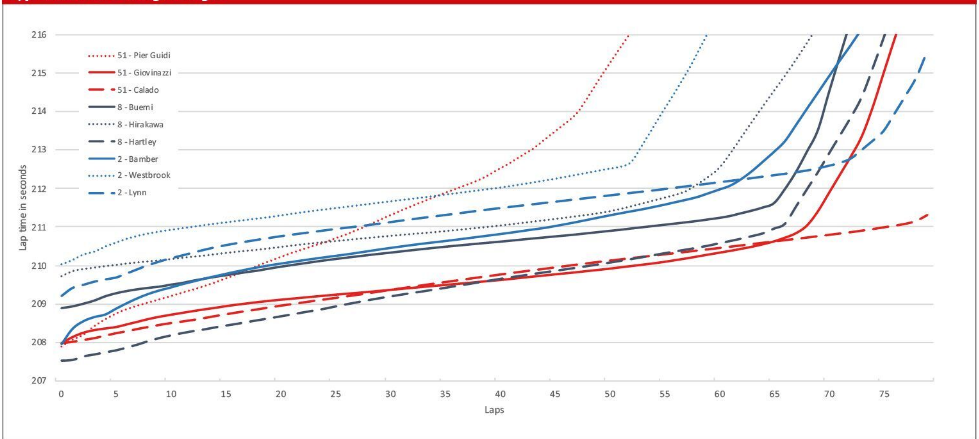
engine. We wanted to be careful. This track is not easy, when you have issues that involve safety, we didn't take risk as we were not fighting for position at the time.'

By the time Menezes crashed out of the lead, Toyota's challenge had dropped to a single car and the Japanese team was not even sure the car would make it through the night, having seen raised engine temperatures with no obvious reason why.

The team elected to change the nose of the car and that solved the problem - debris was found in the nose, which blocked cooling. The car started to pick up pace again, but so did the Ferrari. On soft tyres that were used by almost all the competitors during the night, the Ferrari had the ability to catch and pass the Toyota. However, power cycling issue in the pit stops handed the advantage back to Toyota in terms of track position.

That put the 499P on a recovery drive, taking the lead in the 16th hour of the race. By then, Ferrari also only had one bullet left in the gun, as the sister car of Antonio Fuoco, Miguel Molina and Nicklas Nielsen had their own debris-related issue. The stop cost them six laps and, with the pace of the front

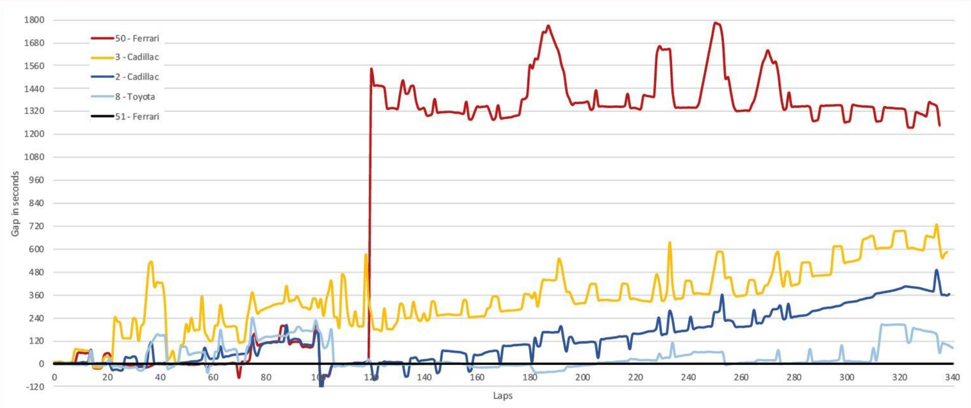
Hypercar drivers' rising averages



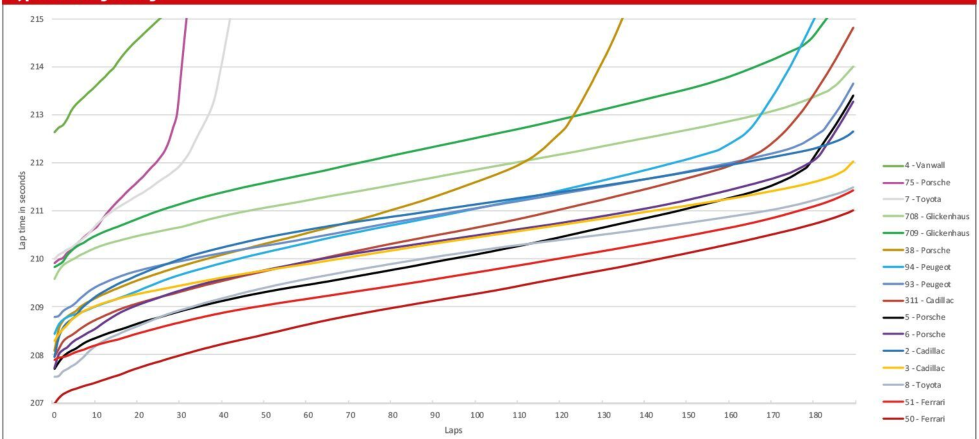
Hypercar performance

Pos in class	No.	Team	Car	Laps	Best lap	Per cent	Ave best 20 per cent of green laps	Per cent	No of pit stops	Total time in pit
1	51	Ferrari AF Corse	Ferrari 499P	342	3:27.890	0.44%	3:28.875	0.32%	30	47:58.893
2	8	Toyota Gazoo Racing	Toyota GR010 HYBRID	342	3:27.549	0.27%	3:29.184	0.47%	31	44:20.277
3	2	Cadillac Racing	Cadillac V-Series.R	341	3:27.967	0.47%	3:30.232	0.97%	29	46:25.833
4	3	Cadillac Racing	Cadillac V-Series.R	340	3:28.298	0.63%	3:29.602	0.67%	30	47:36.460
5	50	Ferrari AF Corse	Ferrari 499P	337	3:26.984	0.00%	3:28.212	0.00%	31	1:13:55.271
6	708	Glickenhaus Racing	Glickenhaus 007	335	3:29.577	1.25%	3:30.870	1.28%	30	53:43.480
7	709	Glickenhaus Racing	Glickenhaus 007	333	3:29.835	1.38%	3:31.350	1.51%	33	51:22.198
8	93	Peugeot TotalEnergies	Peugeot 9X8	330	3:28.796	0.88%	3:30.101	0.91%	31	1:14:15.622
9	5	Porsche Penske Motorsport	Porsche 963	328	3:27.712	0.35%	3:29.094	0.42%	30	1:07:52.308
10	311	Action Express Racing	Cadillac V-Series.R	324	3:27.963	0.47%	3:29.484	0.61%	29	1:58:29.775
11	6	Porsche Penske Motorsport	Porsche 963	320	3:27.739	0.36%	3:29.529	0.63%	28	1:59:21.637
12	94	Peugeot TotalEnergies	Peugeot 9X8	312	3:28.446	0.71%	3:29.831	0.78%	30	2:27:39.205
13	38	Hertz Team JOTA	Porsche 963	244	3:28.075	0.53%	3:29.789	0.76%	25	6:44:21.276
14	4	Floyd Vanwall Racing Team	Vanwall Vandervell 680	165	3:32.636	2.73%	3:34.426	2.98%	N/A	DNF
15	7	Toyota Gazoo Racing	Toyota GR010 HYBRID	103	3:29.993	1.45%	3:30.803	1.24%	N/A	DNF
16	75	Porsche Penske Motorsport	Porsche 963	84	3:29.916	1.42%	3:30.604	1.15%	N/A	DNF

Hypercar gap graph



Hypercar rising average



runners at the time, victory slipped from their grasp, despite being the quicker of the two Ferraris on track.

Pier Guidi was at the wheel when the 499P refused to fire with around five hours remaining, following a pit stop. The Italian ran through a power cycle that saw the car get moving again, and it ran well until the final pit stop, when the issue hit for a second time.

The same procedure, with the same driver, got the car going again, but its lead to the Toyota had reduced by more than a minute at that point as the Ferrari sat for 1m46s on pit road. Fortunately, the team had time to make the repair as Hirakawa had already crashed his GR010 in pursuit of the race leader.

Cadillac's V-Series Rs came closest to challenging Toyota and Ferrari, and secured a podium position, but the team had a troubled race

Risky business

Toyota had a relatively good run through the 24 hours, but didn't consistently have the outright pace of the Ferrari, so the drivers had to take more risks. That explains why the Toyotas looked more vulnerable than they have during the opening races of the season, while Ferrari's pace advantage gave the team the cushion it needed.

'We are missing 1m21s and the BoP effect was 2m30s,' said Toyota's Pascal Vasselon after the race, and following initial data analysis. Clearly angered by the Balance of Performance change (see sidebar on p18), he clearly felt it cost Toyota the victory on pace, yet the team had many other issues during the race, including Kobayashi's retirement.

'At that moment, we really thought we were going to lose the two cars,' admitted Vasselon. 'We had the engine temperature going sky high on car no.8 and no indication of what was happening. We couldn't see anything from the outside. The aero figures were good, but we decided to change the nose anyway, and found a big piece of Kevlar stuck inboard of the suspension blocking the flow of air to the cooler.'

Once that was sorted, it was clear the Ferrari had the pace in the darkness, but Toyota believed the track was coming back to them as temperatures started to rise.

'There were several windows when we were dominating Ferrari,' said Vasselon. 'There is a logic behind that and, just after one of these moments that we were competitive, Ryo hit a squirrel – and probably not a small one either – because it caused a lot of damage, and he was in trouble until we could change the front end of the car.'

Mixed fortune

The other competitive car in the field was the Cadillac. Three of the V-Series.Rs were entered, and they had a mixed bag of fortune. Brought closer to the front of the grid by the BoP changes, the team had also worked on tyre wear before the race and was cleared to go for four stints on a set of tyres if it wanted.

Michelin had imposed a mileage limit of 450km on a set of tyres at full pace in order for it to analyse the tyre and ensure its safety. Toyota, Cadillac and Porsche all did this mileage in practice, and were cleared to go, but Ferrari had not. While cleared from a construction point of view, Toyota had high wear on the front axle and so would have been slower to quadruple stint than to stick to triples.

For Cadillac, this was a string to its bow, but the race began to unravel for the American team even before the start. Sebastien Bourdais set third fastest time in qualifying, behind only the Ferraris, but lost his time for causing a red flag. A high-pressure fuel hose had broken, leading to a fire in the engine bay. That lost the team its race engine, so it had to revert to the test unit for the race.

British driver, Jack Aitken, then crashed his car on the first lap, breaking the front left corner and rendering it immediately out of the running for overall victory.

The third Cadillac had a clean run to the flag, driven by Earl Bamber, Alex Lynn and Richard Westbrook, but was delayed at every fuel stop during the second half of the race.

'Every fuel stop we had to add a lot of oil, so all the time we gained we lost,' said Lynn. 'We need to go back to the drawing board, as that made the difference between vying for the win and vying for the podium.'

Nevertheless, the car still looked to be competitive until the middle of the night when, according to competitors, the team opted to run the medium softs, while the others were all on Michelin's soft tyre. That tyre choice dropped them down the order, but the cars did not have the pace of the Toyota and Ferrari ahead once the pace picked up toward the end of the race.

An errant lump of Kevlar nearly put paid to the no.8 Toyota's race but, with a new nose fitted, the car came in second

Glickenhaus brought two cars to the end of the race, in sixth and seventh places, but not before both crashed on Sunday morning. Olivier Pla had a race to forget in the car he shared with Ryan Briscoe and Romain Dumas. The car started from the pit lane after a gearbox issue that cost it a lap even before the green flag was shown. Pla was then responsible for a crash with an LMP2 car that earned a five-minute stop and go penalty, and was also behind the wheel when the car crashed at Arnage.

The sister car, driven by Franck Mailleux, then crashed out at the same place an hour later. An aggressive throttle response was given by the team as a reason for the accidents, catching out two of the team's most experienced and careful drivers.

Disappointments

Vanwall also had a disappointing race. The team suffered a damper failure on the rear suspension, and then a clutch failure which, according to one engineer, 'made the engine do things it shouldn't do.' It was consequently retired in the 16th hour.

Porsche, meanwhile, had a dreadful race. One car finished ninth, in the hands of Kevin Estre, Andre Lotterer and Laurens Vanthoor, but the race was otherwise little short of a catastrophe for the German car maker.

A multitude of mechanical failures hit the three cars during practice and qualifying, and that form continued during the race. The team had conducted a massive development programme prior to the test day, including tests at Monza, Paul Ricard and Watkins Glen in the US, as well as seven-post rig testing and engine dyno testing. The result was a car that was better in every area, including braking, turn in, traction on acceleration and tyre wear.

The key difference, according to the drivers, was that the team went back to more traditional methods of car set-up, putting less reliance on computer simulation work. However, one driver commented that the sim' correlation was not good enough, and that issues faced on track could not be replicated in the virtual world.

The issue seems to have stemmed from the ride control. At Sebring testing in January, the car couldn't brake as late as the others, or turn in as well, and didn't have the acceleration. The ride was so bad in fact that the car's ride height had to be raised to compensate. Subsequent rig testing allowed the team to control the ride better, which meant they could drop the ride height back down and improve downforce, which helped in every area of cornering.

Software updates were also introduced to the cars, including the privateer version run by Hertz Team JOTA, but these had the unwanted side effect wiping their favourite settings. It was, said Porsche, like updating your phone, and then losing your data.

It was not an ideal situation, but the 963 did show flashes of speed, notably in the first half of the race. It led some of the early stages but, by the time the race picked up speed, not only could the 963s not match it, the drivers were forced to over-drive in order to try.

Porsche had a dreadful race. One car finished ninth… but the race was otherwise little short of a catastrophe for the German car maker

One of the weak points of the team, according to some of the drivers, is its decision making. Having multiple decision makers in the pit is not producing the clear forward vision needed to take the team to a more successful place.

Porsche's fortunes started well during the race. Having failed to set a time in qualifying, the JOTA 963 started from the back of the grid, as per WEC regulations, but ACO supplementary regulations stated that the car should start from the back of the Hypercar field. In the end, it didn't much matter as, following Aitken's crash on the opening lap, under the new safety car regulations the car moved back up to the Hypercar field before the field went green anyway.

From there, the team played a strong game strategically, and so Yefi Ye found himself leading the race overall at one point. Unfortunately, the Chinese driver then crashed in the Porsche Curves, damaging

LMP2 performance

Pos in class	No.	Team	Sub class	Laps	Best lap	Per cent	Ave best 20 per cent of green laps	Per cent	No of pit stops	Total time in pit
1	34	Inter Europol Competition		328	3:36.739	0.32%	3:38.373	0.41%	34	50:23.313
2	41	Team WRT		328	3:36.146	0.05%	3:37.902	0.19%	31	43:59.868
3	30	Duqueine Team		327	3:36.607	0.26%	3:38.659	0.54%	34	47:30.513
4	36	Alpine Elf Team		327	3:37.406	0.63%	3:38.477	0.46%	33	45:05.519
5	31	Team WRT		327	3:36.043	0.00%	3:37.486	0.00%	32	52:59.074
6	48	IDEC Sport		327	3:36.204	0.07%	3:38.012	0.24%	32	43:49.604
7	10	Vector Sport		325	3:37.719	0.78%	3:40.145	1.22%	31	51:43.956
8	23	United Autosports		323	3:37.200	0.54%	3:38.517	0.47%	33	01:04:54.107
9	35	Alpine Elf Team		322	3:38.063	0.93%	3:40.675	1.47%	32	01:00:15.719
10	45	Algarve Pro Racing	P/A	322	3:38.010	0.91%	3:41.069	1.65%	31	54:41.300
11	22	United Autosports		321	3:36.715	0.31%	3:38.080	0.27%	34	01:22:07.430
12	37	COOL Racing	P/A	317	3:37.073	0.48%	3:39.003	0.70%	34	01:16:19.408
13	28	JOTA		316	3:37.300	0.58%	3:39.032	0.71%	29	01:22:49.883
14	65	Panis Racing		316	3:37.525	0.69%	3:38.978	0.69%	30	01:24:35.591
15	43	DKR Engineering	P/A	311	3:37.795	0.81%	3:39.730	1.03%	33	02:09:12.874
16	9	Prema Racing		310	3:37.815	0.82%	3:38.974	0.68%	31	02:01:40.871
17	39	Graff Racing	P/A	303	3:37.312	0.59%	3:38.743	0.58%	30	02:34:11.656
18	80	AF Corse	P/A	183	3:39.807	1.74%	3:40.898	1.57%	N/A	DNF
19	47	COOL Racing		158	3:37.338	0.60%	3:40.200	1.25%	N/A	DNF
20	32	Inter Europol Competition	P/A	117	3:39.388	1.55%	3:42.586	2.34%	N/A	DNF
21	63	Prema Racing		113	3:39.270	1.49%	3:40.160	1.23%	N/A	DNF
22	923	Racing Team Turkey	P/A	87	3:37.594	0.72%	3:41.330	1.77%	N/A	DNF
23	13	Tower Motorsports	P/A	19	3:39.086	1.41%	3:39.298	0.83%	N/A	DNF
24	14	Nielsen Racing	P/A	18	3:44.189	3.77%	3:44.416	3.19%	N/A	DNF

The surprise victory in LMP2 by InterEuropol Competition is, at time of writing, still subject to final approval by the FIA / ACO

the left side of the car and losing the lead through a long pit stop.

The car was then further delayed by needing to change the accident recorder located beneath the seat in the cockpit, while another crash by Antonio Felix da Costa meant it crossed the line as the last of the classified finishers, 13th in class and 98 laps down on the race-winning car.

At least it made it to the flag though. The Porsche driven by Nick Tandy, Mathieu Jaminet and Felipe Nasr stopped on Saturday night following a fuel pressure issue and was the only one of the 963s entered to fail to make it to the end of the race.

The no.5 car of Fred Makowiecki, Michael Christensen and Dane Cameron spent 20 minutes in the pits fixing the cooling system before limping around the final lap so painfully slowly that it received a four-lap, post-race penalty for exceeding the six-minute limit for the last tour.

The third factory car, of Andre Lotterer, Kevin Estre and Laurens Vanthoor, crashed several times, with repairs taking more than 40 minutes in total. The car lost further time when it needed a hybrid battery replaced, finally finishing 22 laps behind the winners.

LMP2

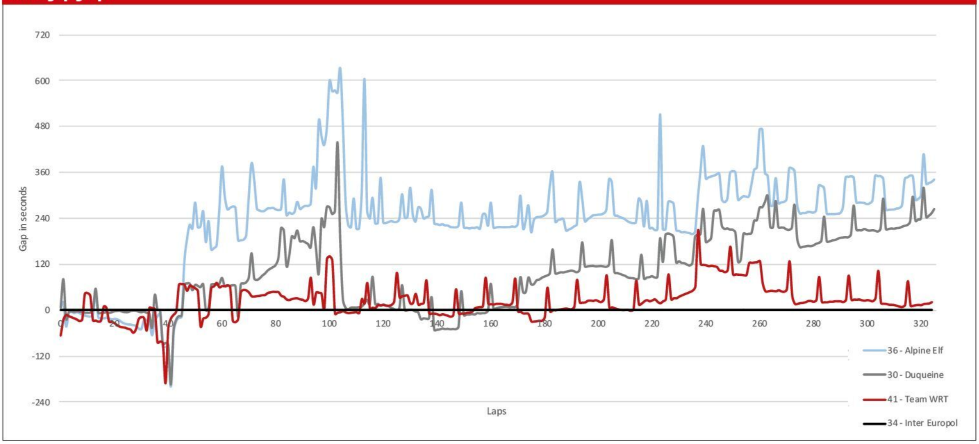
The most unlikely of wins at this year's Le Mans fell to the InterEuropol team in LMP2. The small Polish team hadn't won a single WEC race before, had a driver who broke his foot in the first hour of the race after being run over by a Corvette, and certainly did not have the fastest car in the category.

Against the likes of IDEC, WRT and United, the team didn't even qualify in the top 10, but some good fortune in the rain showers on Saturday saw it move into the lead in the seventh hour, benefiting from slow zones on Sunday to extend its lead.

The team even had time to take a penalty later in the race, 12 hours after driver, Fabio Scherer, had committed an infringement behind the safety car. Scherer had taken to pit road behind the safety car and accelerated before the pit lane speed limit came into effect, overtaking two cars. However, as he was in pit road, which follows a different profile to the circuit, and not on the track, he was a bit baffled as to why he picked up the penalty at all.

'At the beginning of the year I knew we had some chance,' said Scherer after the race.

LMP2 gap graph



'It made me laugh that in the press we were the underdogs from Poland. We are the underdogs but, at the end, if you have the right people, and you know what to do, you can destroy the big ones.

'We got into the lead early. I knew that if you are in the lead, don't do too much to try to keep there, it is important with the slow zones. Without the drive through, it would not have been the hardest six to seven hours.' The results of the race remain provisional while extra checks are carried out on the car by Cosworth, which supplies the spec' ECU.

The LMP2 class was more of a traditional race, with mechanical and driver errors taking priority. United lost one car after a driver tried an ambitious move on the Mulsanne Straight, its other car suffered a brake failure.

WRT had a suspension failure on one car, the other hit a guardrail in the wet on its way to second place. In terms of outright performance, WRT's no.31 car had the fastest average 20 per cent of green flag laps, but also spent nearly 53 minutes in the pit lane, compared to the winning car's 50m23s.

The Le Mans-winning Corvette C8.R is equipped with a full Alcon brake system, the elements of which have been carefully designed and selected to ensure optimal performance, as well as the serviceability and robustness required at the highest level of GT racing, says the manufacturer.

The PBA800 sliding pedal box has enjoyed success in many GTE, GT3 and GT4 platforms, thanks to its compact, lightweight and robust design featuring 180mm of adjustment, highly wear resistant and low friction, lubrication-free bearings plus low cut-off, ABS compatible, lightweight forged master cylinders.

Calipers are of topology optimised, high-grade billet aluminium monobloc construction for stiffness, with a semi-open bridge to enable quick pad changes during a race where minimal time spent in the pit is strategically vital. Electroless nickel plating, plus castellated titanium pistons help keep brake fluid temperature under control.

Brake discs are formulated of Alcon's proprietary metallurgical composition to ensure high conductivity, whilst maintaining the strength required to cope with the extreme thermal cycling associated with lapping one of the world's most demanding race circuits. Also incorporating patented vane geometry to maximise cooling efficiency, as well as minimising unsprung mass and inertia, this technology is known for being able to complete a 24-hour race.

GTE-Am

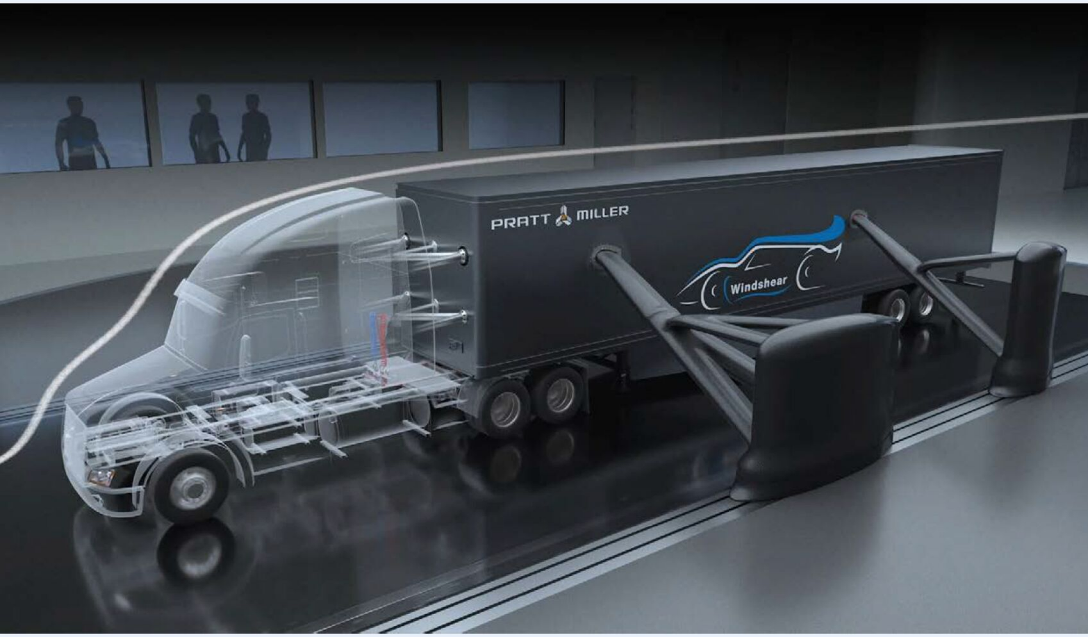
Corvette Racing raced to an unlikely victory too, having lost two laps on Saturday while in the pits for a damper change. It took some determined driving through until Sunday before it was back on the lead lap, the team not worrying about a late brake change and consequently saving a pit stop towards the end of the race, which gave it the lead.

This was the last year of the GTE cars at Le Mans, bringing to an end a golden era of GT racing. It was perhaps fitting then that Corvette, one of the stalwarts of

Corvette bowed out in style, winning the last year of GTE competition at Le Mans with pace and good strategy

GTE-Am performance

Pos in class	No.	Team	Car	Laps	Best lap	Per cent	Ave best 20 per cent of green laps	Per cent	No of pit stops	Total time in pit
1	33	Corvette Racing	Chevrolet Corvette C8.R	313	3:50.439	0.00%	3:52.102	0.24%	24	43:16.554
2	25	ORT by TF	Aston Martin Vantage AMR	312	3:51.530	0.47%	3:53.385	0.80%	25	40:45.634
3	86	GR Racing	Porsche 911 RSR - 19	312	3:50.771	0.14%	3:52.008	0.20%	25	51:06.089
4	85	Iron Dames	Porsche 911 RSR - 19	312	3:53.573	1.36%	3:54.759	1.39%	22	35:28.554
5	54	AF Corse	Ferrari 488 GTE Evo	312	3:52.124	0.73%	3:53.666	0.92%	24	37:35.760
6	98	Northwest AMR	Aston Martin Vantage AMR	310	3:51.992	0.67%	3:54.381	1.23%	23	56:14.316
7	56	Project 1 - AO	Porsche 911 RSR - 19	309	3:51.446	0.44%	3:52.781	0.53%	25	48:30.029
8	100	Walkenhorst Motorsport	Ferrari 488 GTE Evo	307	3:54.519	1.77%	3:55.735	1.81%	23	36:32.641
9	74	Kessel Racing	Ferrari 488 GTE Evo	303	3:53.240	1.22%	3:55.316	1.63%	25	41:40.630
10	57	Kessel Racing	Ferrari 488 GTE Evo	254	3:52.468	0.88%	3:54.468	1.26%	N/A	DNF
11	911	Proton Competition	Porsche 911 RSR - 19	246	3:53.056	1.14%	3:54.452	1.26%	N/A	DNF
12	88	Proton Competition	Porsche 911 RSR - 19	170	3:51.811	0.60%	3:52.627	0.47%	N/A	DNF
13	777	D'Station Racing	Aston Martin Vantage AMR	163	3:54.651	1.83%	3:55.714	1.80%	N/A	DNF
14	77	Dempsey – Proton Racing	Porsche 911 RSR - 19	118	3:55.060	2.01%	3:56.875	2.30%	N/A	DNF
15	66	JMW Motorsport	Ferrari 488 GTE Evo	89	3:53.086	1.15%	3:55.905	1.88%	N/A	DNF
16	72	TF Sport	Aston Martin Vantage AMR	58	3:55.043	2.00%	3:55.396	1.66%	N/A	DNF
17	83	Richard Mille AF Corse	Ferrari 488 GTE Evo	33	3:52.485	0.89%	3:52.852	0.57%	N/A	DNF
18	60	Iron Lynx	Porsche 911 RSR - 19	28	3:51.385	0.41%	3:51.543	0.00%	N/A	DNF
19	16	Proton Competition	Porsche 911 RSR - 19	28	3:58.707	3.59%	3:59.095	3.26%	N/A	DNF
20	55	GMB Motorsport	Aston Martin Vantage AMR	21	3:56.189	2.50%	3:56.375	2.09%	N/A	DNF
21	21	AF Corse	Ferrari 488 GTE Evo	21	3:54.797	1.89%	3:54.947	1.47%	N/A	DNF



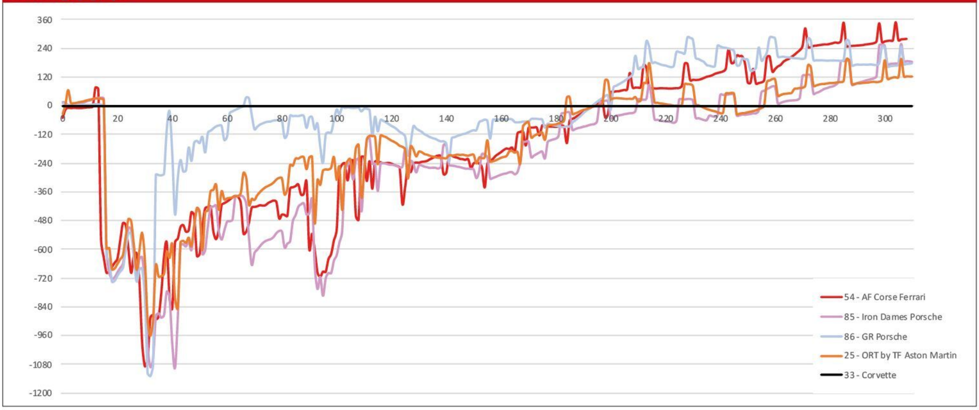
Take cutting-edge wind tunnel technology. Add a 180 mph rolling road. And build in the best in precision data acquisition capabilities. When we created the world's first and finest commercially available full-scale testing environment of its kind, we did much more than create a new wind tunnel. We created a new standard in aerodynamics.

