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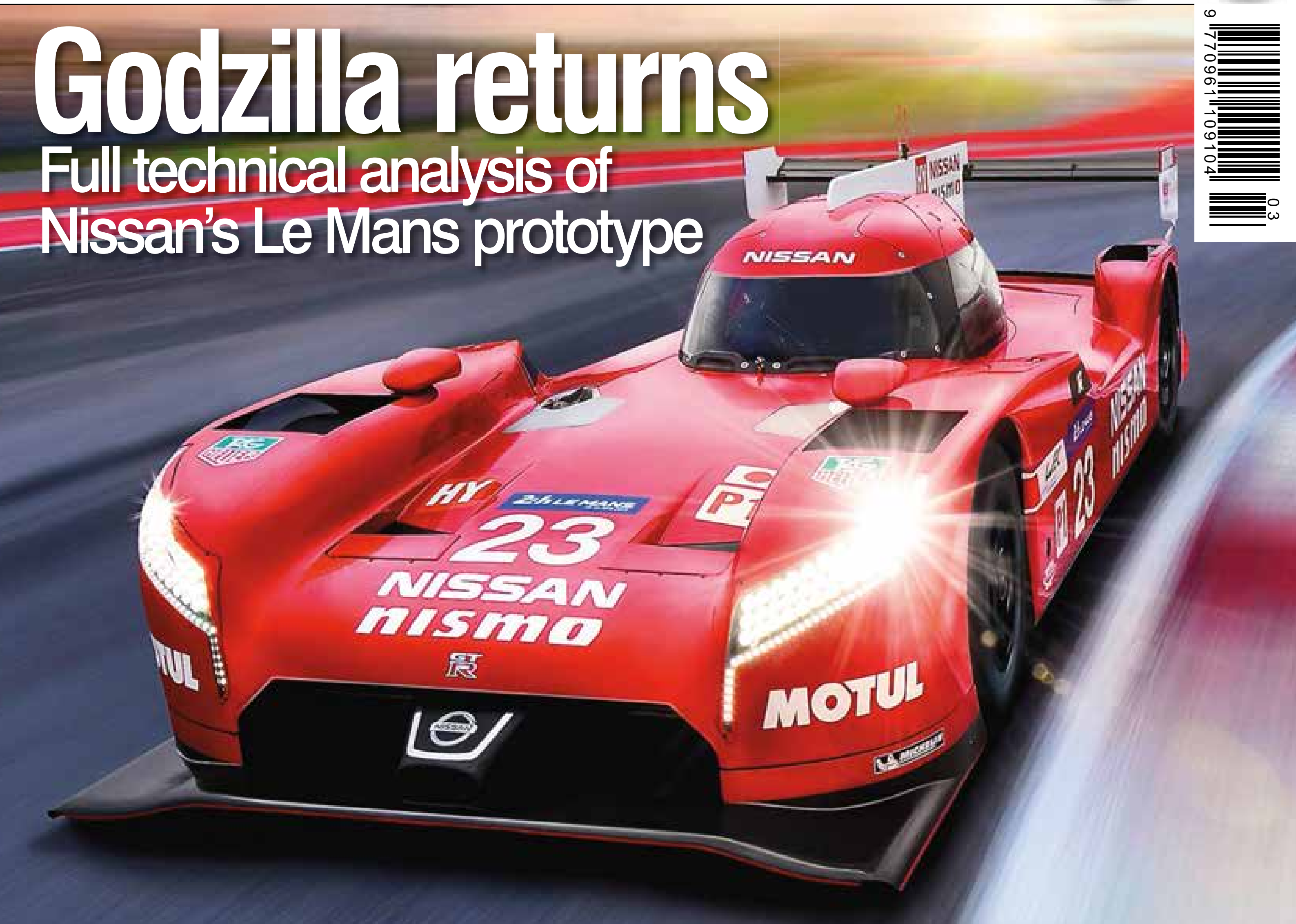
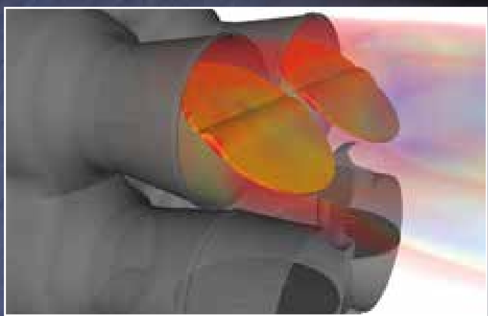


Godzilla returns

Full technical analysis of Nissan's Le Mans prototype



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Peugeot tackled the Dakar Rally. See REV24N12 for full details of the car Mini won the event.

Keep on trucking

Remembering transport troubles back in the days when racing was simpler...or was it?

Preparing and fettling racing cars takes a lot of time and energy, but there is always another facet to racing; actually getting the cars to the racing track.

Today the logistics and maintenance are competent, with professional drivers in immaculate, low mileage state-of-the-art behemoths and custom-built trailers, but not so long ago we were still running converted buses and trucks, which also served as impromptu hotels and living quarters in the long-haul continental races.

The circus was exactly that, racing teams going from town to town and performing for a stipend. Racing cars always started even if the whole rear end had been plucked off.

The transporters were usually second hand, and the time we weren't maintaining the cars was usually dedicated to keeping them going – having spare sets of gaskets and our own acetylene welder and tools on-board meant you ended up being very self reliant in in their maintenance.