Windshear

704-788-9463   INFO@WINDSHEARINC.COM   WINDSHEARINC.COM

WSI-28

GTE-Am gap graph



the category for so many years, racked up the programme's ninth win at Le Mans.

Porsche teams didn't fare so well. Proton Competition had a series of cars written off during the race and didn't bring a single car to the finish. Ferrari lost several cars in accidents, too. Of the 22 starters in the class, only nine made it to the chequered flag.

Aston Martin finished second with the ORT by TF Vantage, after the Iron Dames' Porsche needed a brake change toward the end of the race. GR Racing finished third, salvaging at least a podium for Porsche.

Garage 56

The plan was to race a NASCAR at Le Mans and, while from the outside it appears the team did exactly that, the development work that went into the Chevrolet Camaro ZL1 Gen 7 car removes it completely from its home environment. The car was a lightweight version of its base car, ran different aero, brakes, tyres, all but the gearbox. That only had minor modification to allow for a paddle shift system to be used.

One thing that could not be denied, however, was its location on the circuit. Pure NASCAR noise, amplified by the trees that surround the 13.6km circuit, reverberated for many of the 24 hours. The car qualified ahead of the GTE field, and was allowed to stay in its grid position rather than be moved to the back as planned. Its performance throughout the race justified its place on the grid, and the car proved a hit with the fans and the media.

After spending an hour in the pit having a gearbox changed, it completed the race and came in 39th overall. R

The Chevy Camaro NASCAR thundered around the circuit for almost the full 24 hours, a credit to the programme

Racecar says

The late change to the Balance of Performance was not a surprise, and did give a better race than had been expected, but at a price.

At the start of the season, the BoP was released and it covered races including Sebring, Portimão, Spa and Le Mans (Sebring actually had slightly different BoP numbers due to the nature of the circuit, but the balance of the cars was the same).

The organisers promised their figures were right, and said they would not change before Le Mans, unless it was a platform change that would bring the LMDh cars up to the level of LMH.

What actually happened was that prior to the Le Mans test day, the organisers went into both of the categories, LMH and LMDh, and made changes. It did what it said it would not do, and started to balance the second-order parameters, such as tyre wear and overall team performance.

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

Toyota, the most heavily penalised of the manufacturers, was outspoken in its criticism of the last-minute change, most notably in the timing of it, but also because the FIA had previously promised not to balance second-order parameters.

There is no doubt the decision to balance the cars brought about a closer race, but the promises made to competitors at the start of the year were broken. From that point, it is going to be hard for the FIA and the ACO to regain the trust of the competitors and manufacturers in whatever system comes in the future.


TotalEn
PLASTIC OMNIUM
TotalEnergies
Dietsmann
Maintaining Energy

Hydro-matic

The ACO is introducing a hydrogen class for Le Mans in 2026, and the cars will be racing for overall victory against the current Hypercars. Racecar *talks to Bernard Niclot, the man behind the regulations, to find out how*

By ANDREW COTTON

That the Automobile Club de l'Ouest is to introduce hydrogen to its Le Mans grid in 2026 is not a surprise. A technical director of the FIA, Bernard Niclot, has been working on the regulations since 2017, the ACO has involved itself heavily in the development of a hydrogen fuel cell prototype and the regulations are ready to be written. The surprise is that the new cars will be going for outright victory at Le Mans from 2026.

The plan is to finalise the regulations by December 2023, to allow manufacturers time to start looking into the technology, and understand what it has to offer.

Ten manufacturers are sitting around the table to thrash out the rules. While no one was willing to reveal the identity of the ten, they do pan the globe from Asia to the US via Europe. Some have already announced their intention to compete at Le Mans with hydrogen-powered cars, notably Toyota,

The ACO-backed MissionH24 hydrogen-powered racecar on track at Le Mans during this year's centenary parade while others have shown an interest in developing the technology. These are include Alpine, Kia and perhaps Ford.

And there is definitely development to be done. Toyota is already ahead, having a proven, race-ready car in its Corolla that is currently competing in the Super Taikyu series in Japan, and which in May became the first racecar to compete with liquid hydrogen.

Having a car that is developed for racing at prototype level, though, is another matter entirely, but this is the challenge the ACO has set for itself, and its partner manufacturers.

To become involved, the manufacturers need a carrot on the end of the stick, and the ACO has delivered one by saying hydrogen cars will be eligible for the overall win at Le Mans. That will require not only a major upgrade in facilities at the circuit, but also a downgrading of the current Hypercars, notably in the pit stops.

Current Hypercars can complete a fuel and tyre stop in around 90s, but refuelling a hydrogen car is going to be almost double that length of time. Under the regulations, that will have to be ratified by the FIA World Motorsport Council, storage will be limited to a standard gas tank, pressurised to 700bar, and the increase in temperature filling that tank is just one of the hurdles attached to the switch to hydrogen.

Technology drive

There will need to be a major change of the regulations in order to balance all the cars, and for this Niclot has turned back the clock. He was part of the technical working group that formulated the Equivalence of Technology (EoT), a set of regulations that took the best potential of any technology and compared it to another.

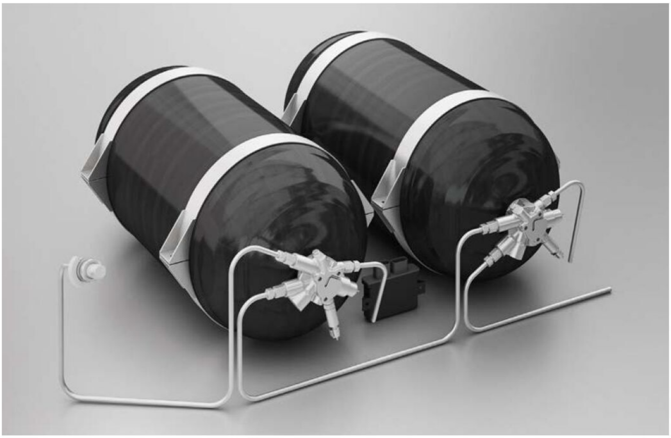
Out of this rule set came the awesome LMP1 cars from Porsche, with their turbocharged petrol engines and a combination of MGU-K and MGU-H storing energy in a battery; Toyota brought out a normally aspirated engine and a super capacitor storage system, while Audi campaigned a turbocharged diesel that stored kinetic energy in a flywheel.

It was an extraordinary rule set, one that was designed by engineers rather than accountants, and that showed in the final cost of the cars. This new direction has the potential to do the same, as hydrogen technology is still relatively new.

However, says Niclot, you have to start somewhere: 'If you have no climate change problem and no limit on petrol, nobody would go to hydrogen,' he says. 'Now, petrol one day will stop and, perhaps before that, we will have a massive climate change that we cannot accept, so we have to do something.

'It is clear this transition to green mobility will take investment, but humans must make an effort to do this now. The reward is zero emission technology, and this is what we need.

'When you compare today's hydrogen technology to gasoline it is heavier, but if you ask one of the current cars to do a lap without emitting CO_2, they will just stay on the starting line. The hydrogen [car] will do the lap. It is a sort of joke, but you have complexity and drawbacks in the technology, but you also have some advantages, which is the zero-emission characteristic. If we want to go zero emission, we have to pay this price.'



Developed by Plastic Omnium for the aerospace industry originally, Hydropack hydrogen storage tanks are certified to 700bar

The way forward

With the number of manufacturers sat around the table, it seems the ACO has hit on a way forward for the regulations. It started by just looking at fuel cell technology, but has now opened up the regulations to allow internal combustion engines to run on hydrogen. The commitment to both technologies is pretty evenly split among the manufacturers, according to Niclot, with roughly 50 per cent committing to fuel cell, the other half to ICE.

For the storage tanks, the ACO is less adventurous. 'For the storage system we wanted to have common tanks, common technology, and this will be done by Plastic Omnium,' says Niclot. 'The rationale behind this is that we wanted to define and develop a refuelling system, and that will be done by TotalEnergies. When you refill with hydrogen, it is not a standard liquid, it is a gas, so you have a thermo-dynamic problem. You have to understand the internal state of the tank in order to follow the target curve for refuelling.

Pierre Fillon, president of the ACO, behind the wheel of the GreenGT and ACO-developed MissionH24 hydrogen-powered prototype racer

Toyota competed in the Super Taikyu series in Japan with a Corolla using liquid hydrogen storage. The ACO considers this technology not mature enough at this stage for racing at Le Mans, given that liquid hydrogen needs to be stored below -250degC

‘You have complexity and drawbacks in the technology, but you have also some big advantages, which is the zero-emission characteristic’

Bernard Niclot, Technical director at the FIA

The protocol of which is closely linked to the temperature and pressure inside the tank.

‘For this, we thought we could not develop such optimised refuelling protocols for different types of tanks. It is mainly a question of efficiency, but also one of cost, time, development and safety.’ The door is open to widening the scope for storage tanks in the future, Niclot says the technology to have liquid storiage is still too immature to be considered for racing. Even though Toyota did just that, the working committee feels it is not ready for top-level racing such as will be seen at Le Mans, notably due to the temperature at which the liquid must be stored.

‘You have to really separate the storage and the way you use hydrogen,’ continues Niclot. ‘[In the case of the Toyota Corolla] the storage is liquid, but the use of hydrogen in the engine is gas, so you could do the same type of gas storage.

‘Today we consider that the liquid is promising, it has some advantages, but it does not have the maturity of gas storage. In racing, we need to rely on existing and reliable technology.’

Fuel management

To that end, however, there is a discrepancy. Burning hydrogen in an ICE is not so easy as it isn’t as flammable as petrol, and therefore needs even more careful management within the cylinders.

‘In general, you have two technologies for injection – port and direct,’ says Niclot. ‘As I understand it, direct injection is more promising in terms of efficiency and management of the combustion process. Many people have started to develop engines with port injection, but then you cannot achieve the same level of efficiency that you can with direct injection.

‘The choice of which to go with won’t be defined by regulation. We want in the ACO to be quite agnostic, to lay out different technologies, but we are at the beginning of a complete revolution and new history, and it is always difficult to know which technology will prove to be the best. We want to allow all the possibilities.’

One of the main hurdles the ACO is facing is that it does not have its own test facilities, so has to rely on the manufacturers to do the research for it, and then work with the numbers it is given. It seems to be a cost-saving measure that could potentially backfire, and Niclot is well aware that the manufacturers might not be completely accurate with their predictions.

That’s the issue with ICE, but there is fuel cell technology available, too. While it seems logical to go with an ICE, due to the reduced

Florent Gooden / DPPI

TotalEnergies is the partner for the FIA WEC providing sustainable fuel, and will invest heavily in a safe, efficient hydrogen refuelling system for the new prototype class when it arrives in 2026

cooling requirements, known technology and road relevance (in terms of being able to convert an existing engine), there is a lot to be said for fuel cells, too.

Fuel storage

Fuel cells combine hydrogen and oxygen to produce electricity that then drives an electric motor. For the purposes of racing at Le Mans, hydrogen will be stored in the same tanks as used for the ICE.

'Both technologies are more or less the same in terms of storage, perhaps a slight advantage for the fuel cell because they can go to lower pressures,' says Niclot. 'Then perhaps they can better use the hydrogen on board, but this can be compensated by a pressure regulator.

'The fuel cell is probably heavier for the same power as ICEs for racing, but the level of technology in the H24 car is more or less the level you have in [contemporary] road cars. These are basic fuel cells, because no one has developed a fuel cell for racing yet. It is like comparing the engine of a standard road car with a Formula 1 engine. They are completely different.

'I made some evaluations with a fuel cell engineer with different materials, and we quite easily achieved 100kg less weight, on paper. One of the problems with the fuel cell is that efficiency decreases with power, so the more you try to get power from the fuel cell, the less efficiency you get, but so far no one has developed a membrane for racing.

'For road cars the goal is to limit the quantity of expensive material used, so the platinum you need in the fuel cell, but in racing you don't have this problem.

'I imagine you could focus the development for racing. When you add all of this together, and on the periphery the compressor and accessories needed to make the fuel cell work, there is a lot of progress that can be done.

'There are drawbacks and advantages to the fuel cell. It is a recent technology, less mature than ICE, and it is heavy, but the learning curve is more important than for ICEs. If one fuel cell manufacturer says they want to see the limit, they could make a lot of progress, so it is not easy to compare the technologies because they are not at the same level of development.

'For me, the *raison d'être* of the Le Mans programme is to make the progress come quicker. If you apply this to the fuel cell, perhaps you can push the limit.'

Sticking point

Refuelling is going to be the big sticking point for these regulations. The Hypercars currently lap Le Mans at around 3m30s at race pace, and the hydrogen cars can match this. But for them to be equivalent, the pit stops will have to be longer for all cars. This, says Niclot, is entirely possible from a technology point of view, but one has to ask, what would a two- or three-minute pit stop do for the 'show' of Le Mans?

'We have to find a way to compensate one way or another,' says Niclot. 'What you have to consider is that on a road car, whether you refill with gasoline or hydrogen, there is no real difference. If you take the recharging of a battery electric car, the difference compared to gasoline is already huge.

'For many years, for many reasons, we have used devices to reduce refuelling time [in racing], but these systems are not relevant to road cars. They have been developed for sport, for fun, but they are not linked to what you can have on road cars. What you can have for hydrogen cars will be close to what you can have on road cars, so for me it is not a problem to align the racecars.

'There are drawbacks and advantages to the fuel cell. It is a recent technology, less mature than ICE, and it is heavy, but the learning curve is more important than for ICEs'

Bernard Niclot

Which brings us back to the thermodynamic problem mentioned earlier.

'With a [hydrogen] gas tank, the temperature you start with is around -40degC and [you finish refuelling] at +80degC. You start at a tank between 20-50bar, and go to 700bar, so you massively compress the hydrogen in the tank. Which obviously increases the temperature.'

Controlling that temperature in the tank is in itself not a big issue, until you consider the practicality of a racing stint, particularly one over 24 hours, with very different day and night temperatures.

Control strategy

'For safety, you have to control it,' says Niclot of the temperature of the tank itself, and the gas in it. 'What we have realised with MissionH24 [the ACO's hydrogen Prototype] is you have a sort of battle between pressure and temperature. If you have some long

Toyota GR H2

Toyota is known to be one of the manufacturers sat around the table trying to push forward hydrogen regulations, and at Le Mans unveiled its Prototype, the GR H2.

Toyota has been competing in the Super Taikyu series since 2021 using a hydrogen-powered Corolla and, 'honing its technologies in the harsh environment of motorsports and, with like-minded partners in and outside the automotive industry, accelerating its efforts for producing, transporting and using hydrogen toward the realisation of a carbon-neutral society.'

Unveiled by Toyota chairman, Akio Toyoda, the ICE-powered car was on display in the ACO's Hydrogen Village at this year's event.

'We look forward to our new GR H2 racecar in view of the new Le Mans H2 class in the future,' said Toyoda.

Toyota chairman, Akio Toyoda, is enthusiastic about hydogen as a means of propulsion, both for its new racecar and in road cars of the future

Noriaki Mitsuhashi/N-RAK Photo Agency

Polar Technology Management Group Ltd and Moog Controls collaborate on Hydrogen Storage Solutions

Polar Technology has developed a novel concept in hydrogen storage and is working with Moog Controls to develop an integrated hydrogen storage and management solution termed "Hydrogen in a Box". The system benefits are based around optimal packaging efficiency, gravimetric efficiency and the ability to integrate valves and control systems into one optimised solution.

A six-month long technology evaluation process has been completed and test hardware will now be manufactured. The design has been evaluated as Type 3 and Type 4 version for both 350Bar and 700Bar applications.

Kieran Burley, Lead Engineer at Polar Technology said "This is a very exciting time to be working on hydrogen storage solutions, there are so many opportunities for innovation, optimization and integration. Combining novel design solutions along with innovative manufacturing processes we can package hydrogen storage efficiently in a series of co-dependent chambers forming a storage bank, rather than fitting a number of standard independent cylinders into the space."

Mark Lawton, Moog's General Manager of the Aircraft Control Components division stated, "It has been great for Moog to collaborate with Polar in providing novel methods to efficiently store and release hydrogen in mission critical environments. This project is an integral part of Moog's commitment to develop future green technology for commercial air travel."

The joint project will establish an appropriate specification and set of system level requirements for hydrogen storage and delivery systems for aircraft and other Industrial applications.

A sustainable and healthier future

yellow safety zones, then you are slow for quite a long time, and the temperature in the tank has a tendency to increase because you don't have a high flow rate. The ambient temperature then becomes important.

'If you continue to decrease the pressure, there is a risk you achieve your stint with low pressure, which means not so much hydrogen on board, but with a high temperature in the tank, so you don't start refuelling at -40degC, but at maybe -30degC, or zero, or even +20degC. Then you can only put less hydrogen in. So, you have to manage it so that when the tank is empty you are around -40degC.

'On the other side, if you have a very quick race where you consume a lot of hydrogen, then the risk is you decrease the temperature in the tank too quickly, and so you achieve the -40degC lower acceptable limit when the tank is not yet empty, and then you have to stop.

'It is clear that management of temperature and pressure must be consistent during the whole stint, and this becomes an element of competition. This could provide a performance reward.'

This careful management of hydrogen temperature and pressure is a relevant technology for road cars, too. Electronics would play a major part in this performance element and, as the Hypercar regulations are effectively already a software war, this fits nicely with what is currently on track.

Ligier JS2 RH2

One of the least likely offerings launched at Le Mans was the Ligier JS2 RH2. Developed with Bosch as a GT car, the team was hoping it would be accepted into the top class for the Le Mans 24 hours.

The car features a full carbon monocoque with three hydrogen tanks, each housed outside the monocoque, encased in individual protective sheaths.

The engine, says the team, has been on the test bench for 18 months, and with hydrogen as a fuel it has the same power and driveability as a petrol car, with only a small change to the ignition system.

'Just inside, using Bosch facilities, we can cool to -40degC, and we can expect [a refuelling time of] below five minutes,' says Pierre Humbert, project manager at Bosch. 'In cold conditions, maybe two minutes, in hotter conditions, maybe four minutes, or higher. When you put hydrogen in the tank, you are contemplating your temperature rise and you cannot go above a certain level.'

For Bosch, investigating hydrogen is a key technology. 'As an engineering service provider, we are open to technology and see it as our task to explore the various technical options on the path to climate-neutral mobility in parallel, and to devise the best solution in each case for all the requirements of our worldwide customers,' says Dr Johannes-Jörg Rüger, president of Bosch Engineering GmbH.

'In this context, hydrogen propulsion has great potential, especially for use in motorsports and high-performance roadgoing sports cars.'

With Bosch as development partner, the new Ligier is the first hydrogen-powered GT car

Say no to NO_x

The other issue with low CO_2 emissions, particularly around petrol and diesel, is the high NO_x emissions. The two are inextricably linked until, that is, you start to look at hydrogen technology.

'With fuel cells you have no NO_x,' notes Niclot. 'With hydrogen ICE you reject water. Now, it is true that depends on the level of mixture. If you have a lean mixture, you will not have the same level of NO_x. The beauty with hydrogen, though, is that you can have combustion with very lean mixtures, thanks to the speed of flame of the hydrogen. You can work at lambda 2.5-3. If you work in this range, you have almost no NO_x, because you are working at a low combustion temperature.

'If you work with richer mixtures, then you do have NO_x and you have to treat them with catalytic converters. This is a point we have to discuss with the manufacturers. We want to be zero emission, and need to discuss how we achieve this, either with the characteristics of the mixture, or the use of catalytic converters.'

Another obvious issue is crash testing. Running any racecar with high pressure gas tanks onboard is not for the faint of heart, so the FIA and the ACO have to come together to produce a set of regulations that will be safe, above all else. That means rigorous testing, and that will probably lead to the cars carrying more weight. This, in turn, could have a knock-on effect for the Equivalence of Technology tables.

Niclot's argument on this front is an interesting one. Many are looking at the current Hypercar regulations and noting that with only three spaces on the podium, and eight manufacturers competing, there will be some who won't achieve their objectives and will leave. Or they will achieve their objectives, and then leave. That then puts the emphasis back onto the privateers on which racing has always relied.

Round table

But for Niclot, having 10 manufacturers around a table wanting to come to Le Mans with a new technology and compete for an overall win, their might would be enough to sway the regulators.

It would come at the expense of the privateers initially, and that cannot be said lightly. Nor can its effect be underestimated.

'We want to have a classification for the hydrogen category, but we want to have those cars able to win against gasoline Hypercars. We think they can achieve this provided they have enough performance, so 3m30s, which is the current level,' says Niclot.

> **'It is clear that management of temperature and pressure must be consistent during the whole stint, and this becomes an element of competition. This could provide a performance reward'**
>
> *Bernard Niclot*

'We will therefore have an EoT between hydrogen and gasoline cars. It is the same idea.

'At the end, this category will arrive in 2026 / '27, near the end of the Hypercar golden age, so the transition will be quite smooth. If we had started in 2024 [there was a two-year delay due to Covid], we would have had more problems because we will have new Hypercars and it would have been difficult to tell them they must compete against hydrogen cars. The delay will make the transition easier, so I am quite confident.'

The ACO has long pushed for hydrogen cars to race at Le Mans, and will soon have its chance to do so.

Dark horse rising

Ford released the latest version of its Mustang, the GT3, at Le Mans and expects to race it there next year

By ANDREW COTTON

Ford has returned to GT racing for the first time since the remarkable Ford GT that raced in the WEC and IMSA from 2016 to 2019. This time, however, it has brought a completely different beast, based on the perennially popular Mustang, which has been built to the new GT3 regulations.

The 5.4-litre Coyote engine is prepared at M-Sport, the rest of the car by Multimatic, and there is a global race programme in place already, with Multimatic running the factory team in IMSA, and Proton Competition announced at Le Mans as a partner for the World Endurance Championship.

The new car was unveiled at Le Mans, a clear indication from Ford Performance that it wants to race it at the world-famous event, although it is likely to be only Proton Competition that will enter the great race. Multimatic is not signed up for the WEC programme, and with spaces on the grid at Le Mans likely to be limited, the likelihood of the US team gaining entries to Le Mans are slim.

Customer support

There is a huge customer support network that Multimatic will provide, with the car eligible to race around the world as a GT3. By regulation, Ford needs to sell 20 cars into competition within first two years of production to meet homologation requirements. That should not be difficult to achieve, with the car also eligible in SRO-sanctioned events in Europe and Asia, ACO-sanctioned events on both continents too, and in national series, including the VLN and the ADAC GT Masters in Germany.

The car has yet to complete its homologation, with testing still ongoing, both on track and in the wind tunnel, and there are plenty of hurdles yet to overcome.

Larry Holt, owner of Multimatic, sat down with *Racecar* and ran through the list of dramas that have already been experienced by the team during the homologation process, and the car itself.

One of the big areas of the homologation process is the aerodynamics of the car, and

The 5.4-litre Coyote engine is prepared at M-Sport, the rest of the car by Multimatic, and there is a global race programme in place already

The car's dramatic but deliberately benign aerodynamic package was developed in scale at Silverstone, UK, and then in both Windshear, North Carolina and the Sauber wind tunnel in Switzerland

Photos: Wes Duenkel

‘What we have here is the solution to all the mistakes we made in the past… This car is in the window’

Larry Holt, chief technical officer and founder of Multimatic

Aftermarket suppliers have been chosen carefully to reflect the quality of the product Ford is selling. The brake package, for example, comes from UK-based Alcon Components Ltd, a company Multimatic’s Larry Holt refers to as industry leading

to this end the Mustang GT3 has to be tested in both the Windshear wind tunnel in North Carolina for IMSA homologation, and the FIA’s preferred tunnel at Sauber in Switzerland. Here, the sheer size of the car has thrown an unexpected curve ball that has baffled Holt.

Putting such a large car in a closed tunnel has resulted in upwash from the body being interfered with at ceiling level, which then skews the figures. The different sizes of the two tunnels has also meant the development team received different figures from each, and therefore the car is prepared differently for European racing compared to US racing.

Pressure point

It is not, says Holt, anything to do with the downforce levels, it is the centre of pressure [COP] that has moved and led to a re-design of the front splitter for the European tracks.

‘The centre of pressure has moved back 3-3.5 per cent,’ says the Canadian. ‘I don’t know what to do about it. Everyone says it’s a blockage factor, but it doesn’t [mess with] the drag number, it’s about the upwash, and it is not even about the downforce, it moves the

COP back. Then we have to tune up the splitter, and it's going to be on the nose everywhere. I complain a lot, but haven't got anywhere.'

The car has been largely designed in CFD, with more than 1000 runs done on computer simulation, plus scale tunnel testing at Silverstone, UK before the full-scale testing for homologation purposes.

The base model of the car is the 2024 Mustang Dark Horse, under a new Ford Performance design logo that will now be featured on all of its racing models. Under new GT3 regulations, very little of the donor car has to be retained. New front and rear subframes therefore carry the engine, gearbox and suspension mounting points, leaving only the central part of the car as the original production design.

It is, says Holt, a revelation to see the GT4 and GT3 cars together. 'You would think that they are different base cars. If I stripped out the chassis and showed you what is left of the original Mustang, it's maybe 30 per cent. From the firewall to the back of the seat it's all real, but the rest is subframe. If you backed it into the wall, you should be able to get it out for the next session. If you went front end in, it's a bit more complicated because of all the cooling.'

The subframe suspension design offers a range of options for the customers, and Multimatic has made it rather more complicated by running a five-way DSSV damper in the tower that would normally house the MacPherson strut in the base car.

'We turned it into a double wishbone suspension, so we had to put some structure in there,' says Holt. 'The subframe has all the pick-up points on it, and the tower for the damper, so we can do anything we want with the geometry.'

One of the things Holt is most proud of is the benign attitude of the car at different ride heights, and at different phases of braking. That makes it easier for a customer driver to manage, particularly compared to the old GTE Ford GT. This is important as today's GT racing is less about overall performance and more about performance over a stint, on different types of tyre.

User friendly

The Mustang GT3 has incorporated all the learnings from the Ford GT programme and rectified the mistakes made with that car. That includes thought given to potential accident damage, and how the suspension would break down to leave the team with the least possible amount of repair work should a driver hit a wall.

The gearbox is the same as that used in the Ford GT, just mounted in a different way. While the GT had its gearbox bolted to a bellhousing at the back of the engine, this set up 'has a different snout, but it's the same as we are putting in the Ford GT Mk4,' explains Holt. 'This has a carbon prop' shaft and then it has a different interface on it, but it's the same 'box.' Bosch has supplied the electronics for the engine, including the ECU, ABS and the crash avoidance system.

The car is powered by a naturally aspirated, 5.4-litre Coyote V8 developed jointly by Ford Performance and M-Sport

'The [front] subframe has all the pick-up points on it, and the tower for the damper, so we can do anything we want with the geometry'

Larry Holt

Electronics are by Bosch, pedal box and braking system by Alcon, clutch by Megaline and seat by development partner, Recaro

A new clutch from Megaline has been introduced, with different launch settings that can either fire you off the line quickly, or allow you to pull away from the pit without drama.

The pedal box comes from Alcon, as do the brakes, which Holt says are industry leading. 'The pedal box is the best in the industry. When you try to adjust it, it doesn't jam up, it's really well made.' Multimatic builds its own rollcages, and developed its own seat together with partner, Recaro.

Window dressing

'What we have here is the solution to all the mistakes we made in the past,' says Holt. 'You could not sell a Ford GT to a normal Am' driver. This car is in the window. We could have way more downforce, we could be way more efficient, but then it's outside the box.

'We made the diffusers at the rear and under the front more benign, so you generate the same amount of downforce at a higher or lower ride height.

'We looked at the teams that will be running it, made the car easy to work on, and made the car easy on the tyres, so it can make the same lap time at the end of a 25-lap stint as on the first. We are not looking to go four seconds faster than the pole position time, we just need to be there, at race pace.'

The car will make its debut at the 24 hours of Daytona in January 2024, and then will continue in the IMSA WeatherTech Sportscar Championship with Multimatic, and the World Endurance Championship with Proton.

At time of writing, there is no confirmation that the car will race in SRO-sanctioned events next season, but it is a possibility.

WIN A £200 FORTNUM & MASON VOUCHER

Help us fill every issue with more of the things you love

Take our short survey to let us know what we're doing right – and how we can improve. You could be in with a chance of winning one of three Fortnum & Mason vouchers, each worth £200. Enjoy spending it on Fortnum's famous tea blends, delicious biscuits, fine wines or an entire hamper.

Scan to enter

Thank you, in advance, from all of us here at
The Chelsea Magazine Company, part of Telegraph Media Group

Fill out our survey today at
www.telegraph.co.uk/chelseamag-survey2023 or scan the QR code*

*The survey and Fortnum & Mason voucher prize draw is hosted by Telegraph Media Group Limited ("The Telegraph"). Chelsea Magazine Company is a subsidiary of The Telegraph. The prize draw is open to residents of the UK, Republic of Ireland, Channel Islands or Isle of Man who are aged 18 years or over and have completed the survey. To enter the prize draw, customers must complete the survey before 23:59 on Monday, 2nd October, 2023 and the winners will be contacted on or before Monday, October 16, 2023. Your name and contact details will be used for the purpose of the prize draw only. For full prize draw terms and conditions visit www.telegraph.co.uk/prizedraw-t&cs. The Telegraph is bound by the Market Research Society Code of Conduct, your responses will go directly to The Telegraph for processing, but your personal information will not be shared. Any information you provide for the survey will be used solely for research purposes, remain confidential and treated in accordance with data protection law. Research will be anonymised and analysed on an aggregate level. For more information please see The Telegraph's Privacy Policy at https://www.telegraph.co.uk/about-us/privacy-and-cookie-policy/ and Chelsea Magazine Company's Privacy Policy at https://www.chelseamagazines.com/the-chelsea-magazine-company-privacy-policy/.

Full steam ahead

After a couple of false starts, RBPT is taking the bull by the horns and developing its own Formula 1 power unit, in technical partnership with Ford

By DIETER RENCKEN

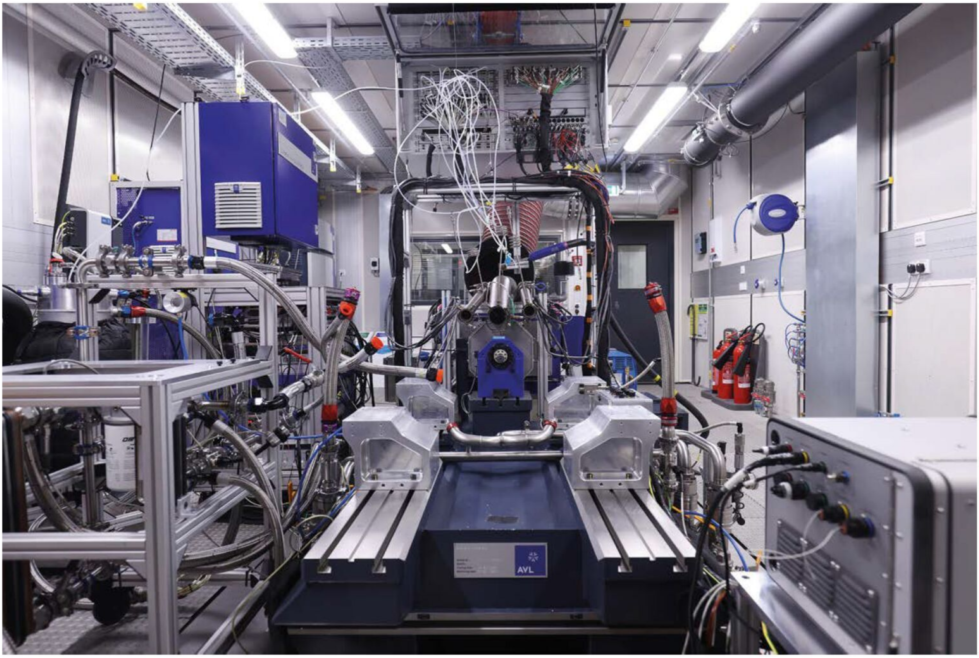
Formula 1 used to be easy: design a chassis, acquire a Cosworth DFV and Hewland transmissions, sign deals for brakes and tyres, assemble the bits and within months, or weeks, maiden grands prix beckon. That's how McLaren, Williams, Tyrrell (now Mercedes), Jordan (Aston Martin) and Stewart (Red Bull) started out – exactly 50 per cent of the current grid.

However, as turbochargers, hybrids and brake-by-wire systems were adopted, so power units (PU) became increasingly complex. Add in costs and time scales for development of PUs, coupled with zero prize monies and a kick up the exhaust pipe from customer teams and drivers when things go awry, and it is little wonder the PU suppliers exited one by one after Formula 1's heyday of seven during the mid-2000s.

XPB

Red Bull has enjoyed dominance in Formula 1, but says it has out-grown being a customer and is ready to take the next step to become a Power Unit supplier

The PU construction process is complicated by so many of the components being designed and manufactured in-house, from castings and machined components, all the way down to spark plugs



Practically every component in the powertrain is then put through its paces on a test rig, and the majority of the rigs are designed and built in house at RBPT, the cost of which is eye watering

RBPT is housed in a purpose-designed warehouse on the Red Bull campus in Milton Keynes, UK, a short stroll from the race team headquarters, offering seamless integration of the whole process

RBPT's ICE and hybrid divisions are largely separate units operating under the same roof, albeit overseen by [technical director, Ben] Hodgkinson

Tellingly, not a single engine supplier has joined F1 this millennium, yet five new teams entered the series in the same timeframe. Crucially, just one of that quintet, namely Haas, remains alive today, thanks in no small part to its unique Ferrari powertrain, and component-sharing business model, as detailed in *RE* V32N12.

All that is about to change, though, with the impending arrivals of Audi and Red Bull Powertrains (RBPT), the former operating out of effectively a re-purposed WEC / Formula E / Dakar PU complex at its Neuburg base.

Many of the RBPT staff were recruited from Mercedes High Performance Powertrains, also based in the UK, and the current head count is over 400, with that planned to rise to a final figure of 475 by the time the new powertrain regulations come into play in 2026

RBPT, on the other hand, is a start-up in every sense of the word, based in a warehouse within the Red Bull Racing (formerly Stewart / Jaguar) campus in Milton Keynes, UK.

In fact, when *Racecar Engineering* visited in January 2022 on a different assignment, we were banned from touring what was then known as Hall 8 due to heavy duty construction activities within, but we were left with no doubts about the purpose of the work (helped by a number of the enormous crates stacked up outside the hangar bearing the logos of AVL, the Graz-based go-to motorsport engineering specialist).

Fast forward to the end of July last year and Red Bull Racing CEO, Christian Horner, told *Racecar Engineering* that RBPT (the Ford deal was cut later, see sidebar on p38) had fired up its first power unit, albeit without the full hybrid ancillaries attached.

'Single cylinder concept?' we ventured.

'No, V6,' came the proud reply as the team boss headed off on his 2022 summer break, secure in the knowledge that critical flow paths had been met.

He did later reveal that both a one-pot and full-fat 1.6-litre had run almost simultaneously as time pressures made parallel developments programmes critical.

Convoluted tale

How RBPT got this far is a convoluted tale. In 2016, at a time when Renault's PU was not doing the business in the back of Red Bull and Toro Rosso (now AlphaTauri) chassis, and Mercedes refused to supply a top-line competitor, the energy drink brand's F1 adviser, Helmut Marko, admitted the team was considering establishing a power unit operation to secure its independence from the vagaries of external suppliers.

However, two aspects eventually killed off such thoughts: the complexities of prevailing exhaust-driven energy recovery systems (MGU-H) and the unlimited budgets the likes of Ferrari and Mercedes threw at their PU programmes.

Forget not that latecomer, Honda, was then struggling with the technologies, while Renault openly admitted costs were spiralling out of control. Saliently, even Porsche refused to enter for both reasons.

About turn

Honda did eventually master the complexities and replaced Renault in the Red Bull camp, only to abruptly announce its exit from F1 at the end of 2021, just as Max Verstappen headed for that year's title.

Simultaneously, the FIA announced the sport's 2026-onwards regulations would be governed by a power unit budget cap, with MGU-H dropped completely and a freeze on current engine development.

The time was right for Red Bull to re-visit its earlier plans.

Significantly, RBPT was, if not the last major project approved by Red Bull founder, Diedrich Mateschitz, before his untimely death in October 2021, certainly one of the very last, and he is said to have done so to ensure the autonomy of his main passion, the Red Bull Racing F1 Team. Plus, of course, that of sister outfit, AlphaTauri.

Christian Horner, who oversees the entire Milton Keynes campus, which comprises Red Bull Racing (the race team), Red Bull Technology (design and engineering services for both teams), Red Bull Advanced Technology (external consulting and non-F1 projects) and now RBPT, is adamant Mateschitz would not have committed to RBPT without a budget cap in place.

'That was key,' he explained during *Racecar*'s exclusive visit. 'What we were initially looking at was to have a licencing deal with Honda to build their engines under licence, but the more you dug into it – their IP, trying to work with Japanese suppliers and so on – it would have been extremely difficult, maybe even impossible.

'Thankfully, due to the good relationship we have with Honda, we were able to contract their services to the end of 2025, whilst at the same time focusing on the new set up for 2026.

'If you remember, initially it was going to be a four-cylinder engine and a very different architecture, which would have been a clean sheet for everybody.

'Basically, what we've ended up with [for 2026 onwards] is the current engine architecture without the [MGU-H] and a bigger battery size. So, apart from the 'H', that gives the incumbents significant carryover advantages, which we are obviously pedalling hard to catch up on.'

Christian Horner… is adamant [Red Bull founder, Dieter] Mateschitz would not have committed to RBPT without a budget cap in place

For clarity, the MGU-K, which recovers kinetic energy under braking, is retained.

Of course, Red Bull did not know then that Honda would about turn (for the umpteenth time) and remain in F1, eventually cutting a deal with Aston Martin, announced during Monaco Grand Prix week. Horner admits they would not have embarked on the RBPT route had Honda not vacillated, but there are no regrets.

Integrated advantage

'We wouldn't have made that jump had it not been for Honda's withdrawal,' he said, speaking in reaction to the Aston Martin announcement. 'However, for the prospects of Red Bull, we've outgrown being a customer.

'For us to have the power unit on site, integrated fully with the chassis and the

The Ford logo is evident wherever you look around the RBPT headquarters and, in a similar vein, the Red Bull logo is clearly obvious on iconic Ford products such as the latest version of Supervan

The partnership with Ford came late in the day, after Honda confirmed its withdrawal and Porsche pulled out of negotiations. Ford says it will benefit greatly from its participation in Formula 1

synergies that creates with engine and chassis engineers next to each other, for the long term, the advantages are significant.

'To repeat, we wouldn't have made that jump had it not been for Honda's withdrawal, and it was certainly an expensive decision.'

The Ford deal

Crucially, though, Horner and his team managed to persuade Ford to enter into a technical partnership with RBPT, after a much-mooted deal with Porsche imploded rather publicly. This should help defray some of the costs and aid with development. Indeed, during our visit, a little over a month after the Ford deal was confirmed at the end of January, Red Bull Ford logos were much in evidence in all visible areas.

How expensive the whole operation becomes will only be apparent once RBPT publishes full-year operating results, but an idea of start-up costs can be obtained from the fact that high-level staff were recruited – mainly from Mercedes High Performance Powertrains, situated just 30 miles north, but also from outside the motorsport industry and Britain – in May 2021. The RBPT workforce currently numbers over 400 highly qualified heads.

The highest profile recruit was Ben Hodgkinson as RBPT technical director, who moved across from Mercedes in May 2021 after 20 years with the company where he oversaw internal combustion engine development during the halcyon Lewis Hamilton era. Thereafter, numerous HPP heads followed suit.

'About 475 eventually,' is Horner's estimate of the payroll number come 2026, but he points out that some heads were transferred across from the F1 team as an alternative to widespread lay offs imposed by the team budget cap introduced in 2021.

Impressively, where the Mercedes race and PU operations are split by 27-odd miles, and Alpine-Renault's equivalent facilities are separated by the English Channel, in Milton Keynes a mere 100-yard walk enables key race and PU personnel to have coffee machine chats. Not even Ferrari can brag that sort of proximity.

That said, RBPT's ICE and hybrid divisions are largely separate units operating under the same roof, albeit overseen by Hodgkinson, then integrated into a full PU at the car assembly stage.

The process is complicated by the sheer number of components designed and manufactured in house, ranging from major castings and machined components through pumps and even bespoke spark plugs. By contrast, Renault operated mainly to a buy-in basis.

Given RBPT's practical inexperience in the field, it faces steep learning curves. Data collection and analysis is therefore crucial to ensure maximum power and reliability, particularly given looming F1's cost restrictions, which hammer failure. For example, every torque setting for every fastener on every sub-assembly is electronically recorded and stored to enable issues to be traced back to source.

A further complication is Honda's continued presence in F1 beyond 2026. Current PU data is ring fenced by the Japanese engineers, while RBPT ensures nothing leaks across.

'Honda people are basically banned from here,' a source told *Racecar Engineering*. 'We have to, as they have to.'

To gain an idea of the costs and complexities involved, consider that virtually every component is put through a test rig – or two or more where separate performance and reliability tests are involved. Yet, none of the rigs are catalogue items, so RBPT not only designed every rig, but built the vast majority in house, too.

'A very big number is involved,' is all our guide would admit to on that front. And as tests change, so new rigs are required, so costs continue to ramp up.

And there are more tests to come. During our visit, our host, Steve Brodie, who followed Hodgkinson across from Brixworth to take up the position of PU operations manager, pointed to an under-construction

'We wouldn't have made that jump had it not been for Honda's withdrawal, and it was certainly an expensive decision'

Christian Horner

building that will house test equipment and shaker rigs for hybrid components like the MGU-K, inverters and high-speed balancing.

Target cycle

The eventual target is for all components to undergo full cycle durability testing in-house before being sent out to race.

On 'our' day, a V6 was undergoing transient dyno tests and, while the exact nature of tests remain secret, the maze of pipework and readings made clear the PU was at top speed before stepping down gears in steps as part of a fuel and lubricant development programme, in conjunction with partner Exxon Mobil.

RBPT has now been existence for a little over two years and faces roughly the same timeframe before a Red Bull car officially heads down a pit lane powered by an in house-designed and built PU. The two timescales perfectly illustrate the extent of work already done, and the huge task, and cost, that lies ahead before the 2026 opener. That race will simultaneously mark the completion of the factory phase and the start of Red Bull's fully integrated F1 journey.

Continuous development therefore looms if it is to reach the top, and stay there, in the face of enormous competition from OEM projects mounted by Audi, Ferrari, Honda, Mercedes, Renault and, potentially, Cadillac (possibly even Hyundai, too, if rumours are to be believed), all of whom have massive in-house resource.

'Getting there comes down to the same culture, the same approach that we've had to going racing on the chassis side,' says Horner. 'Ultimately, having everything under one roof, and the benefits that brings long term, is significant. That's taking quite a bit of my time and attention just to make sure we're hitting our targets in that area.'

Now, consider that Red Bull currently tops both the Drivers' and Manufacturers' Championships, despite the enormous

RBPT has now been existence for a little over two years and faces roughly the same timeframe before a Red Bull car officially heads down a pit lane powered by an in house-designed and built PU

disruptions and costs imposed by Formula 1's first turn-key engine project this century on Horner and his entire team. On that basis alone, don't bet against the full Milton Keynes campus delivering race wins and titles sooner rather than later, as per Mateschitz's vision when he hit the 'go' button in March 2021.

Q&A with Mark Rushbrook, Ford Performance Motorsports

***RE*: Why did Ford and Red Bull enter into this F1 partnership?**

MR: Our specific focus is the Red Bull Ford Powertrains part of the business. Before this partnership was formed, Red Bull had taken the decision to do their own power unit for 2026, so it was already in motion.

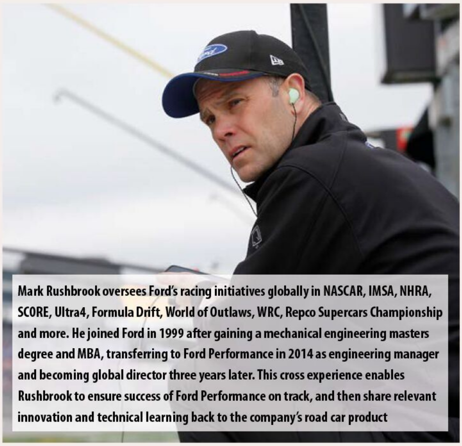
When we started these discussions, the core questions were, what did Red Bull need to be successful in developing its power unit? What were we interested [in], or able to bring? And what could we learn from it?

***RE*: Any examples?**

MR: We're deep into motorsports in different areas, including internal combustion engine technology and electrification, with emphasis on electrification of the road car cycle plan. It's everything our technical teams are learning about, whether battery cell chemistry, motors, inverters, software calibration or analytics. We've built a lot of expertise in that area inside Ford Motor Company.

To answer the question, it's access into [these elements] Red Bull was looking for. Is there something in there that can help them with that is equally exciting for us, something that really can help Formula 1 racing? We continue to identify more areas every day.

Take battery cell technology as one example, and start applying this to the [F1] programme. We're going to learn from that and it will not only help the F1 programme, but will bring learning and technology back to Ford Motor Company. Same on motors, same on inverters.



Mark Rushbrook oversees Ford's racing initiatives globally in NASCAR, IMSA, NHRA, SCORE, Ultra4, Formula Drift, World of Outlaws, WRC, Repco Supercars Championship and more. He joined Ford in 1999 after gaining a mechanical engineering masters degree and MBA, transferring to Ford Performance in 2014 as engineering manager and becoming global director three years later. This cross experience enables Rushbrook to ensure success of Ford Performance on track, and then share relevant innovation and technical learning back to the company's road car product

***RE*: The focus is on electrification but ICE are mandated on a 50 / 50 power basis. Can Ford learn from ICE?**

MR: Absolutely. Our initial focus has been on electrification, but there's also a lot that needs to be developed on the ICE side, so a lot we can contribute to and a lot we can learn from.

We've said since the beginning that nothing's off the table, anything that can help our partnership from inside Ford Motor Company is available. Anything we can learn that's appropriate to share back we will, including things like additive manufacturing, where we've got good resources.

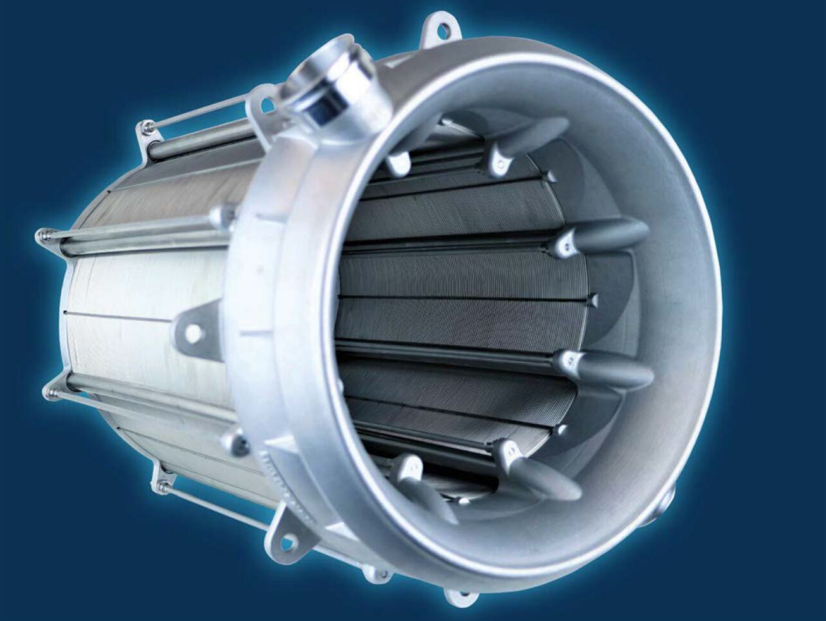
'We've said from the beginning that nothing's off the table, anything that can help our partnership from inside Ford Motor Company is available'

***RE*: If we move on from electrification and ICE, there's the sustainable fuels element. How does that help Ford going forward?**

MR: It's one of our pillars, so very important for us. In many regions of the world, we're going to have ICE for some time, and we know a responsible, renewable fuel will be used in certain markets.

We're already seeing a shift in fuels in a lot of motorsports series we're already in. We've done some on our own, including a low-carbon fuel Ford Ranger Raptor that raced at Baja last year.

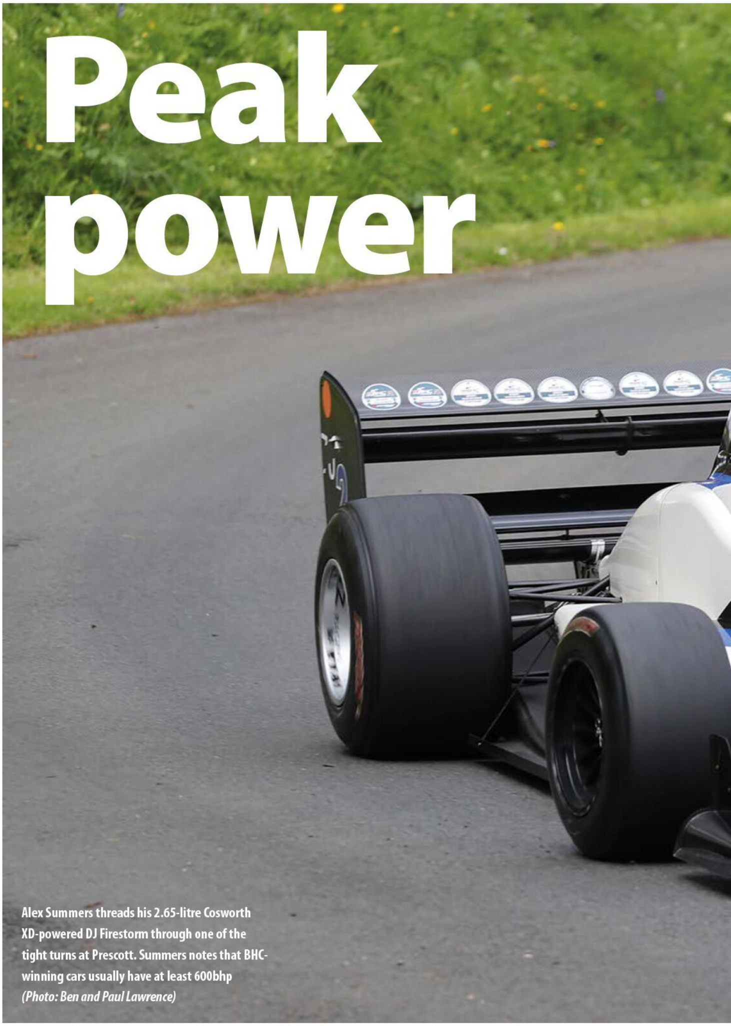
There's a lot more we can do with a strong push in Formula 1. It's fantastic, this commitment from the FIA and F1 to sustainable fuels. Net zero carbon by 2030 is very much aligned with what we want and need to do.



Peak power

In part two of Racecar's *focus on British Hillclimb cars, we lift the engine covers, poke around in the gearboxes and plug into the hi-tech electrics on these no-holds-barred racers*

By MIKE BRESLIN



Alex Summers threads his 2.65-litre Cosworth XD-powered DJ Firestorm through one of the tight turns at Prescott. Summers notes that BHC-winning cars usually have at least 600bhp ***(Photo: Ben and Paul Lawrence)***

When Cosworth designed its XD engine, it was with 500 miles at Indianapolis in mind. Similarly, when Judd produced its DB, 24 hours at Le Mans was the target. And yet now these units have shown themselves to be the very best at pushing cars up a hill of just a mile or so in length for little more than 30 seconds.

These are not the only engines used in the British Hillclimb Championship (BHC), though, and you're as likely to hear a screaming, supercharged motorbike unit as a ripping V8 at Prescott, Shelsley Walsh, Loton Park or any of the other hills that are visited by the BHC.

This is no surprise because, as we discovered last month (*RE* V33N7) British speed hillclimbing is a category with a great degree of diversity due to a relatively open set of regulations. This has resulted in very high levels of aerodynamic and suspension technology in the fastest cars that go head-to-head in the Top 12 Runoff, the climax to an exciting day of uphill racing.

Power or weight?

Those aero developments are very much driven by the engine the car is packing. As we were told last month, drag is not such an issue if you have close to 700bhp on tap. On the other hand, weight might be, and this is where the most intriguing question about engine choice arises: is it better to have a lightweight car with a less powerful engine, or a relatively heavy car with more power?

The word 'relatively' is used here because even the heavier top-line cars are just over the 400kg mark, which, for reference, is half the weight of a current Formula 1 car, with its 798kg limit. The lightest 'bike engine cars can weigh as little as 280kg, with the most highly developed tending to be around 300kg.

The 'bike engine of choice is, predictably, Suzuki's fabled Hayabusa, though others are used. On the car engine front, for Class L (the over 2.0-litre unlimited class, which tends to make up most of the Top 12 Runoff qualifiers) 4.0-litre Judd V8s and Cosworth XD V8s are the preferred motors to have these days.

Do the power-to-weight sums and both lightweight 'bike engine, or a bit heavier with a V8, *should* do a similar job. Yet out on track this is seldom the case.

'On paper, if you look at a methanol [fuelled], supercharged, very lightweight, motorcycle-powered car vs a big car, the small car should be up there with the big car. But in reality, it's not,' says Del Quigley, whose DJ Engineering concern produces the popular V8-engined Firestorm and also 'bike-engined Firehawk racecars. The big cars just manage to punch out of those corners a little bit faster, and the V8 Judds and Cosworths, they're always in the top three or four really.'

Wallace Menzies is proof of that, having won the last three championships with a Cosworth XD – originally designed for IndyCar in the 1990s – fitted in his Gould GR59.

'It started off as a 2.65-litre, and it's now bored and stroked to 3.3,' notes Menzies. 'It's a bit under 700bhp, at 680. I've had the engine since 2008, and have been running it in various guises. This year, we're looking to put it back on to 24 injectors, which it has run previously, and that'll take it up to just a bit over 700 horsepower, hopefully.'

Photo: Ben and Paul Lawrence

'If I hit the limiter by accident, I don't immediately reach for the underwear change'

Alex Summers, Cosworth XD-powered DJ Firestorm driver

This engine was originally developed by Quigley's DJ Engineering concern, which was the first company in the world to provide the XD as a normally aspirated unit. However, despite his recent BHC successes, Menzies still feels he may have a slight disadvantage when it comes to other top-line Goulds, which often run 4.0-litre Judds.

'The torque in the Judd is monstrous,' he says. 'It's also lower and lighter as an engine, but we've done all right with what we've got and we're quite happy with it.'

To put some numbers to this, famed engine builder, John Judd of Judd Power, says the 4.0-litre DB gives around 380ft.lbs (515Nm) of torque, while estimates for the 3.3-litre XD are around the 320 mark (433Nm).

Motorcycle power

Yet while the V8 cars do most of the winning, there are always 'bike-engined machines snapping at their heels, and sometimes taking outright wins. Paul Haimes, for example, regularly finishes in the top 10 with his Suzuki Hayabusa-engined Gould GR59.

'It's a 1300, standard Hayabusa capacity, but with one of the latest generation Garrett turbochargers, a Garrett wastegate, billet plenum and Life engine management,' explains Haimes of his 320kg racecar.

'We saw just high of 460bhp on the rolling road about a month ago. As for reliability, I wouldn't say you could go circuit racing with this engine, but for the speed events, you'll be okay. I mean, we're not running massive amounts of boost to get that horsepower.'

Alex Summers, who now drives and runs a DJ Firestorm with a normally-aspirated 2.65-litre Cosworth XD, also has experience of running big 'bike power in a light car, but he believes this approach can never quite provide both the performance *and* reliability required to mount a title-winning campaign.

'I had a supercharged [DJ] Firehawk, which was a very credible bit of engineering,' he says. 'I won a number of Runoffs and had a lot of success with the car… We gave up in the end, though, because it just wasn't reliable enough. I was leading the championship in 2014, it got to round seven and the engine split in half at Gurston [Down].

'That was a 1298cc engine running on pure methanol, and I think it was making 400bhp at the rear wheels,' Summers adds. 'That was driving a centrifugal blower, so it probably was making about 570 at the crank; you take away a lot of horsepower to run the blower, and then there's all the gearbox losses and so on to account for.

'We worked out that the brake mean effective pressure [cylinder pressure] of that engine was something absolutely ludicrous, in the high 20s. A high-performance diesel would be high 20s, but obviously they're cast iron blocks. This is a motorcycle engine, at 11,000rpm, and it literally just fell apart. They're fragile. And if you run them in such a way that they're not fragile, they simply don't make the power.'

Of course, this is just not an issue with the bigger engine cars.

'When you take a Pescarolo LMP1 Judd engine that's used to doing 24 hours at a canter, on a 24-second run it doesn't even know it's got going,' continues Summers. 'You've just got that reliability, but the word I would use would be redundancy. The XD was designed to do 500 miles with a turbo around Indianapolis at 15,000rpm on the rev limiter the whole way. So, if I hit the limiter by accident, I don't immediately reach for the underwear change. I just think, well, it was designed to do that, it'll be fine. The throttle systems, the injection systems, all that stuff is designed for massive abuse. With the best will in the world, Suzuki never meant to run a 180bhp 1300 at nearly 600bhp. That just wasn't in their plans.'

Big power

Big power is not everything, though. Trevor Willis runs a 3.2-litre RPE V8 in his OMS 28, an engine that was conceived, developed and built by Radical for its SR8 and is, at heart, two Hayabusa engines working off a single crank. This gives around 480bhp, way short of some other cars, which he admits is a disadvantage, though perhaps not as much as might be assumed.

'If we were on very fast circuits, it would make a big difference,' he says, 'but somewhere like Prescott, there's not an awful lot of places you can use 600bhp. You *can*, but not everywhere, so it's not the massive deficit you might imagine.'

Big power does give you the option to run big wing as well, though. 'That's one of the things you can do, you can run a lot more wing and have more downforce if you have the extra power,' adds Willis.

Photo: Ben and Paul Lawrence

BHC front runner, William Hall's Gould GR59, packs a 4.0-litre Judd V8. These engines were originally designed for high-end sportscar racing and are ultra reliable, as well as making tremendous amounts of torque

Dave Uren's Gould GR55 runs with a normally aspirated Cosworth XB, a unit originally designed for use in IndyCar. This engine is becoming rare now, so others use the later XD version

Suzuki Hayabusa motorbike engines are a common choice in the British Hillclimb Championship. This example has been stretched from the standard 1300cc to 1.6-litres and is fitted into a Force PT chassis

So, while some may question whether huge power is so important on such short and twisty tracks, it's still the high-power cars that usually win. Summers has an interesting take on this: 'The thing that seems to ring true is you need, in the big car class, 600 brake, or forget it. Yet the way those engines make their power is quite different.

'I've been very lucky, I've driven a lot of different cars: a 4.0-litre Judd; 2.65-litre IndyCar; 3.5-litre Formula 1 engines, and they are all either high revving and low capacity, or high capacity and low revving. But they all make about 600 brake. Also, if your speed trap speed at somewhere like Shelsley [Walsh] is mid-140s mph, you stand a fighting chance. If it's less than that, realistically, forget it.'

Climbing gear

Another reason the V8 cars usually come out on top is because the drivers don't have to change gear so often due to the massive torque delivery of these engines. When run times are around 30 seconds, even the slightest hiccup in power delivery is a factor.

'You're changing gear a lot, and every time you're changing gear, you're turning the power off momentarily,' says Quigley of the 'bike-engined cars. 'Even if you're turning it off for 40 milliseconds, you're still turning it off for that period of time. But because there's an awful lot of torque with the big engines, you don't have to change gear as often.'

That said, these days the disadvantage is not the same as it once was.

'The majority of people are on air shifters now, on a pneumatic air system run directly off the ECU, so the gear change is extremely fast,' says Steve Owen, the boss of racecar builder, OMS. 'And they're all sequential anyway, so it is a lot better than the old H-pattern ever was. The gain from H-pattern 'box to sequential was massive.'

With a 2.65-litre XD in his Firestorm, which revs over 14,000rpm to make its power, Summers works the gearbox a lot more than some other top runners to keep the engine within its relatively narrow power band. He uses a fully closed loop, pneumatically-operated system called Geartronics, which he says is perfect for hillclimbing.

'I can change gears and, if you look at the accelerometers on the car, it's almost imperceptible. There's 20 or 30 millisecond cut time,' he says, adding that it's particularly effective on down changes for corners.

'When we downshift, it blips the throttle, which has an instantaneous rev limit, so it blips to the exact right rpm for the gear below. So you get no perceptible engine braking or torque irregularity at the rear wheel.

'This is important because, clearly, if you're braking and slightly turning, or whatever, if your engine does something odd, or you experience some retardation you're not anticipating at the rear wheels, you're robbing from the friction ellipse and the tyre has its attention divided.'

The RPE V8 in Trevor Willis' OMS 28 was developed for the Radical SR8 and is essentially two Suzuki Hayabusa motorcycle engines working off a shared crank. This engine is said to give out around 480bhp

Standing start

The Goulds run with a gearbox design that originally began life as an Arrows F1 'box, but has been heavily developed by Gould and Xtrac over the years, while the DJ Firestorm has a version of the gearbox that was fitted to the A1 GP Lolas and, before that, F3000s. Both are very strong bits of kit, which is to be expected given the violence of hillclimb standing starts where 600 to 700bhp needs to be transferred to the asphalt at the drop of a clutch. This is another area in which the bigger engine cars have an advantage over the 'bike-engine runners.

> **When run times are around 30 seconds, even the slightest hiccup in power delivery is a factor**

'The Firehawk was about 345kg and 400 brake at the rear wheels,' says Summer of the 'bike-engine car he campaigned in the past. 'So, the power-to-weight was probably not dissimilar to the Firestorm, but at a certain

Photo: Ben and Paul Lawrence

More torque in the V8s means less gear changing, an advantage on the hills. Pictured is Scott Moran's Gould GR59 with 4.0-litre Judd

Photo: Ben and Paul Lawrence

Paul Haimes has a 1300cc turbo Hayabusa engine in his 320kg Gould GR59. It makes 460bhp and he's often in the mix with the V8s

Driver aids such as launch and traction control are crucial, and usually both can be controlled from the steering wheel. Note subtle sports psychology on the left of Alex Summers' cockpit

point the drive becomes the overriding factor. And because we had such weak transmissions on those engines – they were original motorcycle transmissions – we had no choice but to run small tyres.'

Haimes uses the standard Suzuki gearbox in his car too, but it's beefed up a bit and has a bespoke set of Nova gear ratios and a lock-up clutch (which reduces slip and is used in drag 'bike racing). Drive for the motorcycle-powered cars can be either by shaft or chain, and Ian Dayson, whose Force Racing Cars concern builds many cars that run with 'bike power, says he prefers the latter approach.

'We run chain drive to a diff,' he says, 'and tend to run drag 'bike chains on them, the best quality chain we can, but they still do break occasionally. It is obviously the weakest link, but in some ways, I'd rather have a weak link like that in the system.'

While the start is vital, the first 64ft is the most important part of a run. You need to be through it in under two seconds to even stand a chance of winning a round of the British Hilldimb Championship. Gould GR59 of Sean Gould pictured

In this respect, the chain acts somewhat like a fuse in an electrical circuit.

Most top cars now have plate differentials, with which you can adjust the ramp angles, though few seem to play around with these, or the gear ratios come to that, to any great extent throughout a season.

'You try and get the gear ratios, diff' ratio and pre-load ramp angles all to a point that works pretty well everywhere,' adds Summers.

Electronic control

The differentials and gearboxes are crucial for many reasons, not least the importance of the start. Or, more specifically, the first 64ft, which is very much the magic number.

'The first 64ft is measured everywhere,' says Menzies. 'That's more important than the 0 to 60 [which some estimate to be around the 1.7-second mark for the quicker cars]. To get to the Runoff, you've got to be below two seconds over the first 64ft.'

With the first 64ft so crucial, it's no surprise to find launch control is widely used, as is traction control. Summers, who runs a MoTeC ECU in his Firestorm, says: 'We're talking about a car that's something like 1400bhp per tonne, on cold tyres, up a country lane… So we've got drive-by-wire throttles, yaw-dependent traction, throttle position and gear-dependent traction, and different maps for different things. There are something like 40 combinations of throttle and traction and launch maps I could run if I wanted to.'

Datalogging is also common, with Summers running around 100 channels, but throughout the paddock Menzies is the one who is known for his attention to detail when it comes to the data and, unsurprisingly, he has a very wide array of sensors right across his car.

'We're running a pitot tube, wheel speed sensors, laser ride height at the front, two at the rear, load cells on all the pushrods, all the dampers have got potentiometers, they're all measured, as is the third spring,' he says. 'There's huge amounts of data coming off the car, and it gives you nowhere to hide as a driver. The laptop never lies. But it's really good. It takes away some of the anomalies, and allows you to learn faster.

'The car runs on MoTeC, from LAP Engineer,' Menzies adds. 'With the amount of data coming off, it can look really complicated, but you're probably going to the same half a dozen pages every time. The engine is just a check, and the gearbox and the shift strategy is just a check. We're not normally going near them. We'll adjust traction and launch, but I do that in the car.

The data will just show what the car is doing in pitch and roll and braking and acceleration, and from analysing that we can see which areas we are struggling in.'

Running the car

Despite the very high level of technology, one thing you will not see in a BHC paddock is professional teams running cars. This is still very much an amateur formula and, while some of the top drivers will have experts helping out with specific areas, often on a voluntary basis, most are run from the back of a trailer. Consequently, many of the front-running competitors are as much engineers as they are drivers.

The development decisions these driver / engineers need to make are very time-constrained too, for while there is very limited testing available at some courses, and at Sprint venues such as Llandow and Curborough, running at a regular circuit test day is of limited use.

'Even if you go testing, you can't really do more than the equivalent of one lap because then the tyres get hotter than you ever run them on a hillclimb,' notes Willis. 'Therefore, the results you're getting aren't very useful because you're setting up for a car with hot tyres, which we never really get. It does make development a bit more difficult.'

On top of this, fuel cells are small, so there's no scope for doing lots of laps anyway.

Developing the car through the race weekend is also tricky with, typically, just three runs on the practice day and then another practice run and two timed runs (plus two Top 12 Runoffs, if you qualify) on day two to play with.

'Your opportunity for making changes is minuscule,' says Willis, 'and you have to think very clearly, because it's easy to make a change and then set off on a run and think, oh, this is completely the wrong way. That's then 50 per cent of what you can do on that day done.'

Photo: Ben and Paul Lawrence

Reigning BHC champion, Wallace Menzies, runs a normally aspirated, 3.3-litre Cosworth XD in his Gould GR59, which gives out close to 700bhp. Note the pitot tube at the front, just one of dozens of sensors on this heavily datalogged car

Different drivers have different approaches to a weekend, some taking it relatively easy on the first practice runs, but Menzies, in his quest for relevant data from the start, attacks the hill from the off.

'For us, to learn quickest, we've got to go hard early and see what the car is actually doing at every event,' he says.

Economies of scaling

With no teams running pay drivers, it's difficult to pin down budgets, but the top cars sell new for around 'a quarter of a million [pounds] at an absolute minimum', says Quigley, and there is a great deal of tech involved, so it's fair to assume running one of them is not dirt cheap.

Summers: 'You're probably going to have an engine refresh every three seasons, so that's maybe £20,000 (approx. $25,500). Then there's tyres [£1500 (approx. $2000) a set, and some racers will get through 12 sets a year], your entries, your fuel, travel… It's

If a well-sorted BHC racecar was pitted against a Red Bull RB19 at Prescott, you would be well advised to put your money on the former

impossible [to estimate accurately], but it's not cheap. That said, we're not talking about hundreds of thousands of pounds either. From my experiences of people who've done BTCC or anything like that, it's nowhere near as expensive as that.'

The great thing is, because most hillclimb cars are designed to accommodate a wide range of engines, competitors can start off at a lower level with a standard 1100cc 'bike engine and then progress to bigger and more powerful units as the years go by.

A good, entry-level carbon chassis, with everything except the engine – in this case the Force TA – is around £35,000 (approx. $44,650), which stacks up very well indeed with a circuit car of a similar spec.

However much you spend in a season, when it comes to bang for your buck, there's not much that can beat the BHC. Where else will you get the level of performance of the unlimited class cars without paying serious money to serious teams?

Indeed, such is the speed of these machines over a short distance that some suggest a top car would rival an F1 car over a single lap at Monaco. That may or may not be the case but, one thing's for sure, if a well-sorted BHC racecar was pitted against a Red Bull RB19 at Prescott, you would be well advised to put your money on the former.

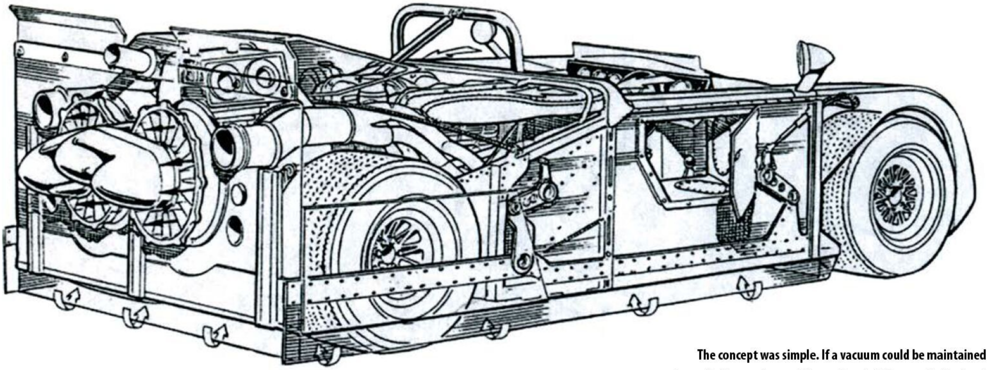
With very little track time, and limited testing opportunities, data is hugely valuable. Pictured is Trevor Willis and his OMS 28. Despite the high levels of technology, most cars are run by the owner / drivers, not professional race teams


It's a new dawn,
It's a new day,
and
we're
Feeling
GOOD.

Sucker punch

Begun as a project at Chevrolet to encourage innovation, and later inherited by Jim Hall, this 1970 sports racer showed phenomenal potential, and the Can-Am series had seen nothing like it

By KARL LUDVIGSEN



The concept was simple. If a vacuum could be maintained underneath the car at speed, it would suck it down onto the track

'It looks like the box it came in,' was a comment heard in the paddock on its debut at Watkins Glen in 1970. Even that harsh judgement of the appearance of the Chaparral 2J may have been generous. However, handsome is as handsome does and, in its own astonishing way, the 2J did handsomely.

A world champion was sufficiently impressed with its concept to drive the new Chaparral that year, and set a fastest lap in very quick company. Although the 2J did not last long enough to come close to winning a race, it showed great potential and restored its developer, Jim Hall, to his well-earned status of wizard technician of Group 7 racing.

In the rest of the 1970 Can-Am season, it revealed phenomenal pace.

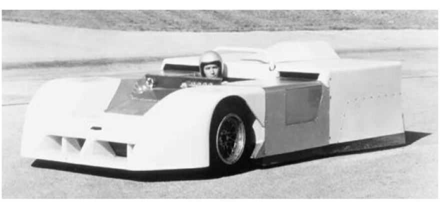
But was it the Chaparral Show, or was it really the Chevy Show with Jim Hall as master of ceremonies? To find out, we have to go back to where the car was conceived and constructed, in its major essentials, at the Chevrolet Engineering Center in Warren, Michigan. This was not a new relationship. Since 1964, Chaparral and Chevrolet's secretive R&D department had been closely cooperating on the building, testing and even racing of advanced sports-racing cars.

Basic concept

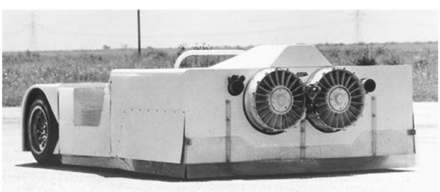
The 2J's basic concept was simple enough. If a vacuum could be maintained underneath a moving automobile, it would hold the car down with greater force. With the latest racing tyres, more force would mean more grip, translating into vastly increased cornering power. The idea was not new. Dresden, Germany's Vasa Nićin applied for a patent on it on 29 December 1925.

> **Their dominant need was for a robust box that would not collapse under the vacuum generated inside it**

The wider and larger the tyres, the bigger the contact patch on the pavement, and the more work they can do before sliding as the downforce is increased. Faster cornering is the key to success on road racing tracks, and this

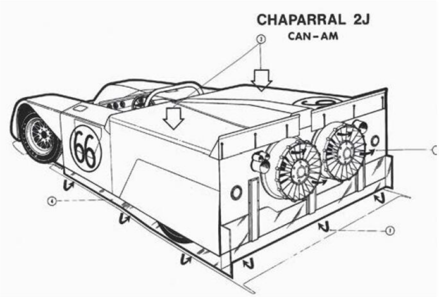


At Midland's Rattlesnake Raceway in mid-1970, Jim Hall looks out of his new creation. The result of a combined effort between Chaparral Cars and Chevrolet R&D, the 2J was the innovative elixir Hall needed after his troubled Can-Am seasons of 1968 and '69

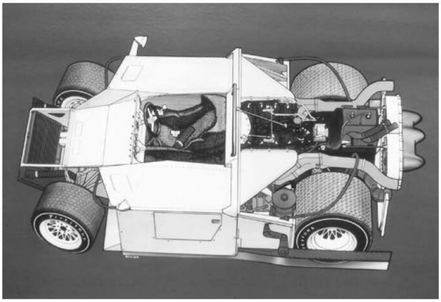


The extraordinary looking 2J was sucked against the road surface by two extractor fans mounted at its rear. Hall's 2J was a much improved (by Chaparral) evolution of a crude test vehicle built by Chevrolet R&D to explore this concept

Images: via Karl Ludvigsen



Driven at a constant speed around 5000rpm by a separate engine, the 2J's twin 17in fans extracted air from an enclosed area of the car extending from just behind the front wheels to the flat tail. At the side and rear, skirts made of General Electric Lexan effectively sealed the car to the track surface



The car's central section was a deep and rugged aluminum monocoque tub. It used front suspension similar to that of the Chaparral 2H and rear suspension adapted from the 2G. The suspension's anti-dive and anti-squat properties were particularly useful for keeping its ground-effect skirts in close proximity to the track

The front end of the 2J was shaped to divert as much air as possible up over the top of the vehicle and around its sides. Front air inlets were for the engine-cooling radiator and ducts to the front brakes, while a pair of slotted intakes either side of the roll hoop inducted air to the car's 7.6-litre Chevrolet V8 engine

Defying convention in every respect, the spectacular Chaparral 2J made its debut at the Watkins Glen Can-Am race on 12 July 1970. The car was relatively untested at this stage, but had completed a successful, 200-mile test at Midland, prior to being shaken down on the Tuesday and Wednesday before the race

phenomenon would later be exploited in so-called 'ground effect' racecars, but these were a decade in the future when the basis of the 2J was created in the winter of 1968.

This concept was available long before the FIA implemented a height reduction on aerodynamic wings that sent all Can-Am and other competitors scrambling for some new competitive advantage.

During 1968, engineers in Chevrolet's research and development department seized on suction downforce as a radical breakthrough that could revitalise its activities under new chief, Charlie Simmons.

With Jim Hall building his Chaparral 2H on his own for the 1969 season, the team of engineers needed something new that might help the Texan in the future. After tests with mock-ups and mule vehicles showed promise, said R&D engineer [and ex-*Racecar Engineering* contributor], Paul Van Valkenburgh, had this to say: 'Simmons gave Don Gates all the draftsmen, technicians and budget he needed to have it ready for the next racing season.'

Suspension Test Vehicle

Gates, the brainy engineer who had won Simmons' approval, concentrated on the suction system of Chevy's 'Suspension Test Vehicle', STV for short. Don Cox, Joe Marasco and Ernie DeFusco designed the car that would carry it.

The challenge they faced in creating a suitable body forced them to ignore conventional aerodynamic ideas. Their dominant need was for a robust box that would not collapse under the vacuum generated inside it.

The STV's monocoque structure was very deep through its centre because that portion, initially unpainted, was a major load bearing section. Hatches in its sides met the rules requiring doors. Longerons extending rearward from the monocoque embraced the Chaparral-prepared Chevrolet V8, an all-aluminum engine of 7.6-litres and 680bhp driving through a Chevy-built transmission comprising a torque converter with three forward gears that were shifted without recourse to a clutch.

Containing the areas where suction was generated was a box-like structure made of 0.25in aluminium honeycomb. With no available technology to give it curvature, the result was a laughably slab-sided appearance. Dzus fasteners joined the major panels together and allowed quick access.

In all, said Van Valkenburgh at the time, 'it was probably the strongest, stiffest racecar chassis that had ever been built.'

Conventional thought

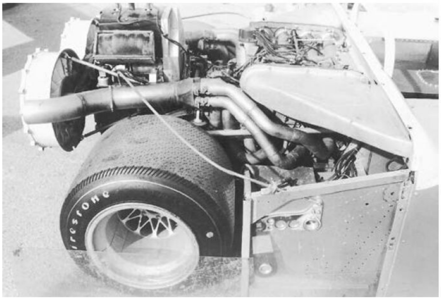
The STV's suspension was conventional. At the front, it had tubular wishbones and coil / damper assemblies like those of the Chaparral 2H, and racing-style linkages like those of the 2E / G at the rear. Their geometries countered nosedive on braking and tail squat on acceleration, both being activities that would upset the car's elaborate skirt system.

An important feature of the STV's springing was that it was trimmed for ideal geometry at 1.5in below the car's stance with its downforce not running. That was the

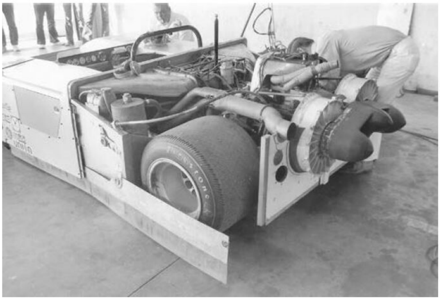
'It was probably the strongest, stiffest racecar chassis that had ever been built'

Paul Van Valkenburgh, R&D engineer at Chevrolet in 1969

Jim Hall obtained the services of reigning world champion, Jackie Stewart, as pilot for the Watkins Glen race. Despite a number of problems during practice, he qualified third behind the factory McLarens of Dan Gurney and Denny Hulme



Ducts from the air inlets provided fresh ram air to the inlet manifold of the 2J, carried over from the 2H. In the foreground, attached to the rear suspension by a Bowden cable, is the bell-crank linkage that kept the Lexan side skirt close to the ground as the rear of the Chaparral rose and fell over bumps



Originally, the cogged rubber drive belts from the auxiliary engine to the two extractor fans were located inboard of the fans, but debris sucked up from the road dislodged the drive belts, so they were re-located outboard mid-season and enclosed by a cover nicknamed the Martian bra by one team member

amount the car was calculated to be pulled down by suction to its operating height. From that datum line, the springing allowed three inches of travel in both jounce and rebound.

To take advantage of its downforce, the STV wore the widest wheel rims it could accept and the widest Firestone racing tyres available at the time. Disc brakes were internally vented for cooling.

As the 1969 Can-Am season progressed, the faults of Hall's Chaparral 2H were found to be many and insoluble. This was not surprising to Chevrolet, who knew that Hall's chosen approach – a car built for maximum speed with little attention to downforce – would not work on the Can-Am circuits.

Meanwhile, tests of the STV were attracting attention at Chevrolet R&D.

'The first time the auxiliary motor fan drive system was fired up, it literally smoked out the engineering lab,' recalled Van Valkenburgh. 'It became rather embarrassing to have around… so ridiculously sensational that everyone was talking about it.'

Hall and Gates

In the spring of 1969, Hall asked Don Gates to join his effort to sort out the 2H. Chevrolet decided that as the STV was Gates' baby, the semi-finished vehicle might as well accompany him to Midland. It was shipped there in September of that year.

As originally built by Chevrolet, and made whole to run at Rattlesnake, the STV's rear wheels were exposed in conventional fashion. Suction was applied over an area the width of the car and the length of the body between its wheelarches. Suction fans were mounted low at the sides of the body, flanking the engine and individually driven by small two-stroke motors.

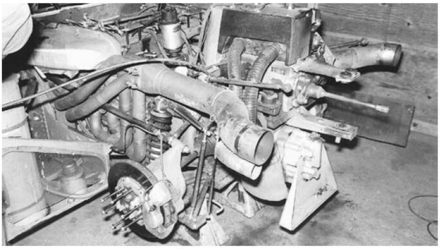
In tests beginning in the November of 1969, this arrangement did give substantial downforce, but the car's handling was treacherous. 'Regardless of how much basic understeer was incorporated with the fans off,' said Van Valkenburgh, 'when they were turned on the car oversteered uncontrollably. Apparently, the centre of downward pressure was too far forward. But, in spite of all the problems, with the fans working, it was as fast as any other car ever run at Midland.'

While Jim Hall was increasingly cool to 'someone else's Can-Am car', the STV found a defender at Midland in Tom Dutton, an engineer / driver who had joined the team during 1969. 'Practically everyone else viewed the project with either distrust or malice,' recalled Van Valkenburgh. Yet in Dutton it found a driver that was able to prove to the sanctioning Sports Car Club of America that the car would not be wildly uncontrollable if, or when, downforce was lost. The SCCA also judged it acceptable, despite FIA rules prohibiting moveable aerodynamic devices.

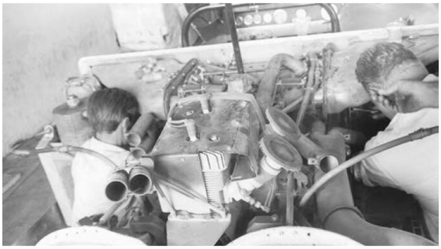
The advantage of having an auxiliary engine was, of course, that downforce was present at all times, especially at low speeds where the extra downforce is most effective, and where wings don't work at all

The Dutton effect

To address the handling problem, Gates re-conceived the rear of the STV. Mocking it up with plywood, the rear of the body was rebuilt to enclose the wheels, nearly doubling the area of suction downforce. In tests of this version at Rattlesnake, Van Valkenburgh noted, 'Dutton was able to circle the skid pad at a fantastic lateral 1.7g! This was a major jump from the previous best of 1.3g. Dutton then went out on the



The Chaparral 2H carried over Chevrolet's torque converter transmission with a three-gear, dog-clutch 'box. Perched on top of this was the two-cylinder, two-stroke, air-cooled JLO snowmobile engine that drove the twin extractor fans. Note the internally ventilated disc brakes



After it suffered from vapour lock, Chaparral engine man, Gary Knutson, equipped the JLO auxiliary engine with fuel injection and capacitive discharge ignition to enhance its reliability. Even then, the driver had to constantly monitor its cylinder head temperature and adjust the mixture accordingly, whilst driving flat out!

Stripped of its front and rear body sections, the 2J reveals its deep central aluminium monocoque structure. The hinged 'doors' met the letter of the Can-Am regulations. Standing behind the car in sunglasses is Cameron Argetsinger, who had joined Chaparral Cars as a vice president in 1970

Providing the vital seal at the front of the suction area was a transverse row of a dozen Lexan pieces. Designed by Chevrolet's Don Gates, each comprised an individual system, with a hinge to the body, and each was backed up by two more Lexan parts, hinged to harness both spring and vacuum force to keep its trailing edge on the track

road course and knocked nearly two seconds off Hall's previous best time.'

This won respect at Midland, where the STV was previously given such a sceptical reception. Now accepted as a potential Chaparral, it was given the 2J designation, 2I being skipped. However, it still needed substantial rebuilding and testing before it could become a *bona fide* racecar, time-consuming effort that had to concede priority to Hall's agreement to take over Chevrolet's Trans-Am Camaro programme.

Its demands meant the 2J missed the first two Can-Ams but was ready – just – for the third one at Watkins Glen on 12 July 1970.

Fan club

Preparations for that race included extending the aluminium honeycomb box to shroud the rear wheels entirely and complete enclosure of the rear of the car. The suction fans were now mounted at the extreme rear and driven by a single central auxiliary engine.

'An alternate plan to use a variable-ratio snowmobile belt drive off the transmission was set aside as too complex,' Van Valkenburgh related, 'but, as it turned out, that might have proved more dependable.'

The new arrangement placed some 200lb of fans and engine high in the air, cantilevered out over the tail – not ideal for the car's centre of gravity. Suction was generated by radiator cooling fans from an M-109 self-propelled howitzer. They had 17in blades, aluminium castings made by the Pesco Products Division of Borg-Warner, whose catalogue said that each fan could pump 9650ft3 of air per minute when spun at 6000rpm, while maintaining a static pressure of 11in of water, or 0.027bar.

Driving two of these fans, through cogged rubber belts and magnesium sprockets, was the best engine Chaparral could find for the job: a German-made JLO, two-stroke, air-cooled twin imported by Rockwell, giving a rated 45bhp at 5500rpm. This motor was judged reliable after engine man, Gary Knutson, fitted a capacitor-discharge ignition system to overcome problems caused by dirt getting into the points of its conventional coil ignition. Problems with blade erosion from roadway debris were tackled by fitting each fan blade with a steel leading-edge guard.

The fans were evidently slightly underdriven, relative to engine speed (about 5000rpm) because their gross horsepower requirement at 6000rpm was 52bhp – 7bhp more than the JLO engine could deliver. That was still enough to maintain a vacuum of 0.020bar under the skirts when the car was at rest or moving slowly.

The advantage of having an auxiliary engine was, of course, that downforce was present at all times, especially at low speeds where the extra downforce is most effective, and where wings don't work at all.

Skirt system

Crucial to the creation and maintenance of downforce was a system of skirts that surrounded the suction area and remained as close to the ground as possible. The closer they conformed to the road, the more effective the suction from the fans would be. But, in being close to the road, they inevitably made contact at times.

To permit this without having the skirts bent or broken, they were made of General Electric's tough Lexan plastic material.

The side skirts were simple 2.3mm sheets suspended from lever arms that adjusted their height in response to suspension movement through push-pull Bowden cables. The side skirts went up and down with the wheels and the rear skirt followed them, being linked to the side skirts at its ends.

The front skirt presented the greatest problem. Running across the car just behind its front wheels, it was crucial to the system's success. While the fans worked hard to pull air out of the suction chamber, the car's forward motion tried to ram air into that chamber. To minimise the extent of the pressure with which this forward skirt had to cope, the

2J's body was shaped to scoop as much air up and over its top surfaces as possible. Transverse rubber strips under the car's nose further interrupted the airflow.

The front skirt had to rub hard against the ground while the 2J was moving. It did this, at acceptable wear rates, because it was composed of a row of 12 thick pieces of Lexan trailing sharply back from the underbody. Each had its own plastic hinge, backed by two others similarly hinged in a way that used combined spring and vacuum pressure to keep its trailing edge down against the pavement.

The front skirt's segmented construction allowed it to adjust to road contours, and the individual parts had enough length to accept some wear. A set successfully survived 200 miles of testing at Hall's Rattlesnake Raceway, showing they could cope with a race duration. A new set was fitted as required, depending on the measured wear rate.

Estimated performance

Based on the suction system's parameters, an estimate would be that it could hold a 0.020bar vacuum through the speed range up to 80mph, at which it was designed to perform best. Applied over the approximately 7400in^2 of skirted chamber, this generated 2220lb of downforce. That was more than the gross weight of the car with its 320l of fuel onboard (57 of them in a separate tank, mixed with oil, for the JLO engine) and a driver in the cockpit. So, theoretically, Jim Hall could have unveiled his 2J with it hanging upside down from the ceiling, the JLO shrieking away.

With its original abbreviated vacuum chamber, the 2J had enough downforce to corner at a lateral 1.8*g*. Best figures for contemporary winged Can-Am cars were in the range of 1.5g. However, Hall said that with the extended chamber, up to 2.0 cornering *g* should be attainable.

A major difficulty was simply finding a driver who could exploit the extra half *g*. Hall himself did not feel that he was up to it: 'I'm driving like I always did, but I just don't seem to be going fast. When we introduced the 2J, we thought who we'd like to [race] it, and we thought of Jackie Stewart.' It helped that both Hall and Stewart were represented by the same management company at the time.

'He agreed to drive it on a one-shot basis at a very reasonable price because he wanted to look at the car and see what it was.'

Special test days arranged at Watkins Glen were wasted because Stewart discovered all too early that stones sucked up from the recently re-surfaced track lodged in the fan sprockets and flipped off the drive belts. A protective guard was made to shield the belts while other problems were diagnosed: overheating of the huge rear brakes and persistent vapour locking of the JLO's Tillotson carburettors. Bathed in engine heat from below and trapped under Lexan above, the JLO was complaining – although, like the skirt, it had kept going through the 200-mile test at Midland.

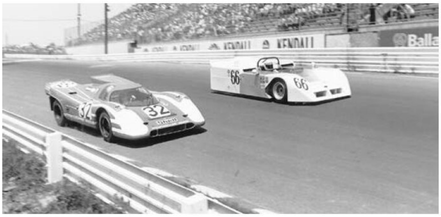
Early tests

The early tests helped Stewart meet one of the challenges of the 2J: its left-foot braking, an important advantage of the car's semi-automatic transmission. 'This called for a new sensitivity in getting things coordinated,' said the Scot, 'almost re-learning how to drive.'

Asked about his new car's attributes, Hall answered, 'With my former car, the 2G, we could get wheelspin and make it violently oversteer by over-controlling the throttle at almost any speed, and at almost any place, on the race course. But not the 2J. We can go full throttle without wheelspin or uncontrollable oversteer at a much lower speed, and accelerate out of the corners at a much higher speed than ever before.'

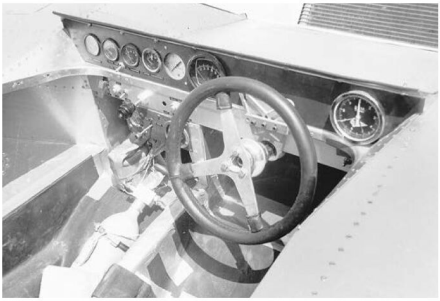
'This [car] called for a new sensitivity in getting things coordinated, almost re-learning how to drive'

Jackie Stewart, Chaparral 2J test driver

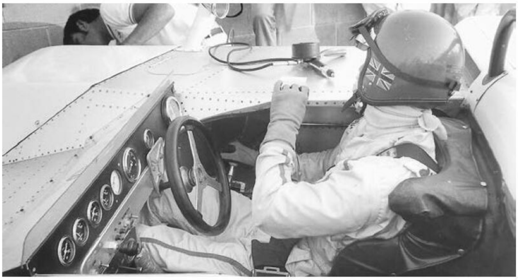


Next to a Porsche 917, considered one of the most advanced racercars of 1970, the 2J was a startling sight. Measurements conducted by Chaparral showed the car to be capable of cornering at least seven per cent faster than the dominant Can-Am McLarens

As much for its potential as for its performance, the 2J had rivals reaching for the rule books. After only a few races, it was concluded that both the rotating fans and the skirt contravened the no moveable aerodynamic parts regulation and, by the end of its first season, the 2J was banned



Among the gauges facing the driver in the cockpit was one which told how much suction was being generated under the car. Tests showed that when suction was lost, the Chaparral remained easily controllable



Briton, Vic Elford, drove the 2J in the three further Can-Am races it contested after Watkins Glen, placing the rapid car on pole in all three. However, at Road Atlanta, auxiliary engine problems demoted him to sixth, while a Chevrolet engine failure kept him from starting at Laguna Seca and a broken crank in the auxiliary engine denied him at Riverside

Micrometric celebrates 40 years of laser material processing

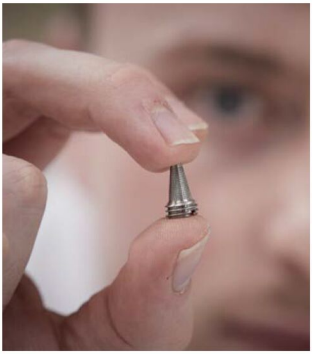
Lincoln-based manufacturing firm Micrometric is continuing to lead the way in micro laser manufacturing and multi-process services during its 40th year of business.

With this special anniversary, Micrometric is reflecting on the evolution of services it provides in a range of sectors including medical, aerospace and automotive. Founded by Maurice Gates and Neil Main, Micrometric began by cutting sheet metal using innovative CO_2 lasers in January 1983 and had a turnover of only £50 in its first month but this soon started growing.

Neil Main, Managing Director of Micrometric, remembers contracts that changed the services provided by Micrometric: "We were asked by the Atomic Energy Research Establishment at Harwell if we could make radiation sensors for detecting alpha radiation. They needed small rectangles cutting with each having a unique letter, number and error code. At that time our competitors were not able to do this, so we rose to the challenge and successfully output the parts using the large CO_2 laser (DE) and BBC Micro."

By 1990, Micrometric was a precision laser processor, and several industries were asking them to make parts: electronics, gas turbines, food manufacturers and medical. Most medical items were for instrumentation but Micrometric was asked to make one part for a prostate cancer remover.

In 1994 the company moved into a new purpose-built factory on Doddington Road, Lincoln. With more space Micrometric invested in new hi-tech lasers including its first Bystronic which was fast, flexible and precise.



A hydraulic filter used in aircraft systems, a great example of the small holes Micrometric can drill

After Neil purchased Micrometric in 2004, he faced a great challenge: the biggest customer bought its own laser. Company revenue declined, and it resulted in redundancies.

Recovery took a while before Micrometric was able to invest in new equipment.

Exhaust manifold flange

However, technological advances meant that new lasers were state-of-the-art and Micrometric was able to produce better quality components more quickly with a higher-skilled workforce.

Over the past five years, Micrometric has invested in new equipment to meet demand for precision components, including the Coherent Starcut tube cutting machine which works with extremely high precision, and a new Lasercube machine which delivers on quality and efficiency. These developments will allow the team to continue producing high-quality components for multiple industries.

Micrometric specialise in the production of fine parts and precision components, cutting a range of materials as thin as 0.05mm. It was this expertise that was required when a leading UK based formula one team approached them regarding a job to cut thin shims when the formula one team had struggled find a company to cut the very thin tolerances required and on a tight turnaround.

When looking forward Neil is positive: "We have seen so much change in just the last three years, but customers are still asking for new parts and processes. We are always looking for new ways of expanding our services so there is huge potential for growth in the automotive, aerospace and medical sectors."

Micrometric are AS9100D certified and are members of the Midlands Aerospace Alliance (MAA), The Manufacturers' Organisation (MAKE UK), Association of Industrial Laser Users (AILU), The Welding Institute (TWI) and Motorsport Industry Association (MIA).

A Micrometric employee working on a Trumpf laser welder

From left to right, Chris Waters, Rosie De Smit and Neil Main standing outside the Micrometric building

Find out more about Micrometric at micrometric.co.uk or call on 01522 509999

MICROMETRIC

Stewart qualified third fastest at Watkins Glen and was chasing the leading McLarens in the same position when various maladies forced the Chaparral's early retirement.

Sub-par power from the JLO reduced downforce which, together with deterioration of the track, caused unexpected tyre wear. Then the brakes started acting strangely and the JLO vapour locked itself into silence.

Finally, Stewart missed one of the tricky shifts with the 'automatic' 'box, scrambling its internals, and the day was done.

'I was impressed with Stewart,' Hall recalled at the time. 'He was fantastic. I was just astounded at his ability. We didn't have enough brakes, we had some other problems with the fans and skirts, but he didn't complain about it. He soldiered on and did a hell of a job for us. He drove the bottom off that car.'

Stewart was impressed as well, finding the 2J, 'extraordinary, almost unbelievable. The car has remarkably good adhesion and it's certainly very easy to drive. Notwithstanding the difficulties we've had with the fans pulling in dirt and fouling the belt drives, the car's traction, its ability to brake and go deeply into the corners, is something I've never experienced before in a car this size or bulk.'

Before the race was even over, the white trucks of Chaparral Cars were headed back to Texas with the asphalt-splattered 2J.

'Hall was disgusted,' Van Valkenburgh related. 'He refused to put more of his own money into the project and, because of its poor showing at the Glen, sponsorship was unlikely. The 2J was disassembled and put into crates to be sent to the warehouse.'

Quick Vic in the seat

But the makers of Lexan had been present at Watkins Glen to observe this car that used so much of their wonder material so effectively. In fact, the car carried small GE decals so, when prompted by Don Gates, General Electric came to the party. GE put up sponsorship 'in the low five figures' to fund three more race appearances. The company's support not extending to Jackie Stewart's fee, Hall installed Vic Elford, a driver of his Trans-Am Camaros, in the 2J. One of racing's most versatile drivers, 'Quick Vic' quickly got the hang of the newfangled racecar.

Skipping the next races on the 1970 calendar at Mid-Ohio, Edmonton and Elkhart Lake, the 2J next appeared at Road Atlanta for the 189-mile Can-Am race on 13 September. This gave the Midland team a break to re-assemble 'the sucker car', as it became known, and make some improvements.

To help its JLO fight vapour locking, Gary Knutson converted it to fuel injection. Drive belts to the fans were moved out of the car's interior to an external position, shrouded by what its creators called a 'Martian bra.'

In early practice at the hilly Georgia track, the 2J was an astonishing three seconds a lap faster than the all-conquering McLarens using similar Chevrolet V8 engines. In spite of their best efforts, Elford retained pole position by a 1.2-second margin. But on the first lap, a fatigued ignition wire caused the JLO to start missing. A lengthy pit stop to diagnose and fix the problem kept Elford from finishing better than sixth place, six laps in arrears, but at least the 2J had finished its first race.

The next Can-Am was missed to concentrate on the two popular Californian events that concluded the championship. At Laguna Seca for the 18 October race, Elford and the 2J were on form, breaking the one-minute mark while qualifying 1.8 seconds ahead of both McLarens. All was set for a dominant display when the 2J's Chevrolet engine broke a connecting rod during the warm-up session on race-day morning.

Re-grouping for the race at Riverside on 1 November, Hall's outfit had its 2J ready. On this longer circuit, the margin of superiority in qualifying was the largest yet, 2.2 seconds over the fastest McLaren. A runaway victory was on the cards, but soon after the start the JLO twin decided to break its crankshaft. With various pit stops, the 2J struggled on, but then retired after only five laps.

> **'Notwithstanding the difficulties we've had… the car's traction, its ability to brake and go deeply into the corners, is something I've never experienced before in a car this size or bulk'**
>
> *Jackie Stewart, Chaparral 2J test driver*

Modest investment

In spite of these profound disappointments, GE's modest investment paid off, said the company. So sensational was the Chaparral 2J that more that 200 million press 'impressions' were totted up by the unique racecar. There would be no more because the SCCA, convinced that a developed 2J would wipe the field in 1971, finally implemented the FIA's prohibition of moveable aerodynamic devices. The 2J had plenty of these, not least the blades of its twin fans, as well as the suspension-linked skirts. It therefore entered legislatively enforced retirement.

A bizarre postscript to the 2J story was Gordon Murray's use of fan-generated downforce for his Brabham BT46B of the 1978 grand prix season. After winning one race, though, it was swiftly banned on the same basis as the Chaparral. By then, modern underbody downforce was widely used after its efficacy was convincingly demonstrated by the Lotus 78 and 79 in Formula 1.

Fathered by both Chevrolet and Chaparral Cars, the extraordinary 2J had been dramatically ahead of its time.

The Chaparral crew push Jackie Stewart out of the pits at Watkins Glen. Although powered ground effects were quickly banned, the same principle underpinned the successful use of venturi-generated ground effects toward the end of the 1970s

Jim Hall leans across Vic Elford into the cockpit of the 2J at Riverside in the car's last race appearance. Although unsuccessful as a racecar, the 2J made history as the first automobile capable of generating so much suction downforce that it could be driven on a ceiling

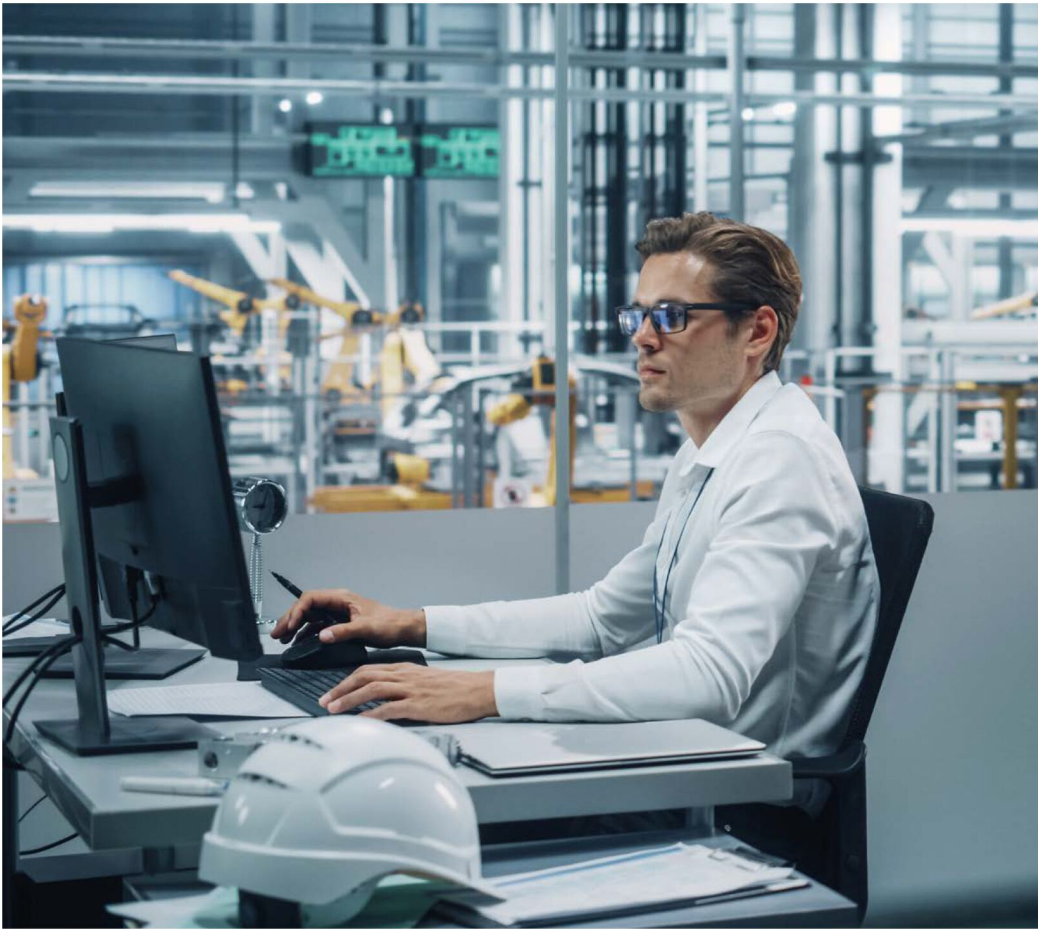

DESIGN | DEVELOPMENT | MANUFACTURE
ARK RACING
STARTER MOTORS | FLYWHEELS | PRECISION MACHINING
MADE IN BRITAIN
Start 2 Finish
Ark Racing excels at meeting the demands of the motorsport industry with exceptional, high-quality Starter Motors & Flywheels.
ARKBM 1.8kW Starter
• D.O.R. available CW + ACW
• Rear Steady Option Available
• Starter Motors & Lightweight Flywheels
• Specialists in GT & Rally1/Rally2 Starters & Flywheels
• Fully Supported Product Development
• Contact us about Bespoke Designed Options
ARKBM 2.0kW Starter
• D.O.R. available CW + ACW
• Rear Steady Option Available
Ark Starter Motor REBUILD/ SERVICING PACKAGE
ARKBM 1.6kW Starter
• D.O.R. available CW + ACW
• Rear Steady Option Available
Tested & proven at all levels of motorsport in the world's most demanding race locations.
Ark Racing Limited | Units 8-15 Croft Street | Willenhall | WV13 2NU | United Kingdom
www.arkracing.com +44 (0)845 557 7408


XCELDYNE™ VALVETRAIN
Titanium & Steel Valves | Lash Caps | Retainers
Spring Locators | Valve Guides | Valve Locks | Valve Seats
Roller Lifters | Custom Manufacturing
XCELDYNE™ ACCELERATED DYNAMICS
800-448-1223
www.xceldyne.com
37 High Tech Boulevard | Thomasville, NC 27360

The AI race

With race teams around the world recruiting data scientists at an alarming rate, Racecar *investigates why*

By GEMMA HATTON



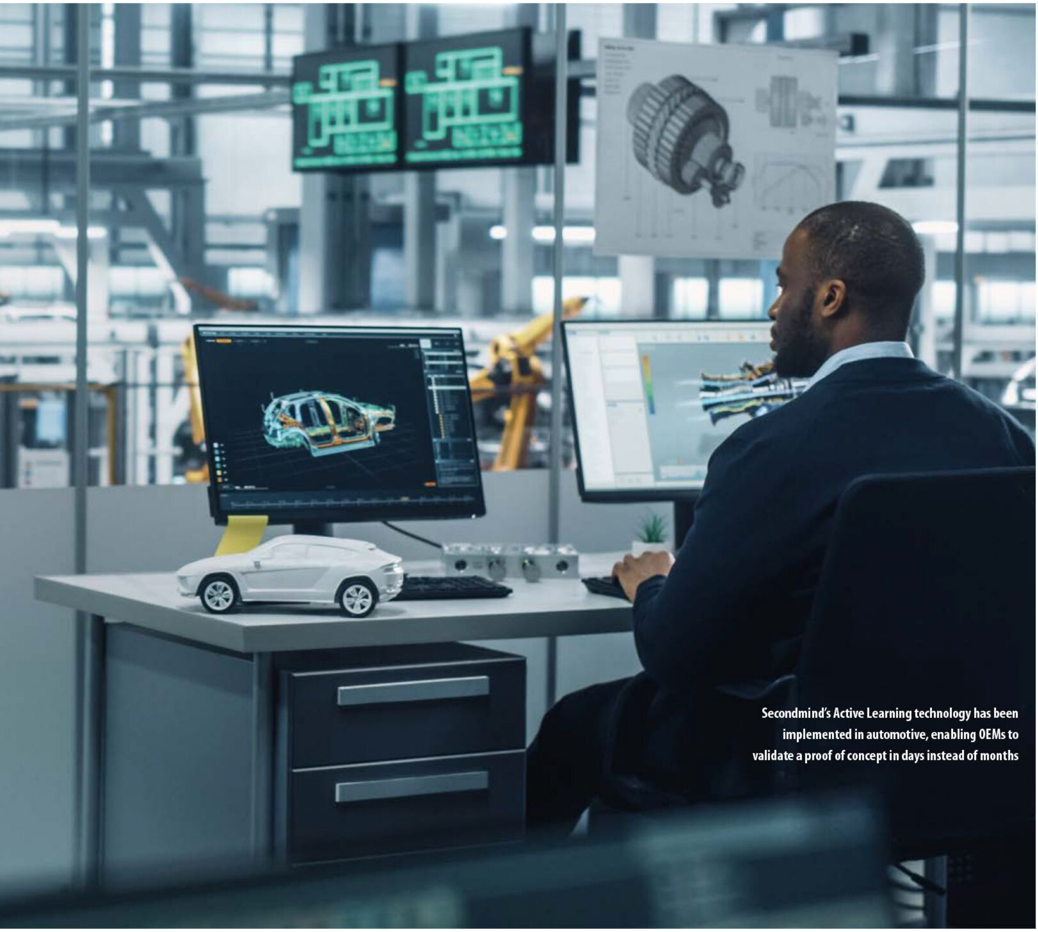
Artificial intelligence (AI) is no longer a futuristic notion of robot armies taking over the world, it has become embedded within the technology we interact with every day. Whether it is opening your 'phone with face recognition, asking Alexa the temperature outside or checking your latest Spotify recommendations, AI is accelerating our ability to consume information and operate technology more efficiently.

Although it may feel like AI has sneaked up on us over the last few years, it has been around since 1956, when the first AI program was presented by John McCarthy and Marvin Minsky at a Dartmouth College conference. Since then, the progress of AI has been somewhat of a rollercoaster.

AI is accelerating our ability to consume information and operate technology more efficiently

‘Artificial intelligence sounds like science fiction, but ultimately it is just maths’

Gary Brotman, CEO at Secondmind



Secondmind’s Active Learning technology has been implemented in automotive, enabling OEMs to validate a proof of concept in days instead of months

Data scientists would develop AI capability until they reached the limit of computing power and then development stopped, until the next advancement in computer storage and processing speed was made.

‘It seems AI has only recently been leveraged in motorsport and engineering, but actually the toolboxes in software such as Matlab use a Gaussian process, which is a machine learning modelling technique, and they have been around since the turn of the century,’ says Gary Brotman, CEO at Secondmind, a company using AI to streamline testing programmes for motorsport and automotive manufacturers.

‘The only difference is AI is now more operational and used at scales only possible due to cheaper, accessible computing power.

‘The algorithms and big data have been sitting and waiting, and now that computing capability has improved, the opportunity for AI in motorsport has exploded,’ continues Brotman. ‘Artificial intelligence sounds like science fiction, but ultimately it is just maths. There are different problems that require different mathematical equations to solve them – AI is effectively just new software.’

Although AI has been quietly underpinning simulation in motorsport for decades, there was a significant turning point in AI research in 2020 that boosted the accuracy of AI algorithms. That year, Google DeepMind released a model called AlphaFold that could accurately predict the shape of a protein, which could be thousands of molecules long, in minutes. This had never been done by a numerical method before and would normally take an entire PhD to achieve.

Key developments

'Some of the developments in AlphaFold were really quite interesting,' says Alan Patterson, co-founder of BeyondMath, which is using AI to enhance CFD in Formula 1. 'There were some new techniques around modelling accuracy in 3D space, which is something machine learning has typically not been great at.'

Another key development has been large language models like ChatGPT, which have recently hit the headlines. These can run on tens of thousands of graphic processing units (GPUs) and train on trillions of data points, enabling scalability of AI algorithms.

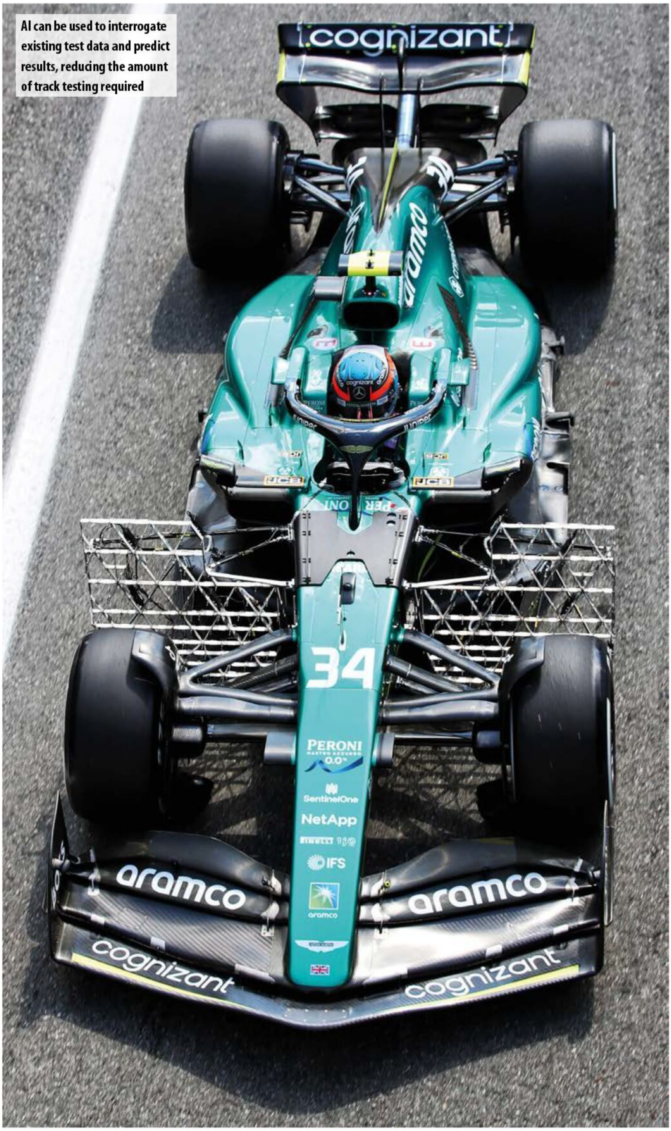
'Any kind of numerical modelling is a very compute intensive task,' highlights Patterson. 'Traditionally, it requires supercomputer power, or a large cluster of computers in the cloud, but now, with AI, we can perform this modelling on GPUs in seconds, so it's orders of magnitude faster.

'If computational biology can be done by AI models, then what about the cases in engineering where we are using Navier Stokes equations in aerodynamics and Maxwell's equations in electromagnetics? In both instances today, we run them on supercomputers to get solutions. So can we actually use AI to do a more accurate job, at larger scales in much shorter timeframes?'

What is AI?

While AI has become a common discussion topic of late, its terminology can still be confusing. For clarity, AI is essentially where machines, such as computers, simulate human intelligence. These machines use algorithms to ingest and analyse training data to establish trends, which can then be used to predict future states. In this way, AI can execute tasks and mimic human cognitive activity.

Machine learning is an application of AI that gives computers the ability to learn without being explicitly programmed. Machine learning algorithms can be grouped into three main categories: supervised learning, unsupervised learning and reinforcement learning. Within these categories are many branches of machine learning, each using a different mathematical model that the algorithms learn by.



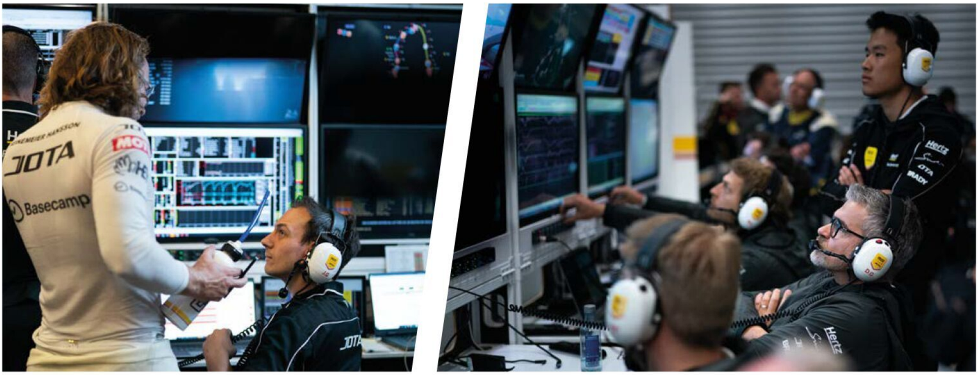
AI can be used to interrogate existing test data and predict results, reducing the amount of track testing required

'Any kind of numerical modelling is a very compute intensive task… but now, with AI, we can perform this modelling on GPUs in seconds, so it's orders of magnitude faster'

Alan Patterson, cofounder at BeyondMath


Measurement without Compromise
Gain the competitive advantage with on-car aerodynamic measurement
EvoScann® miniature pressure scanner range includes:
- Absolute or True-Differential measurement
- 8 or 16 channels of digital data
- Full-scale accuracy up to 0.1%
- Scan speed up to 1000 Hz
- Plug and play
- Small, robust and lightweight
Book a demonstration or request a quotation.
Call: +44 (0) 1264 316470
Email: enquiries@evolutionmeasurement.com
US Office: +1 512 210 2288
E: alberto.villani@evolutionmeasurement.com
EvoScann®
www.EvoScann.com


ATL
AERO TEC LABORATORIES LTD
HIGH PERFORMANCE
SAFETY FUEL CELLS
STANDARD OR CUSTOM
SAVER CELLS
RANGING FROM 10 -170L
FIA APPROVED
CUSTOM DESIGN
FIA APPROVED
CUSTOM FUEL CELLS DESIGNED & MANUFACTURED BY ATL FITTED IN FORMULA ONE AND WRC CARS
CRASH RESISTANT, EXPLOSION SUPPRESSANT & EXTREMELY LIGHTWEIGHT
CUSTOM FUEL SYSTEMS
UTILISING DECADES OF MOTORSPORT KNOWLEDGE, ATL CAN SUPPLY AN FIA APPROVED LIGHTWEIGHT FUEL CELL WITH A FULL INTERNAL SYSTEM
HISTORIC REMAKE
RETAIN THE ORIGINAL LOOK OF YOUR TANK BY SENDING US A SKETCH, 3D CAD MODEL, EXISTING OR RE-MADE CONTAINER
FIA APPROVED
FIA APPROVED
VISIT OUR WEBSITE TO VIEW OUR FULL RANGE OF PRODUCTS
WWW.ATLLTD.COM
@ATLFUELCELLS
AERO TEC LABORATORIES LTD
#ATLInside
#ATLInside
SALES@ATLLTD.COM
+44 (0) 1908 351700



Monolith AI's machine learning algorithms use existing test data to generate aeromaps, reducing the time teams like Jota Sport need to spend testing at the track and in the wind tunnel

These branches include neural networks, deep learning, decision tree, Bayesian and regression. There are then several variations of the mathematical models within these branches, and more are discovered every year.

Streamlining data

So, what benefit can AI bring to motorsport? The biggest application lies in data analytics. As motorsport has pushed the boundaries of sensor technology over the last decade, the amount of data a racecar can capture is phenomenal. A modern Formula 1 car is instrumented with around 250 sensors that transmit over 30MB of live data every lap, and 60 to 90MB when the data is downloaded off the car in the garage. That means that over a typical race weekend, the total amount of data generated by a single car is over 1TB.

Big data is now as important to the likes of Formula 1 as aerodynamics was 20 years ago.

'Ironically, too much data can actually be a problem and get in the way of efficient development,' says Brotman. 'Today's racecars are so complex that the number of parameters that need to be considered when improving car performance leads to an abundance of data that is impossible to process manually. This is where machine learning comes in because it can filter through these vast data sets and identify the most valuable data points, helping engineers to focus on the most relevant data.

'This is particularly useful when you are constrained by time, cost and computing power because teams have to find ways of extracting more from less data.'

Reduced testing times

This approach of utilising AI to streamline data has proven extremely useful in testing programmes, whether that be wind tunnel testing, track testing or powertrain testing, all of which are now heavily limited by the regulations. Machine learning techniques can filter data and identify the next optimisation point faster, helping teams to extract more value from tests, cutting testing times.

'If you had all the money and computing resource in the world, you could test every possible permutation, but you will reach a point of diminishing returns,' says Brotman. 'Data brings a lot of fidelity, but it comes at a cost of time and compute resource.

'Take aerodynamics as an example. It is a very non-linear, complex problem to optimise for and in Formula 1 the regulations limit the amount of wind tunnel and CFD time the teams at the top of the championship can use compared to the teams at the bottom. This constraint, along with others such as cost, adds dimensionality to this technical problem.

'To help solve this, we use an iterative approach to help teams reach the optimum point faster so they can maximise their allocated testing time.'

Secondmind's Active Learning technology uses the Bayesian optimisation machine learning technique that utilises the Gaussian process at its core. These algorithms take a subset of sampling data, which is used to train a model. This model then identifies the next place to sample and, with every iteration, the model becomes more 'intelligent' and closer to the optimum result. This allows the algorithm to reach a highly precise outcome quickly, without having to analyse the entire body of data. In most cases, this approach reduces the amount of data needed by 80 per cent or more, which equates to a huge increase in efficiency.

It's not just Formula 1 that is benefiting from reduced testing times. Sportscar team, Jota Sport, has partnered with Monolith AI to develop self-learning models that can predict results from wind tunnel tests and track tests, helping to reduce aerodynamic testing by up to 80 per cent and car set-up time by around 50 per cent.

'[Engineers] can define the exact output performance they want, and AI can establish what the input parameters need to be. This avoids testing for unnecessary iterations'

Sam Emeny-Smith, head of automotive at Monolith

'Teams can run simulations, but they can't be 100 per cent confident in the results, so they conduct iterative tests at a racetrack until they run out of time or money,' explains Sam Emeny-Smith, head of automotive at Monolith. 'There are three major opportunities where AI can help engineers make more informed decisions from test data. The first is to interrogate existing data sets. This allows teams to better understand the interdependencies between all the different variables, as well as the entire design space, without having to test every condition.'

Working backwards

'Secondly, self-learning models can use this data to predict the results of tests that have never been completed, again saving time and resource. Finally, AI allows engineers to work backwards. They can define the exact output performance they want, and AI can establish what the input parameters need to be. This avoids testing for unnecessary iterations.'

Monolith's software essentially takes existing data and uses machine learning techniques, such as regression models, neural networks and deep learning, to fit complex equations to that data. Although machine

learning doesn't necessarily appreciate the physics that underpin the data it is optimising, because the models are based on real data, the laws of physics are inherent within the data and therefore captured by the model. The platform is hosted on the cloud and, interestingly, has no code. This allows any engineer to leverage the benefits of machine learning, without having to be an expert data scientist.

'One of the main ways the race engineers at Jota have used our platform is to streamline the aero mapping and set-up of the car,' explains Emeny-Smith. 'Our machine learning algorithms use existing simulation and test data to develop models that allow the engineers to interrogate the aeromap for different track and weather conditions. So, instead of the laborious task of measuring drag and downforce at different ride heights to generate an aeromap, machine learning can achieve this in a much shorter time and with higher fidelity, whilst allowing engineers the time to optimise this aeromap for different circuits and conditions.'

AI-powered CFD

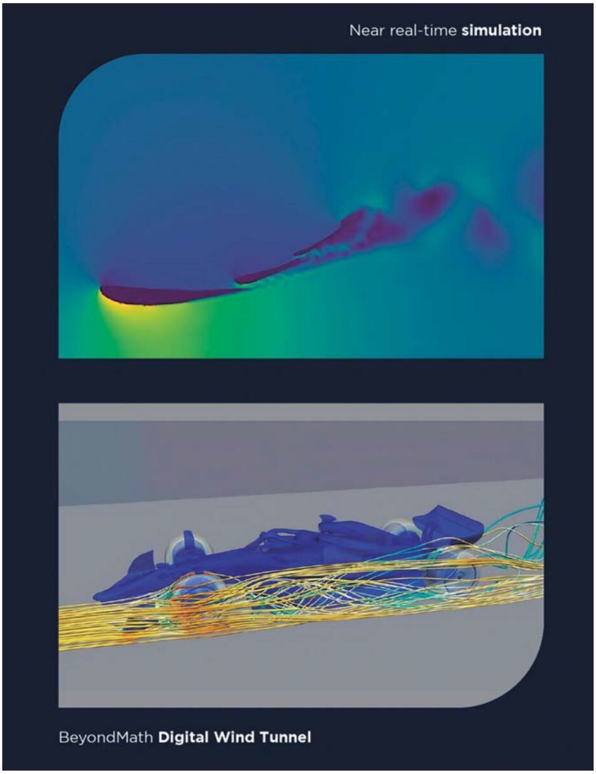
AI could even replace some of the conventional forms of both virtual and physical testing all together. A young start-up called BeyondMath has been working with one of the major Formula 1 teams on developing a machine learning model for aerodynamic simulation that has the potential to eventually replace CFD and wind tunnel testing altogether.

BeyondMath is developing a digital representation of a wind tunnel where models are uploaded into 3D space and the aerodynamic behaviour around the model is calculated, similar to current CFD practices. However, because AI is used to calculate the aerodynamic measurements, there is no need for the model to be meshed. This means that the user can modify the geometry of the model and the aerodynamic results will update in real time, enabling multiple configurations to be tested in minutes.

To achieve this in conventional CFD, each configuration would require a new geometry that has to be re-meshed and run through the simulation again, which can take days.

'In CFD, the airflow is predicted by numerically solving the governing Navier Stokes equations,' explains Patterson. 'To do this, you need to calculate the finite difference across cells, which is why CFD models need to be meshed. Whereas machine learning models are function approximators, so they learn a function.

'We still have to specify the fields it needs to calculate, but we can ask for those field values at any points in space, it doesn't need those points to compute the prediction. So the models in our software can be meshless.'



BeyondMath's aerodynamic software uses meshless models because machine learning algorithms are function approximators, so don't need cells to calculate finite differences

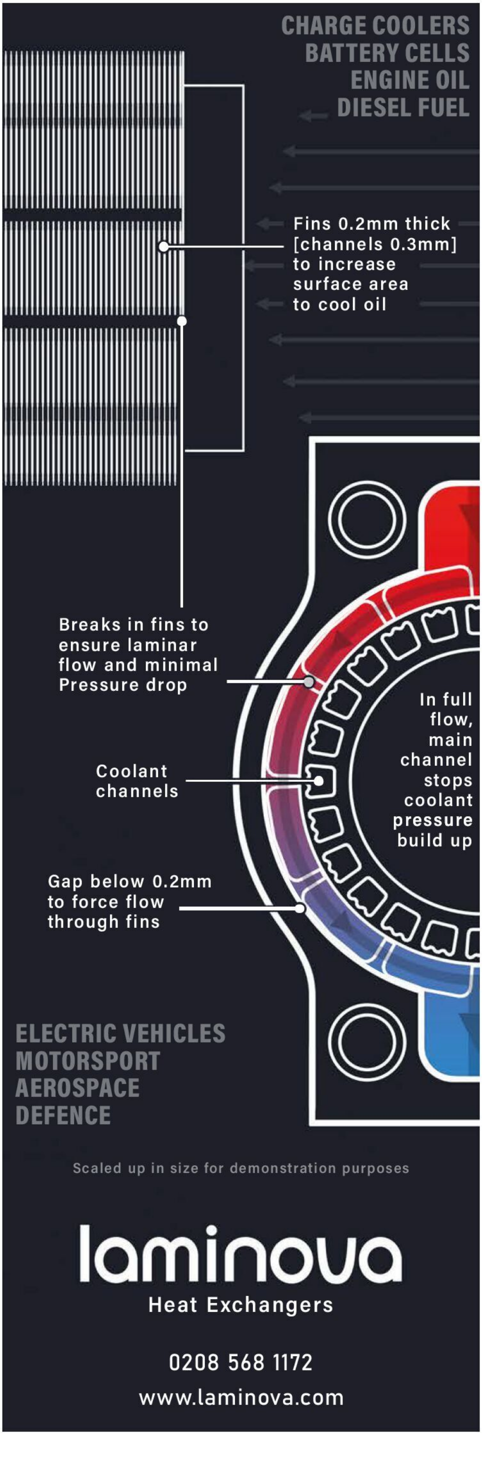
Enabling aerodynamicists to understand the effect of different designs more quickly not only streamlines the development process but also ensures they are prioritising their wind tunnel and CFD time on the most effective designs. This has become particularly important over the last few years as the regulations now scale the allocated time spent on wind tunnel and CFD compute resource according to championship position. Consequently, teams at the top receive less resource than teams at the bottom and are therefore hunting for new ways to maximise the efficiency of aerodynamic development.

Multi-benefits

'The first application we are providing is a fact assessment of designs,' continues Patterson. 'An F1 team might want to increase downforce or minimise drag on a particular component and they could have 10 different ideas of how to modify the geometry to achieve that. Our virtual wind tunnel allows them to quickly test those 10 geometries and gain an understanding of the aerodynamics. They can then identify the designs that show the most potential and run those in a full CFD simulation or wind tunnel test.'

Another benefit of using AI in aerodynamic testing is that as well as optimising for aerodynamics, machine learning can also optimise for the multi-physics of the material, too. Currently, engineers use CFD to simulate the aerodynamics of a part and FEA to simulate its structural integrity. They then have to cross-check these results against each other to establish the optimum design.

A machine learning model for aerodynamic simulation has the potential to eventually replace CFD and wind tunnel testing altogether


CHARGE COOLERS
BATTERY CELLS
ENGINE OIL
DIESEL FUEL
Fins 0.2mm thick [channels 0.3mm] to increase surface area to cool oil
Breaks in fins to ensure laminar flow and minimal Pressure drop
Coolant channels
In full flow, main channel stops coolant pressure build up
Gap below 0.2mm to force flow through fins
ELECTRIC VEHICLES
MOTORSPORT
AEROSPACE
DEFENCE
Scaled up in size for demonstration purposes
laminova
Heat Exchangers
0208 568 1172
www.laminova.com


BREDA RACING REFUELLING SYSTEMS
CE CERTIFIED
Breda Racing
for our complete equipment range please visit
bredaracing.com
or contact us at info@bredaracing.com

'Machine learning makes it possible to model the aerodynamics of a part as well as the stress, flex and even temperature of the material, all in one simulation,' says Patterson.

The other challenge with aerodynamic testing is correlation. Invariably, there is a margin of error between CFD results, wind tunnel tests and on-track tests, which means engineers have to focus more on trends rather than absolute numbers. Artificial intelligence has the potential to minimise these errors because data from real wind tunnel and track tests can be used to fine tune the machine learning algorithms.

'Machines learn by loss functions, which is a way of evaluating how well a specific algorithm models a set of data,' explains Patterson. 'If predictions deviate too much from the actual results, the loss function value will be high but, if the loss function value is low, then the model will provide representative results.

'During optimisation, the algorithms will try to reduce this loss function to zero.

'You can have numerous loss functions, so you can train the model to understand the physics simulations, as well as real data from wind tunnel or track tests, and it will then optimise for both. This results in an AI simulation that is extremely fast, but also produces results that are more closely correlated with real measurements.'

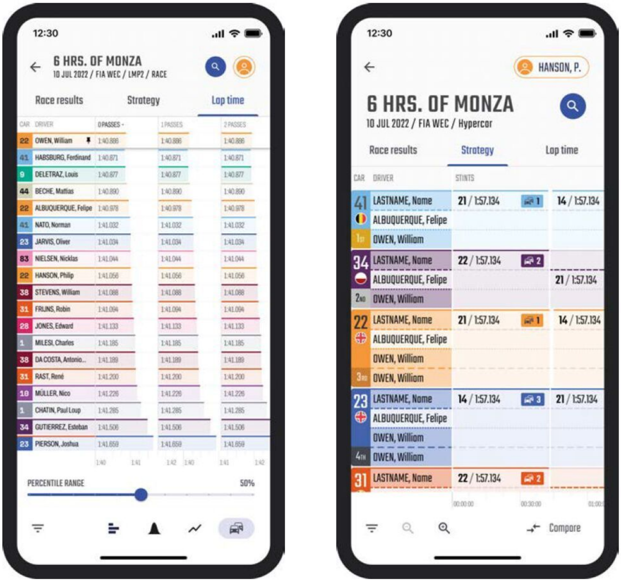
Enhancing history

Alongside the data measured on the car, AI can also be utilised to extract more information from timing and scoring data. Often, this data is relatively limited, both in terms of the type and amount of data recorded. This is particularly true when it comes to historical data from previous races.

'If you wanted to see what happened in an ELMS race 10 years ago, but your team didn't attend the event, then there is very limited information available to you,' explains Toni Calderon, chief growth officer at Valkyrie, who has partnered with endurance racing team, United Autosports.

'We realised that the low hanging fruit was using AI to enhance years of historical timing data, which can then be used to determine the performance trends of other teams and drivers. Engineers have access to the data of their cars, but competitor data has to be extracted from timing information. Having this additional layer of knowledge can help inform engineers when making race strategy decisions.'

A common piece of detail missing from timing data is flag information, which can be used to understand traffic situations on track during a race. With three to four classes in most endurance races, traffic is a major consideration for engineers when determining the optimum race strategy.



The Valkyrie DAG AI app uses algorithms to detect traffic information and enhance performance metrics that engineers can use to make more accurate strategy decisions. It is being developed in partnership with Very Good Venture

> **'Regardless of the championship, size or budget, every race team wants to accomplish more in the least amount of time and for the minimum amount of money, and AI is the key to achieving this'**
>
> *Toni Calderon, chief growth officer at Valkyrie*

'Quantifying traffic is extremely important because a lot of major decisions depend on this,' confirms Calderon. 'For example, a driver's performance is often based on stint averages but, if a driver encounters lots of traffic, their performance will appear reduced, even though this is not necessarily the case. The engineer could then use this to change stint lengths, which may compromise the overall race strategy.'

Valkyrie has developed algorithms that can detect all sorts of information from historical timing data, which can then be used to calculate performance metrics. For example, the 'Valkyrie Pace Score' is based on a proprietary algorithm that essentially normalises the performance of a driver regardless of the track conditions, traffic, car class, and track. This is all accessed by Valkyrie's DAG AI platform, which is being developed with partner, Very Good Ventures, that allows engineers to essentially moneyball drivers and teams.

The next stage is to develop this software to plug into the various strategy tools that teams currently use, to help inform those simulations with more information.

Arms race

'It's clear that the next arms race in motorsport is around exploiting the capabilities of AI,' concludes Calderon. 'Regardless of the championship, size or budget, every race team wants to accomplish more in the least amount of time and for the minimum amount of money, and artificial intelligence is the key to achieving this. But fully integrating AI within a team will require a re-structure of both the hierarchy of the team and the workflows within it.

'We are already seeing numerous positions open up for data scientists within race teams, and I think this will become common in the majority of teams over the next few years. I just hope that traditional engineers remain open-minded to AI because it has the power to help them operate more efficiently, and we are only now scratching the surface of its potential.'

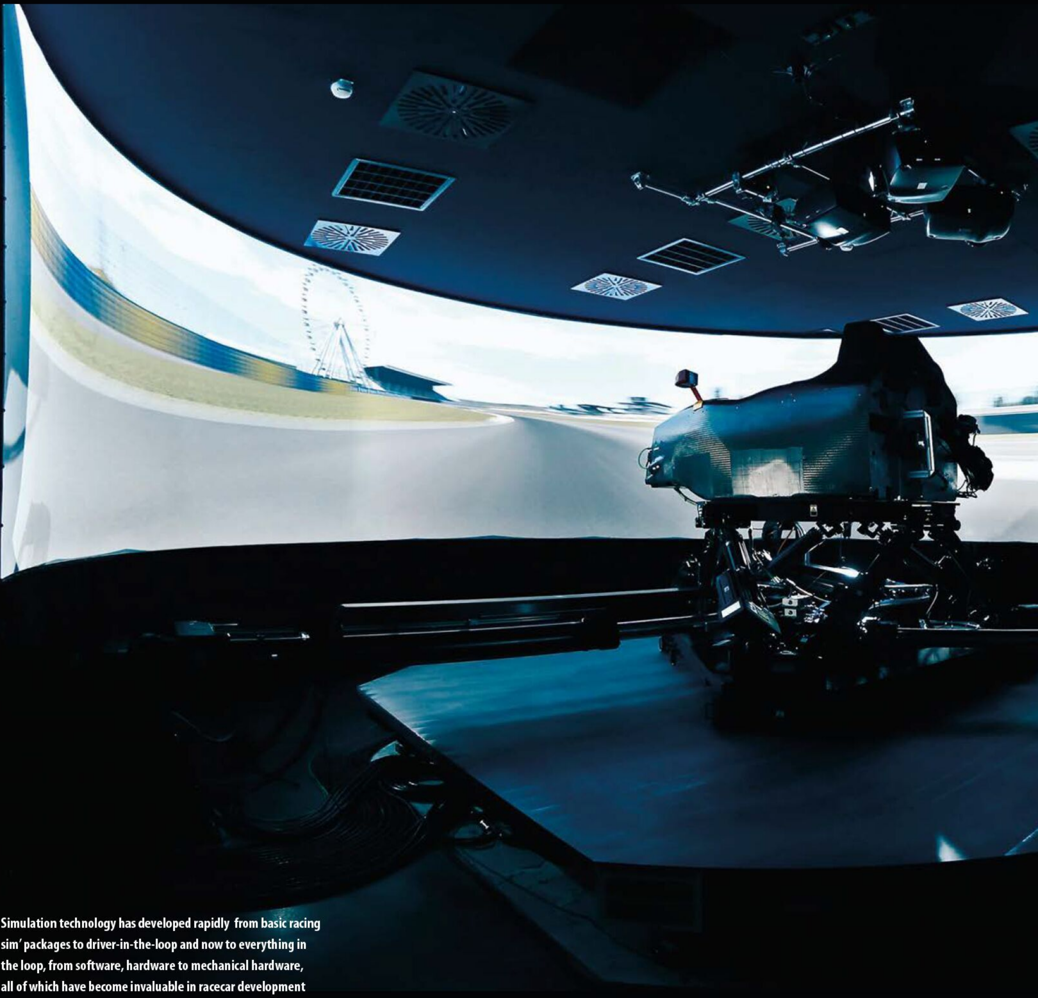

ARE DRY SUMP SYSTEMS
"Products Engineered With a Passion"
Everything Dry Sump!
MINI MITE DRY SUMP PUMP
LS7 Stage III
6 Patents!
"One of the most exciting developments uncovered in research... The new Passive Air/Oil Separator... Providing a double benefit to overall oil system..."
David Cooper- Race Engine Technology
Nissan SR20 Kits
NEW! ARE's "Patented" "Atmospheric Vent Can" 2 sizes available.
ALL NEW! "AXIAL FLOW SPINTRIC" AIR/OIL SEPARATOR
9 Varieties of LS 1-7 Dry Sumps
Over 3000 Sold!!
Subaru Kits
1005M
1009
GTM
WWW.DRYSUMP.COM
916.652.5282
WWW.SPINTRIC.COM
SEE US AT PRI INDY AND AUTOSPORT ENGINEERING


LifeCheck
STAY ON TRACK AND DRIVE UP PERFORMANCE
Intuitive Part Lifing and Management software provides:
• Reliability and results
• Safety reassurance
• Reduced costs
Let LifeCheck manage your Component lifecycle while you concentrate on the racing
For further information contact
trenchant-tech.com/lifing
To book your FREE demo of LifeCheck call:
+44 (0)1724897318
Or email
sales@trenchant-tech.com
MIA MOTORSPORT INDUSTRY ASSOCIATION MEMBER

X marks the loop

Racecar *investigates the latest advances in simulation, and how in-the-loop testing is bringing together all aspects of racecar design and development*

By LAWRENCE BUTCHER



Simulation technology has developed rapidly from basic racing sim' packages to driver-in-the-loop and now to everything in the loop, from software, hardware to mechanical hardware, all of which have become invaluable in racecar development

The boundary between the virtual and physical world is constantly evolving and becoming ever more blurred. Nowhere is this truer than in the realm of the development and testing of vehicles, both in mainstream automotive and motorsport. The virtualisation of testing through simulation and modelling allows for much expensive physical prototyping to be avoided, and is now a necessity in many current racing series, thanks to extensive restrictions on track testing.

However, there is only so much that can be achieved in the purely virtual domain, and the sooner physical components can be introduced into the picture the better. This is where X, or everything-in-the-loop testing, comes into play. Put simply, it's the integration of physical and software components into models and, not to be forgotten, the driver.

Various in-the-loop testing methods have been commonplace in racing for years, but the arrival of electrified powertrains has increased their importance considerably. Racecars are now heavily software dependent. Thirty years ago, there was only really an engine and its associated ECU to worry about. Now some cars incorporate multiple motors, inverters and battery systems in addition to the ICE, as well as elements such as brake-by-wire systems. Ensuring these are singing together in perfect harmony requires a system level approach to simulation and testing.

To complicate matters further, the various hardware and software elements invariably become available at different stages in the development process, and this is where hardware and software-in-the-loop testing can be invaluable in proving out these complex systems well in advance of the car hitting the track.

SILS, HILS and MHILS

The various branches of in-the-loop simulation can be divided into three main categories: software, hardware and mechanical hardware-in-the-loop. Add to this driver-in-the-loop, with the possibility to combine these various approaches.

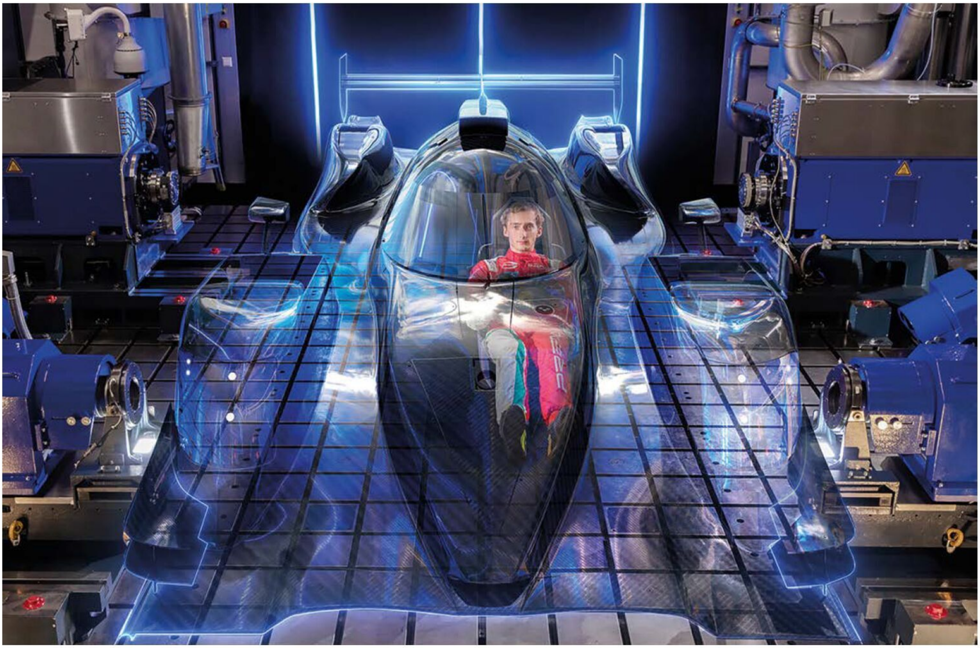
Software-in-the-loop simulation (SILS) is where the control code of a device, such as an engine control unit (ECU), is tested using a simulation model. In this case, the model represents an engine – which can be relatively simple or highly complex, including elements such as combustion modelling – and provides inputs to the control unit software, which responds as if it were being run by the control unit.

The outputs generated by the software are then fed back into the model. This enables checking and modifying the functionality of the control software, as well as investigating the impact of refinements on the overall operation of the model and the final, physical engine.

A crucial aspect of this simulation is the availability of a flexible computing resource that can replicate the functionality of a fully developed embedded controller. These dedicated units, known as target machines, are essential for running control designs that will eventually be implemented in an embedded control unit.

During the initial testing phases, before committing to building an embedded controller, it is advantageous to have a more adaptable platform that allows easy addition of input / output (I/O) and protocol support.

This sophisticated approach allows engineers to come as close as currently possible to replicating a car's on-track performance, and gain a comprehensive understanding of the intricate interactions between the numerous on-car systems



Modelling the driver has traditionally been one of the most challenging parts of simulation, so integrating a driver simulator as part of the whole vehicle model can yield significant benefits

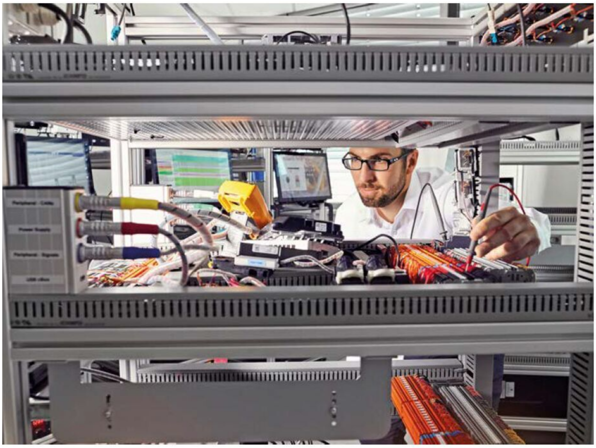
When working with an ECU, the control code is initially designed based on a model and, once it is deemed satisfactory in a desktop simulation, the code (C code) is created and executed on a target machine acting as the ECU. This approach significantly accelerates the development process.

If one were to start with the embedded controller, the process would not only take longer, but the controller would only have the specific I/O it was built with. With a target machine, the ability to add or remove I/Os is readily available.

Hardware-in-the-loop simulation (HILS) takes this concept further by incorporating hardware components into the simulation loop for complete assemblies. Instead of running the control software on a target machine in conjunction with the model, the entire control unit is integrated into the model. The control software is executed from the control unit, and all the inputs and outputs function as if the controller were running an engine.

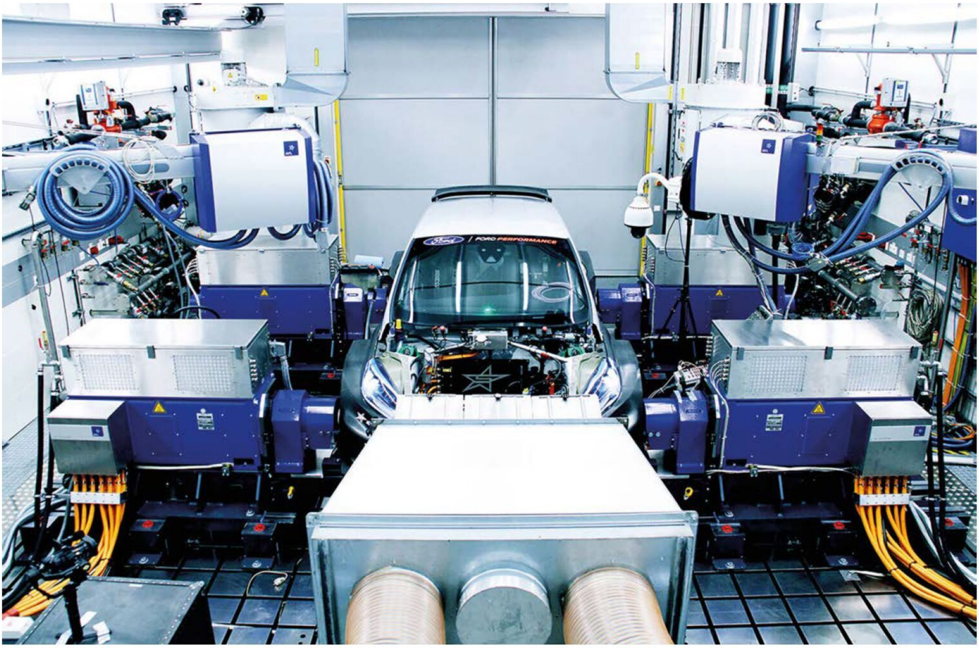
Dedicated sensor simulators generate the various inputs for the controller, providing either analogue voltages or digital signals based on the model's behaviour. The advantage of this approach is that it allows thorough testing of a controller without the need for it to be physically connected to the device it is intended to control. This flexibility proves beneficial for various purposes.

Firstly, HILS enables the simultaneous development and testing of devices and controllers, thereby reducing lead times, especially when the device to be controlled does not yet exist. Secondly, it is often preferable to avoid testing a new and unproven device on a potentially expensive component. For instance, in the context of



Hardware-in-the-loop simulation (HILS) integrates physical components of the racecar-into the process

It is better to have a virtual engine failure caused by a controller than risk a physical engine failure in the dyno cell



Whole vehicle model testing, as the name suggests, encompasses all elements that affect performance, and can be derived from offline simulations or real-time models, as here at AVL Racetech

Formula 1 power units, the cost of a failure caused by a controller error, such as in the case of the MGU-H, can be significant. It is better to have a virtual engine failure caused by a controller than risk a physical engine failure in the dyno cell.

Moving beyond electronic controllers, mechanical-hardware-in-the-loop simulation (MHILS) extends the concept of HILS to a mechanical level. MHILS allows not only the use of electronic controllers, such as ECUs, as integral parts of a simulation model, but also the introduction of complete mechanical assemblies as inputs to drive the model. This approach ensures the physical behaviour of a system aligns with its modelled behaviour. When incorporated into a larger model, MHILS has the potential to improve the accuracy and resolution of the model's results.

Whole vehicle model

Consider the example of a real-time whole vehicle model. In simplified terms, the model consists of multiple smaller blocks, some derived from offline simulations such as an aerodynamic map, while others are independent real-time models, an example being suspension kinematics. The overall model encompasses all elements that affect vehicle performance, including the powertrain, suspension, brakes, tyres and aerodynamic loads.

One of the common applications of HILS is the integration of a driving simulator into the modelling environment. These simulators serve as valuable engineering tools for teams, extending beyond driver training. All current Formula 1 teams have their own in-house simulator, or access to one through a technical partner.

Historically, modelling the driver has been one of the most challenging factors, particularly when it comes to set-up changes that impact the car's driving characteristics. A change may theoretically make the car faster, but if it alters its behaviour in a way the driver cannot control, it becomes practically useless. Therefore, integrating a driving simulator as part of a car model yields significant benefits, and it is a common application of hardware-in-the-loop simulation methods. Effectively, the vehicle model responds to the driver's interactions with the steering, throttle and brakes, and the model's outputs provide the driver with a realistic response that mirrors the sensations experienced in a real car.

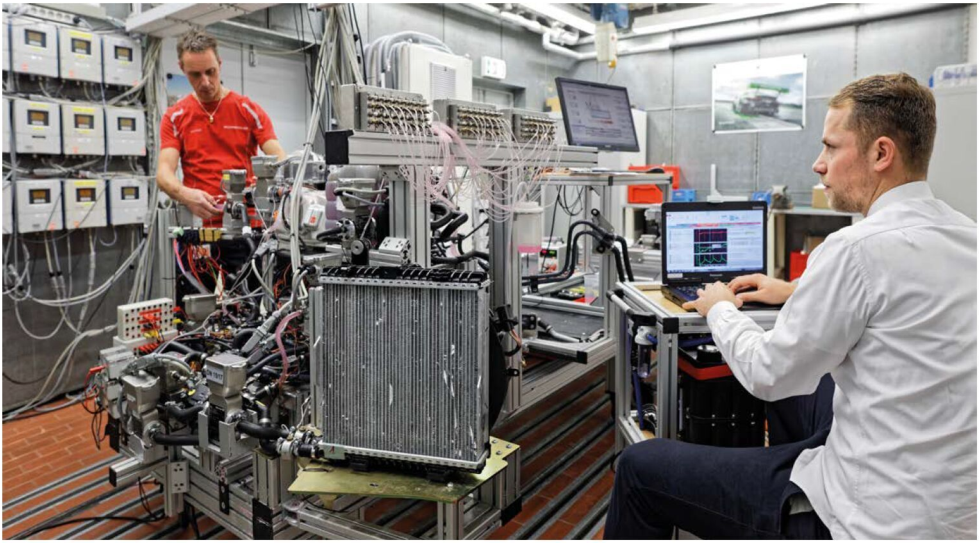
Mechanical elements

While having a driver-in-the-loop simulator integrated into a team's simulation and modelling programme brings significant benefits, the integration of other challenging-to-model components as physical parts can offer even greater advantages.

Consider the example of a suspension model. Initially, this model would be developed mathematically and validated using data obtained from a combination of rig testing and, where feasible, track data. This validation process ensures factors like compliance, spring rates and geometry changes align with expectations. By adopting a MHILS approach, the suspension model can be replaced with the actual physical suspension system running on a rig within the overall vehicle model.

The complexity of an MHILS set up can vary depending on the specific scenario. For instance, it can range from representing a single element of the suspension, such as the dampers, to incorporating an entire vehicle chassis. In the former case, the dampers would be placed on individual damper dynos, which are instrumented to record damper performance. The dynos can drive the dampers by conducting sweeps at different rates, or by following a map of an actual circuit. The data generated by the dynos is then fed back into the vehicle model, replacing the damper model with a simple force input.

How complex an MHILS can be is limited primarily by the capabilities of available computing resources, the ability to maintain low latency between different system elements and the financial resources of

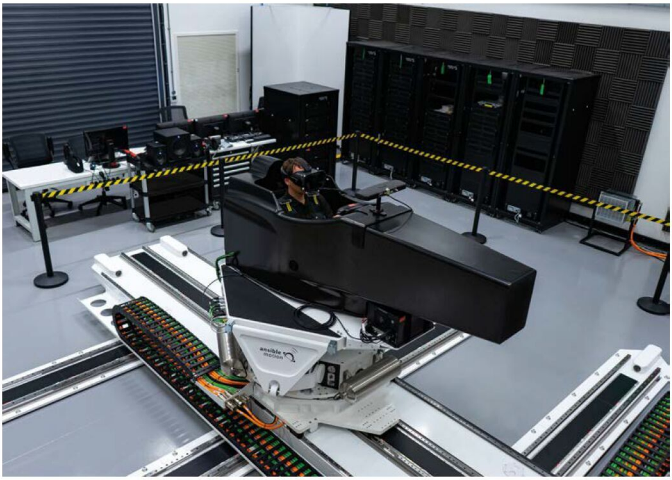


With track testing strictly limited, and expensive should a component go wrong, incorporating real systems and control units in a network with digital prototypes offers many advantages

the team conducting the testing (as this hardware is costly and requires extensive code development by engineers). While mathematical models can be highly reliable, the intricate nature of modern racecars necessitates physical testing of components to ensure their performance.

By integrating these physical parts into a team's modelling environment, the reliability of the outputs can be significantly improved, ultimately leading to enhanced performance and reliability on the track.

Formula 1 teams are embracing this approach, with several reportedly employing exceptionally complex systems that involve the entire car and powertrain running on a full chassis dyno, incorporating a seven-post rig and engine dyno. This sophisticated approach allows engineers to come as close as currently possible to replicating a car's on-track performance, and gain a comprehensive understanding of the intricate interactions between the numerous on-car systems.



Formula 1 teams, in particular, are embracing simulation, using or building increasingly complex systems (Ansible Delta S3 HILS shown)

Target machines

Having dedicated computing resources capable of running algorithms at the required speeds is essential for conducting the real-time simulations in-the-loop testing relies on, whether they involve software or hardware. These specialised computing units are known as target machines, and are designed to handle complex modelling algorithms quickly enough to run in real time.

A target machine is essentially a computer optimised for running these algorithms. They are often highly configurable, allowing for the addition of multiple input and output modules. Additionally, they are equipped with complex multi-core processors and support for various I/O interfaces such as CAN links, fibre optic links and Ethernet, as well as analogue connections.

In cases where there is a need to run a complex model, such as a hybrid system, multiple target machines can be employed to serve as individual controllers within the system. For instance, one target machine may be dedicated to the battery, while another

A target machine is a computer optimised for running [modelling] algorithms. They are often highly configurable, allowing for the addition of multiple I/O modules

VI-grade's AutoHawk is a flexible, highly configurable hardware-in-the-loop platform that can be used across the entire product development cycle

Simulation has always been a slave to computing power, but with the huge advances on that front in recent times, together with more affordable tools on the market, even those of modest resource can now realise the very real benefits of in-the-loop testing

handles motor control. These target machines can be interconnected through a low-latency data link, utilising shared memory resources and fibre optic links for seamless communication between them.

Furthermore, target machines find another use in HILS scenarios, particularly when a finalised embedded controller requires testing. Instead of developing control algorithms in packages such as Simulink, a model is created to simulate the component or factor influencing its operation, such as an aerodynamic map. From this model, C code is generated, which can then be executed on a target machine. The target machine processes the code while incorporating the necessary I/O interfaces to control the components under test, such as an ECU, or even a motion control platform for a driver simulator.

Neural networks

An interesting recent advancement involves the utilisation of neural networks in lieu of traditional models, offering the advantage of reduced computational requirements. Neural networks are particularly valuable in simplifying complex physical models. For instance, in an engine simulation model, the combustion process sequence can be derived from the control signals of the ECU. The simulation generates output variables such as torque and sensor signals, which are then fed back into the ECU. By employing a neural network, these output values no longer need to be computed using a physically accurate model. Instead, the neural network provides the real-time outputs.

To achieve this, the network is initially trained using data obtained from either a prototype engine or a more complex, offline model, which cannot be executed in real time.

Another notable evolution is the harnessing of cloud-based resources for X-in-the-loop testing. This means that whereas previously, the hardware, software and associated computing capacity had to be in the same location, this is no longer the case. Models can be hosted on the cloud, allowing them to utilise scalable processing power when needed, while the hardware can be in one place and the software engineer in another.

While this is arguably of greater benefit in automotive, it is also applicable in racing. Take, for example, the development of the current generation of LMDh cars, where chassis and powertrain partners can be on different continents to their manufacturer customers. Cloud capabilities allow these teams to work on every element of the package together, but remotely.

The electric revolution

As noted, the electrification of racing has raised the profile of x-in-the-loop simulation techniques. One area where they are particularly relevant is the development of battery management systems (BMS) at both a software and hardware level.

BMS are complex and are responsible for balancing the demands of the powertrain (motor and inverter) against the needs to the battery. They monitor battery state of charge (SoC), thermal profile and a host of other parameters and must be able to react to any anomalous behaviour to keep the battery within safe operating boundaries. Testing a BMS on a live battery could be a risky business, so HILS testing is relied upon heavily. This entails testing the BMS using a dedicated system that incorporates a real-time model of the battery pack from a cell level upwards. The operation of the BMS can be simulated through every conceivable situation and its impact on the battery analysed. This process can be used for both the software and, once available, the hardware the software will be run on.

Models can be hosted on the cloud, allowing them to utilise scalable processing power when needed, while the hardware can be in one place and the software engineer in another

Upping the complexity, other hardware elements can be brought into play, such as the inverters and motors. Using a battery cell emulator (version are available that can provide the exact power delivery profile of even very high voltage packs), the powertrain can be run in real time with the emulator reacting precisely as the real battery would.

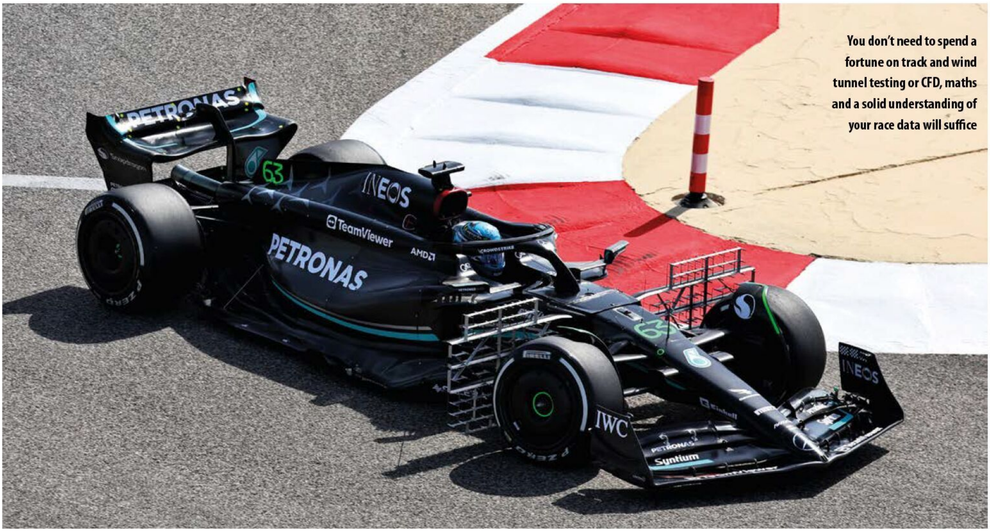
One particularly interesting application of this type of approach is when coupled with a driver-in-the-loop simulator. Formula E teams, for example, will run simulations where the ECUs that monitor energy management are tested with a driver also in the loop in preparation for a race. This is done in order to determine the best energy strategy, encompassing both the driver's and the ECU's role in the process.

Formerly the preserve of only the most well-resourced teams and manufacturers, the prevalence of tools on the market mean that even those of modest resource can now harness the benefits of in-the-loop testing. This can range from the use of a relatively basic, static driver-in-the-loop simulator as part of a vehicle development programme, through to harnessing cloud-based target machines and easy to operate user interfaces to assess hybrid and electric drive systems. R

'Map reading

The essential engineering practice of aeromap generation, part one

By DANNY NOWLAN



You don't need to spend a fortune on track and wind tunnel testing or CFD, maths and a solid understanding of your race data will suffice

XPB

One of the most essential yet overlooked skills of any performance data / race engineer is the ability to generate an aeromap. Yet time and time again I see this important skill atrophied or, worse still, engineers and team owners buying into the myth that the only way you can have a useful aeromap is if the manufacturer of the car gives it to you, or you spend a fortune on wind tunnel testing and / or CFD. This month, I'm here to tell you nothing could be further from the truth, and I'll show why in this article.

Experience counts

Before we discuss this in depth, though, it's worth noting that all of what we will be talking about is based on hard-won experience. I've also discussed this subject informally in the ChassisSim bootcamps, so figured now it was time to write this all down.

The first elephant in the room we need to address is how we can generate aero data from race data. To do so, go back to your fundamentals, and nothing encapsulates that better than the beam pogo stick visualisation of the racecar, as shown in **figure 1**.

This cuts through all the nonsense and gets straight to the point. Where the aeromap comes from is a force balance from the above. That is not magic, it pops straight out with a static force balance.

So, now that we have established where this comes from, how do we quantify it? The answer is simple. Every damper pot on the car is a load cell, and the numbers come from that shown in **equation 1**.

$$F_S = \left(k\left(x_s\right) + c\left(\dot{x}_s\right)\right) \cdot MR \qquad (1)$$

Where,
F_S is the force of the spring damper unit at the wheel
x_s and $\dot{x}_s$ is the movement and velocity of the spring
k is the spring rate or function
c is the damper rate or damper function specified at the damper
MR is the motion ratio of the spring expressed as damper / wheel movement

It is assumed the zero of the spring function is when the car is on the ground, but in most cases the spring function, k, is a spring rate. If bump rubbers are used, the spring function, k, can be easily deduced by a look-up table.

If you are fortunate enough to have strain gauges fitted to your car, then all the hard work in **equation 1** has been done for you.

Now the spring force has been determined we need to determine tyre deflection. In the absence of laser ride height sensors, this is given by **equation 2**.

$$w_m = \frac{F_S}{k_t} \qquad (2)$$

Where,
k_t is the spring rate of the tyre

Once we have this, we can now calculate the ride heights using **equation 3**.

$$rh_f = rh_{f0} - \frac{d_1 + d_2}{2}$$
$$rh_r = rh_{r0} - \frac{d_3 + d_4}{2} \qquad (3)$$

Where,
rh_{f0} and rh_{r0} are the initial ride heights

Granted, there are things that can make this a bit tricky, such as tyre spring rates varying with load and speed, but that will give you everything you need to know to calculate what is going on with your ride heights in a nutshell. Once you understand that, everything else falls into place.

Now that we understand the how and why of how to calculate downforce, we need to understand what we get back from race data. So, when you analyse ride heights from race data, whether it be a lap or from straight line running, you get a thin sliver of the aeromap back. This is illustrated in **figure 2**.

The crucial bit here is that you get a line back from race data. That line is great for comparing downforce levels from one configuration to another. It also gives you a good indication of pitch sensitivity. Where it falls flat on its backside is you can't create a ride height map from this. There is simply no way you can create a surface from a line. This is the reason I turned off the one touch aero modelling in ChassisSim, though I regard that as one of the biggest missteps of my career.

Smart test plan

The good news, however, is that we can deal with this effectively via a smart test plan, as outlined in **table 1**.

Where,

frh_0 = baseline front ride height as specified in the starting set-up

rrh_0 = baseline front ride height as specified in the starting set-up

d_rrh = delta rear ride height

d_frh = delta front ride height

The deltas you choose will depend on what the racecar is. For example, for an open wheeler / sportscar, these might only be in the order of 5mm, whereas for a touring car they could be around 10mm. As a rough rule of thumb, choose the delta where you know it will have an effect on the car.

The goal of tests one to six is to establish a pitch sensitivity map. The goal of tests seven to nine is to assess variation in downforce levels.

Table 1: Aero test procedure for a Sportscar

Run no.	Set-up
1	frh_0 and rrh_0 + baseline rear wing
2	frh_0 and $rrh_0 + d\_rrh$ + baseline rear wing
3	frh_0 and $rrh_0 + 2*d\_rrh$ + baseline rear wing
4	frh_0 and $rrh_0 + 3*d\_rrh$ + baseline rear wing
5	$frh_0 - d\_rrh$ and rrh_0 + baseline rear wing
6	$frh_0 + d\_rrh$ and rrh_0 + baseline rear wing
7	frh_0 and rrh_0 + baseline rear wing
8	frh_0 and rrh_0 + baseline rear wing + 2 holes
9	frh_0 and rrh_0 + baseline rear wing + 3 holes

As a rough rule of thumb, choose the delta where you know it will have an effect on the car

Figure 1: The beam pogo stick visualisation of the racecar

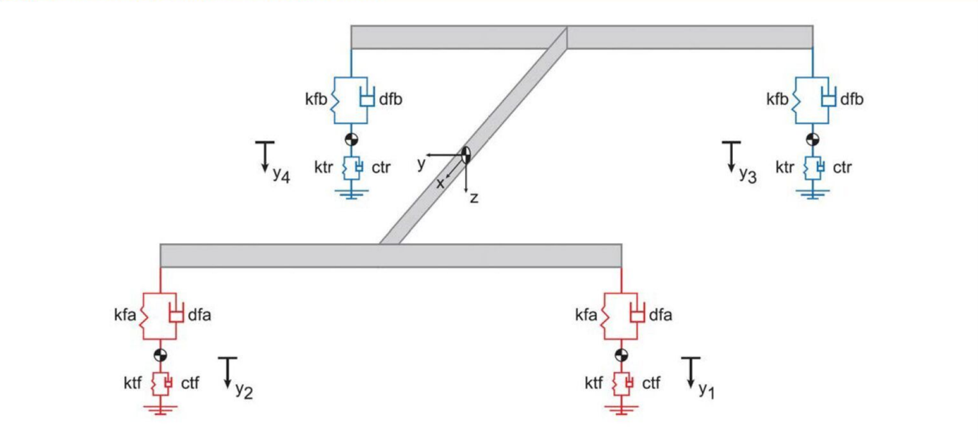
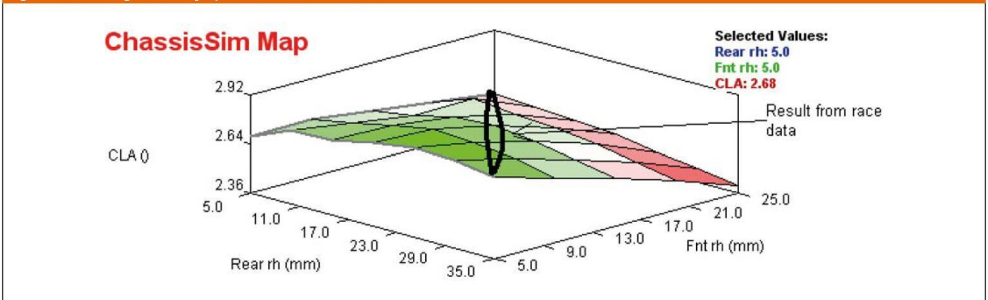


Figure 2: Ride height envelope you obtain from race data



Believe it or not, what we just outlined in **table 1** is not just battle proven, but myself and other members of the ChassisSim community have used this to create aeromaps for everything from open wheelers, sportscars and GT3 through V8 Supercars and cars with aero configurations where you shake your head and ask what on earth were people thinking?

Straight line tests

So, how do we execute the tests outlined in **table 1**? There are a number of ways we can do this. The first is straight line tests. Here I want to address another elephant in the room. A lot of on-track testing tries to replicate what you see in a wind tunnel. You take the car to a fixed speed and spend a fortune on an active suspension system to maintain a certain ride height. Now that has its place and, if someone was going to offer me that for a car I was running, I wouldn't turn it down.

However, if we review **figure 2**, you want to spread the net far and wide, so you are much better off doing an acceleration test from 120km/h to flat out velocity. You might question the validity of this methodology, but I've been using it for over 15 years and haven't gone out of business yet!

But what if you can't do straight line testing? Surprisingly, there are quite a few work arounds here. You can either do in / out laps (a customer of mine used this method recently and the results were stunning) or you can incorporate runs one to six in your test running. I've done this on multiple occasions in categories like A1GP and World Time Attack Challenge with really good results.

The other thing we need to address is what to do about other dependencies like speed, side slip, steering angle and roll.

You need to treat [wind tunnel and CFD testing] like a comparative dyno

These are great questions, so let me break these down by their dependencies. Before we do this, though, one key thing to address is the basis of any good aeromap is the interaction of the front and rear ride heights. Any study of CFD or wind tunnel results make this totally self evident.

The first dependency, then, is speed. Speed will make its presence felt but, if you do your aero testing right, this actually turns into a trim tab. Of all the aeromaps I've had to generate, I reckon I've touched the speed adjustment map in ChassisSim only about 20 per cent of the time. If you do find you have to adjust this, focus your efforts on the straights.

Next is side slip and steering angle. Where you adjust the former is in the high-speed corners. We are talking cornering speeds greater then 150km/h. Here, the steering angles are very small, two to four degrees at most. So, if there is any correction that needs to be done, the side slip angle will be your primary driver.

In terms of quantifying slip angle, the ChassisSim track replay is about to become your best friend.

Finally, in terms of steering angle, you should focus on the mid-speed corners (those between 120 and 150km/h), but you should only do this after determining the side slip effects.

The last thing we need to incorporate is roll. Where this really makes its presence felt is when you are running on high-speed ovals. The starkest example of this is an IndyCar at Indianapolis. To deal with this, you determine the baseline aero ride height aeromap, then use a tool like ChassisSim track replay to help play with the correction maps. It's not the most elegant solution, but it gets the job done.

The testing ecosystem

Now that we have discussed on-track aero testing, how does wind tunnel and CFD testing fit into the ecosystem, and how do you treat the results? Firstly, you need to treat them like a comparative dyno. They are great for comparing one configuration to another but, if you think you can go straight from wind tunnel / CFD to track, you will be disappointed. Trust me on this.

What these tools are great for is prepping you for what you need to do. Keep that in mind and you're laughing.

Incidentally, if you go down the CFD road, allow me to give some recommendations based on people I have worked with. TotalSim in the UK and USA are fantastic, Rob Lewis and Ray Leto know what's going on. Also, Andrew Brilliant from AMBAero and Kyle Forster. All these guys get it and are battle hardened as well. Work with them and you won't go wrong.

In closing, I hope this takes some of the mystery and misconceptions out of doing aeromaps. Despite what some may say, they can be done effectively by any competent performance / data / race engineer and, once you recognise what drives them, know the test matrix you need and use some of the practical tips and tricks here you'll be winning.

In part two next month, we'll discuss how you execute this process.

XPB

To establish a valid aeromap, you need to consider other dependencies such as speed, side slip, steering angle and roll, as well as the interaction of the front and rear ride heights of your car

IN BRIEF

Bosch has won the tender to become sole supplier to Formula 1 with its knock sensor technology. The German manufacturer was approved by the FIA World Motorsport Council to supply the new 2026 power units, which also received 'several refinements', according to the FIA's press release.

Meanwhile, Bender GmbH has won the tender to be the single supplier for Formula 1's insulation monitoring device.

The introduction of the second generation of Formula Regional cars has been delayed until 2025. The technical and homologation regulations were approved by the FIA WMSC, including prescribed designs for key aerodynamic components to ensure the correct performance levels. The FIA aerodynamic design concept will serve as a baseline for manufacturers to help reduce development costs. There will be limits on brake discs and underfloor planks, an update to the survival cell and modifications to the crash test requirements for the cars.

The Macau Grand Prix has returned to the schedule for 2023 with FIA World Cups for both Formula 3 and GT cars as part of a three-year deal. The event will take place from November 16-19.

'It is fantastic news that the story is set to continue with the current generation of Formula 3 cars that made their successful debut on the streets of Macau in 2019,' said Nikolas Tombazis, FIA single-seat director.

The FIA World Cups were suspended between 2020 and 2022 due to the global pandemic and resultant travel restrictions, although the event did go ahead with regional entries during those years.

Tokyo has been confirmed to host a round of the FIA Formula E Championship next March, the first time the all-electric series has raced in the Japanese town.

The calendar for next season includes 10 races, with 22 cars competing, entered by 11 teams. The Tokyo track will be built around the Tokyo Big Sight convention centre by the waterfront.

Toyota fury after last minute BoP change

A furious Toyota railed against the Balance of Performance change that was issued shortly before the Le Mans test day, which penalised the GR010 for its successes in the FIA World Endurance Championship so far this season.

The Japanese manufacturer introduced an updated car for this season, with a modified engine and gearbox, a shift in weight distribution and improved aerodynamics, using its performance 'jokers' that are allowed under the regulations. It dominated the races at Sebring, Portimão and Spa before a change for the Le Mans race.

'In this year's Le Mans 24 Hours, battles outside the race track hindered everyone's battles as sportsmen,' said Akiyo Toyoda. 'I am truly sorry, sorry, and sorry about this. However, in such a way everyone in the team fought fair and square.'

Cars were balanced prior to the season through aerodynamics, power and weight and the system was approved by all parties involved, including the manufacturers.

The process has been made more complicated by bringing in two-wheel drive hybrids and 2WD non-hybrids to compete against the four-wheel drive hybrids.

Initially, it was said the only change prior to Le Mans would be a platform change, so for the LMDh rear-wheel drive hybrids, when compared to the LMH cars.

A timetable for such a change was shared with the manufacturers but, according to Toyota, that agreement was broken, and any change should have taken place before Spa at the end of April.

When the change came late in May, the FIA and ACO did not make a platform change, as promised, but instead changed the performance parameters of the cars within each group, having noticed a larger than expected gap between the cars due to second-order parameters such as tyre wear.

A statement from the FIA said: 'When it comes to computing the starting BoP, there's obviously only homologation data and simulation data available. When it comes to further BoP adjustments, certain track data is taken into account. These are, however, not lap times, but elements from timing data that are correlated with simulation data.

'What is important in this process is the actual performance potential (where all cars ran at their optimum), rather than lap time performance.'

XPB

Critics of Balance of Performance argue that the Japanese manufacturer was unjustly penalised just days before the 24-hour race took place

F2 and F3 extends Dallara contract

The FIA World Motorsport Council has confirmed both the FIA Formula 2 and Formula 3 series will continue to be supplied by Italian racecar constructor, Dallara, until the end of the decade. The decision to extend the homologation for the two F1 feeder series to 2029 and 2030 respectively has been taken on the grounds of cost and stability, according to the FIA World Motorsport Council.

Dallara will introduce a new Formula 2 chassis next season, and it will be eligible for six years, double the length of the outgoing model. The new Formula 3 car will come in 2025.

The duration of the single chassis supply contract will be aligned with these life cycles.

Alpine launches new prototype

Alpine unveiled its new LMDh-specification Le Mans Hypercar at the 24-hour race last month.

The French company has selected ORECA as its chassis partner, continuing the relationship it forged with the LMP1 programme, and the A424 will be powered by a 3.4-litre V6 engine from Mecachrome that shares its architecture with the company's Formula 2 engine.

The team will be run by Philippe Sinault's Signatech team in the World Endurance Championship, and the manufacturer is looking for a partner team in the US for the 2025 season.

As the car runs to LMDh regulations, it will feature the Xtrac gearbox, Bosch MGU and WAE-supplied battery that is standard for the category. It will be a two-wheel drive hybrid, with the electronic system producing a maximum of 50kW of energy. Minimum weight of the car will be 1030kg.

French outfit, Alpine, clearly has its sight set on the American market with its new LMDh car, and is looking for a partner team for the 2025 season

The details of the project have been known for some time, but the launch at the flagship French event was significant as it marks the progress of another manufacturer entering the top class of endurance racing for 2024.

However, entering the LMDh category, with many parts already defined and developed, and with an engine clearly developed from the Formula 2 power unit, suggests this is not a high-investment programme for the French manufacturer.

'In 2021, we decided to enter the Hypercar category and have been fully committed since January 2022,' said technical director, Bruno Famin, who re-kindles his relationship with Mecachrome, having worked with the company at Peugeot.

'The pace gradually quickened and, given Alpine's ambitions to penetrate the American market, the LMDh option was obvious as it requires more limited investment in engineering than the LMHs.'

While the majority of teams have gone for either Bosch or McLaren, Alpine has partnered with Marelli for its ECU, again similar to the Formula 2 set up, and, uniquely for the class, has retained the single turbocharger layout that is used in the single-seat formula.

Choosing Marelli brings the engine even further away from the company's Formula 1 project, but the team says it has employed expertise from other areas of the company.

'Mecachrome has experience in endurance racing, and we conducted several studies and tests starting in June 2022,' commented Christophe Chapelain, chief engineer of the LMDh project.

'It enabled us to analyse its advantages and disadvantages so our teams of Formula 1 engineers could draw up specifications, define the architecture and calibrate it for the desired performance range.'

This means coming as close to the 500kW maximum power limit, and specified torque curve, as possible.

Unlike its Formula 1 rivals, Alpine has made it clear there is significant crossover between its F1 and endurance development teams, and says it has taken advantage of the F1 cost cap regulations to help the A424.

'It must be noted that our synergies with F1 are such that our LMDh software is strongly inspired by F1,' confirms Chapelain. 'The F1 cost cap also works in our favour as it frees up dyno hours in addition to those available at Mecachrome.'

The team is aiming to start track testing in July and have a second car ready to ship to the US for homologation at Windshear, as that wind tunnel governs cars that race in the IMSA WeatherTech series.

The car will make its race debut in March at the 1812km opening round of the WEC in Qatar.

Upgraded Emira GT4 ready for customers

Developed in conjunction with RML Group, the improved Lotus builds on the reputation of the Evora GT4 and looks set to become a global GT4 contender

Lotus has announced an upgrade package for the Emira GT4 racer that was featured in *Racecar Engineering* last year.

Amongst the improvements are a 10 per cent increase in power to 455bhp, a new six-speed, paddle-shift gearbox and control system from Hewland, as well as enhancements to the braking system, dampers, springs and cooling packs.

The company worked with renowned racing expert, RML, to develop the car further, and it is now ready for delivery to customers in the UK, Europe, China, Australia and the US, where it is eligible for competition in global GT4 classes and non-homologated and specialist race series.

'The Emira road car was such an excellent starting point for a GT4, and we've now refined and tuned the package with the team at RML to create what we believe is a highly competitive and performance-oriented race car,' said Gavan Kershaw, director of vehicle attributes at Lotus.

The Emira will replace the Evora GT4, which has won prestigious in such as the British GT, Dubai 24 hours and Pirelli World Challenge.

The car is priced at £179,000 (approx. $251,250) + tax and delivery.

Audi F1 preparations taking shape

German auto maker, Audi, has confirmed Swiss driver, Neel Jani, as its simulator driver for its new Formula 1 car that is expected to race from 2026.

The 39-year old, who has long driven in endurance racing, notably for Porsche in the LMP1 919, will be the lead driver on the simulator for the powertrain.

'Just like in production development, simulation plays a major role in our Formula 1 project,' says Oliver Hoffmann, member of the board of management for technical development Audi AG. 'It requires a development driver who, in addition to a grasp of technology, brings versatile experience to the project, especially in terms of energy management in racing conditions.'

As a former test and reserve driver at Red Bull Racing, Jani worked in the team's Formula 1 simulator before he moved to Porsche to continue as a factory driver.

Since the end of 2022, testing of a one-cylinder engine has been delivering valuable results for the development power unit. The continuing concept phase is laying the performance-related groundwork of the power unit for 2026 when the new regulations provide for increasing electrification.

'At the moment, we are mainly focussed on fundmental concept questions with high relevance to performance,' says Adam Baker, CEO of Audi Formula Racing GmbH. 'However, in evaluating various technical solutions, we rely not only on digital methods. Know-how, experience and practicality relevant development are indespensible elements of drawing the right conclusions from the simulation.

The first hybrid PU, consisting of the ICE, electric motor, battery and control electronics, is planned to be on the dyno before the end of the year, and will provide the basis for the future vehicle concept.

IN BRIEF

British manufacturing technology company, Helixx, has confirmed its collaboration with Siemens to deliver a 'Factory of the Future', a technology-driven manufacturing ecosystem that will allow affordable EVs to be built anywhere in the world within 180 days. The Helixx system empowers customers to operate licensed factories, or Helixx Mobility Hubs, to produce a range of mini commercial EVs.

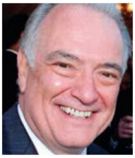
McLaren Racing announced IT service management and professional services automation company, Halo, as official partner for its F1 team. The team will use the system to collaborate effectively and deliver managed IT services through centralised workflows across all areas of the team.

The FIA is to release the tender for the engine specifications for the next generation of LMP2 cars shortly for introduction in 2026. According to paddock rumour, there is no specified layout or size, but instead the tender will be solely cost-driven. The engine will be fitted to the LMDh chassis developed by Ligier, ORECA, Multimatic and Dallara.

The FIA and ACO confirmed the LMP2 cars would not race in the WEC from next season, but would be eligible to race at Le Mans. It will remain the top class in European and Asian Le Mans Series races, and will continue in the IMSA WeatherTech series, too.

Motorsport Australia CEO, Eugene Arocca, has confirmed he will retire from his post at the end of 2023. Arocca has been in post for 11 years.

Australian Supercars will conduct a parity review after Chevrolet dominated the early part of the season and met the criteria of wins that triggered an automatic review. Teams have been consulted after the Chevrolet Camaro model won every race bar one, in which the top two finishers, both in Chevrolets, were disqualified for a technical infringement. Ford teams complained and the series' trigger of race wins was activated.



What a year so far

We're only half way, but 2023 is shaping up to be a year to remember

Are we really just six months into this year? So much is happening to the UK motorsport industry, hardly a week goes by without unexpected news. Despite some lingering post-Covid and Brexit overhang, it fails to diminish the excitement and enthusiasm for the sport, and demand from the industry.

We are certainly in the global sports entertainment business these days, no question. The FIA reports that, globally, the motorsport industry has annual gross output valued at some £140bn and provides1.5 million paid jobs. Experts say this will double in 10 years. They could be right if current trends continue and under-exploited new markets emerge.

Over seven days in July, at least, 680,000 people will attend the Formula 1 grand prix at Silverstone and Goodwood Revival in the UK. Easily, one of the most popular sporting weeks in the UK's history, which many believe is just the beginning.

The loud show

To capture new audiences, motorsport needs to put on a show with fun, success and colour, which NASCAR and IMSA certainly brought to their Garage 56 Le Mans celebrations. The star of that particular show was the extremely fast, and loud, V8 Chevy Camaro NASCAR Cup car, albeit heavily modified, stealing the limelight from the GT and Hypercars.

The mix of three great drivers, full of personality and fun, outpaced most of the field, on and off track, with great TV entertainment.

NASCAR is clearly taking its international expansion seriously, with races in Canada, Mexico, Brazil and Europe – positive news for the series' UK suppliers.

What value do these growing audiences bring to your business? Directly and indirectly, you can invest confidently knowing there is strong future demand. The number and diversity of audiences will attract increasing income from sponsors, whose brand ambitions need success on track to capture attention that, in turn, brings future demand for your winning product.

Even more valuable perhaps is the fast-growing popularity of motorsport amongst young people. The sport lost touch with this age group in recent years, but is now back with a vengeance, and that's exceptionally valuable to our future.

Social media makes theis age group active, key influencers and, through motorsport, 'competitive engineering' has become cool. Battles on track excite their competitive instincts, encouraging them to study or work in motorsport engineering.

Success story

Liberty clearly understood the latest US-based knowledge of how to increase the popularity and value of sport, and has created a highly successful version of F1.

XPB

The number of fans attending events in July alone is a testament to support for motorsport in the UK

However, a little-known, yet huge benefit to those in motorsport's supply chain is the real value of the equipment needed to compete.

To play golf, you just needs clubs and balls; for tennis a racket and balls; football just requires the ball, and perhaps a net; cricket – bats, balls and stumps; horses start to get more expensive, but the world's most popular sport, basketball, is back to just a ball and a hoop!

This is all really good news for keeping people the world over entertained and healthy, but there is no comparison to the equipment needed to compete in motorsport, by far and away the most valuable and lucrative sport to supply into, and it always will be.

October is the best month for you to secure new business for the 2024 season. With free admission and car parking, register now to visit our popular CTS Motorsport Engineering and Technology Show in the Silverstone Wing on 11 October – see www.the-mia.com/events for more information.

If you want a stand, just a few are left so move quickly to secure one now. Check online our outstanding exhibitors, aim to join them at the evening dinner and enjoy fun, laughter and the opportunity to make new friends.

Staffing challenge

Restoring a balanced, productive staffing situation is currently vital, but a challenge. After a turbulent few years, there's a new attitude toward employment, particularly from young people. They are happy to move on quickly from one job to another before building any relationships or showing much commitment. With so many jobs available, and escalating rewards, who can blame them for taking short-term advantage? Even if there could be a price to pay in future as a result of not creating solid foundations.

Last week, I visited a fast-growing motorsport business whose staff increased from 250 to 450 in just three years. Its product is in demand, so, seeing the problem ahead, it decided to improve its approach to human resources. Working conditions were reviewed and changed, as was training and staff reviews, while rewards were offered on a more regular basis. The result is an environment that attracts, and secures, excellent recruits.

The company see this as investing in 'human equipment' to meet future growth. It will lose one or two, of course, but its good reputation and vision means it is ready to replace them. This is clearly a period when human relationships and approach to employees has to be first class, which may, on reflection, be long overdue.

Please contact the MIA any time info@the-mia.com , we are here to help.

This is clearly a period when human relationships and approach to employees has to be first class, which may, on reflection, be long overdue

Inside the world of modern motorsport technology
Racecar engineering

PIT CREW

Editor
Andrew Cotton
@RacecarEd
@RacecarEngineer
Email andrew.cotton@chelseamagazines.com

Sub editor
Mike Pye

Art editor
Barbara Stanley

Technical consultant
Peter Wright

Contributors
Mike Breslin, Lawrence Butcher, Gemma Hatton, Danny Nowlan, Paul Truswell, Dieter Rencken, Karl Ludvigsen

Photography
James Moy, Ben and Paul Lawrence

Group sales director Catherine Chapman

Head of sales operations Jodie Green

Advertisement manager Lauren Mills
Tel +44 (0) 20 7349 3796
Email lauren.mills@chelseamagazines.com

Marketing executive Bret Weekes
Email Bret.weekes@chelseamagazines.com

Publisher Simon Temlett
Managing director James Dobson

Editorial and advertising
Racecar Engineering, Chelsea Magazine Company, Jubilee House, 2 Jubilee Place, London, SW3 3TQ
Tel +44 (0) 20 7349 3700

Subscriptions
Tel: +44 (0)1858 438443
Email: racecarengineering@subscription.co.uk
Online: www.subscription.co.uk/chelsea/help
Post: *Racecar Engineering*, Subscriptions Department, Sovereign Park, Lathkill St, Market Harborough, Leicestershire, United Kingdom, LE16 9EF

Subscription rates
UK (12 issues) £84
Europe (12 issues) £100/€120
ROW (12 issues) £120/USD$165
racecar@servicehelpline.co.uk

Back Issues
www.chelseamagazines.com/shop

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

TELEGRAPH MEDIA GROUP

www.racecar-engineering.com

Trackside

The 100 years of Le Mans was definitely an event to remember

From the inside, it didn't appear that there were more than 300,000 people at Le Mans this year. The centenary race was sold out within weeks of tickets going on sale, with many excited by the prospect of competition for Toyota from the likes of Ferrari, Porsche and Cadillac, plus the chance to see Peugeot's 9X8 at the track for the first time.

As usual, few could have predicted the result. That Ferrari would have the faster car was a given, but that it would last for 24 hours at race-winning pace was a shock.

While it seemed business as usual in the paddock and surrounding area, photographers who ventured out to the rest of the track said they had never seen the place so busy. Hills that are normally considered too much of a pain to climb to see the racing were now full of people, and the many hospitality units that had been squeezed into the track were crammed full.

By contrast, the Le Mans village was not especially busy, even on Friday night, and it was possible to get a table for a table for steak and chips. The low, fast flypast of fighter 'planes nearly sent a guest on our table to meet her maker earlier than she intended. Traffic management around the track also seemed to work well, with only Saturday night becoming a little emotional for those trying to leave the track.

We love the thrill of staying at the track, and this year was particularly special

Campervantastic

With the prospect of so many people attending this race, and with my hotel cancelled on me, I took the decision to borrow my brother-in-law's campervan and stay at the track. Having camped in a tent on many occasions in the past, during one of the traditional thunderstorms that swept the circuit I vowed never to do so again. The van was epic, despite surprise from my brother-in-law that, at nearly 20 years old, it made it at all. I was even able to do a lap of the track with it with my son, which was fantastic. It also remained dry inside, a welcome step up from the aforementioned camping experience.

Many visitors prefer to stay in town, but with increased manufacturer involvement in this year's race, and the huge influx of fans, prices for rooms went into orbit, and will now probably stay there for some time. Still, staying at the track did have its benefits.

This year, the organisation staged a drone show that, during the practice days prior to the race, looked as though it would be terrible. A line of drones went up, turned blue, and came back down again on the first night. The next evening, the drone operators become more ambitious, and tried to outline a lap of the track, but only had enough drones to complete the section from the first chicane to the Porsche Curves. Other shapes were tried with varying levels of success; was that a reindeer with a duck on its back?

When they finally did the complete show, however, on the Friday and Saturday nights, it was a success, reflecting 100 years of Le Mans, the most iconic cars, and the future hydrogen plans. There was also a complete map of the track, and no hint of a animals in odd positions.

The firework display had drama when a cherry picker caught fire, and for a while it looked as though the breakfast tent might also go up in flames as fireworks continued to ping off the damaged tower. It didn't, to the relief of those looking forward to their bacon sandwiches.

There were other moments that won't be a surprise to anyone who works at live events. The DJ who was supposed to play on Friday night, for example, arrived late when his train from Paris was apparently hit by a bird.

Race stop race again

Despite one of the worst races Porsche could have envisioned for its 963, it still held a party for those that had worked so hard in preparing and running the cars. Elsewhere, many teams packed up early, their months of preparation gone west due to no fault of their own. As Ferrari, InterEuropol and Corvette celebrated their overall and class wins, there were others who had worked just as hard, and left with nothing.

That's the nature of racing. Victory makes the pain bearable, but it doesn't take defeated teams long to reset. So, to the engineers, mechanics, strategists, drivers and everyone else involved in the race, take a bow. To those who also did the Nürburgring 24 hours, the 1000km of Paul Ricard and, after Le Mans, the Spa 24 hours, via Watkins Glen, take a second bow. Until the next time.

ANDREW COTTON Editor

TotalEnergies becomes the 1st official supplier of 100% certified* sustainable fuel for the FIA World Endurance Championship (WEC), including the 24 Hours of Le Mans 2022, and European Le Mans Series (ELMS). A fuel composed of biofuel which reduces CO_2 emissions by 65%**.

TotalEnergies

24h LE MANS | TotalEnergies OFFICIAL PARTNER | WEC FIA WORLD ENDURANCE CHAMPIONSHIP

competition.totalenergies.com/eng

*Excellium Racing 100 is a certified 100% sustainable product according to the mass balance system applied by a voluntary certification organization approved by the European Union.
**In line with the methodology provided by the European RED II directive (2018/2001), Excellium Racing 100 can reduce greenhouse gas emissions by at least 65% compared to its fossil equivalent.