As we did the same rounds there was an informal network between the teams to help each other out, and if there was a major mishap, either caused by a terminal mechanical failure or an accident, it was not unusual for teams to put their fiercest rival's cars and spares in their trucks to get them to the start line, thus helping them collect the start money.

The return home was a bit more complicated for the UK-based teams as you had to cross the Channel, which implied earning enough to pay for the ferry ticket. Sometimes a team was stranded on the other side of the Channel at the end of the season with no funds, but we usually sorted them out by having a whip-around between the other mechanics, as the following year it could be us in that position.

Flirting with disaster

Crossing the Saint Bernardino pass into Italy was highly entertaining and disaster was a lady by the side of the road with whom we flirted regularly. Crossing involved going down the mountain in first gear with smoking brakes – we didn't have the luxury of electric retarders or exhaust blockers to aid the stoppage of our lumbering transporters. Hairpin procedure involved keeping the door on our Bedford Duple coach ajar and having on of us jump out, scramble down the slope and flag down any ascending motorist to allow us to barrel through the corner. We had CO_2 extinguishers on hand to cool the incandescent brake linings when we finally managed to stop at the bottom, with billowing clouds of white smoke pouring from the drums.

The twin-axles of the Duple gave us a very good turn-in and good handling, which wasn't always the case with the purpose-built transporter of Team YPF, the Argentinean team that usually travelled in convoy with us. They had a wooden-framed bespoke truck chassis and featured in many memorable incidents, such as getting stuck in the Hockenheim circuit north tunnel. The road sloped up going through the under circuit tunnel, squashed the body onto the wheels and locked it

It was not unusual for teams to help their fiercest rivals to get them to the start line

Team spirit extended beyond the the paddock. The circus looked after its own on the road, too

into place when exiting the circuit after the race. Only after deflating the tyres and getting a tractor to extricate it was it able to continue its trip, which sadly proved to be its last, as we then headed north to Hamburg to catch the ferry to Sweden, as we had races at Anderstorp and Kinnekula Ring.

While driving on a narrow Swedish road with drop-offs on both sides, they went onto the side verge to allow one of the usual monster log trucks to pass them, only to have the soft verge crumble beneath them and the truck roll down the incline. The looping of a cable around the bodywork and pulling by a tractor in an effort to right it and get it on its way resulted in a lozenge-shaped windowless transporter. Exit stage left, but not before doing the two races prior to returning to base, where it was scrapped. The cars escaped major damage, being strapped down by the wheels and just hanging there, but the brace of spare FVA Cossies did a lot of damage to the kit.

Speaking of tyre pressures, we had a rather ancient Ford D200 truck the year before, which decided to drop a valve on the run to Hockenheim.

As the head was examined in a lay-by on the A6, somewhere south of Paris, we found that the piston and head were mashed into a fine metallic mess with the offending valve head embedded in the piston. The quick solution was to pull the piston and conrod apart and soldier on with three cylinders. The small mistake we made was that the injector was still connected and it produced a steady spray of diesel as we chugged along to Germany.

Overcoming adversity

As the sump level increased the thrashing of the diesel/oil mixture in the sump being thrown into the exhaust through the missing piston cylinder generated a smoke screen worthy of a WW1 destroyer, which did not make us popular with the German motorists who tried to overtake us. Eventually the police stopped us, berated us for at least half an hour and hustled us off the motorway, making our already long trip even longer.

A rental car was duly arranged to go to Italy to collect the engines, making for another race without much sleep. And now for the tyre pressures mentioned before, as the truck arrived back in England later than expected, and the replacement of the engine at the local Ford dealer ended up taking longer than expected. Being warned of this problem only at the moment we went to collect the truck to load it up for the next race at Rouen, we were left with having to search for a hire truck. No suitable truck was available in a 100-mile radius, and we had to settle for a 7-tonner without a tail lift.

By the time all this was arranged the only quick way to make the other side of the Channel was to take the Hovercraft. As we pulled up at the port we discovered that the truck was too high to pass under the goalpost that determined the maximum height for the hovercraft. Lateral thinking brought the inspiration of letting all the air out of tyres, which enabled us to scrape into the craft with inches to spare.

Incidentally Emerson Fittipaldi's F1 championship decider race at Monza in 1972 was won in the spare car as his main car had been in a transporter rolled on the autostrada heading to Milan when a tyre burst. It went through the Armco upside down, with one of the sleeping mechanics in the cab being thrown out through the windscreen, landing on his feet and hitting the ground, running to avoid being crushed to death by his own truck.

There are so many incidents involving the transportation of cars, equipment, tyres and food that it would be a challenge to do them justice in this all too short page. The plethora of other team stories will have to wait for another time.

Under pressure

Have you ever considered the time and financial constraints engineers face?

Under Pressure. Not only a track by iconic rock band Queen, but a valid description of the pressure-cooker environment existing in the design and production offices that are responsible for the crop of new racing cars for the season ahead.

This is the time each year when motor racing fans, teams and media begin to anticipate the official launches and accompanying technical appraisals. What many will not fully appreciate is that these last few months have been when the chips have been well and truly down.

Aside from those responsible for procuring the funds essential for taking any project to completion, the heaviest pressure must be on the individual responsible for the overall concept and direction of the car design, and similarly for the powertrain. Almost equal stress rests on the shoulders of the person in charge of production, tasked with turning designs into metal and composites reality.

Naturally this pressure extends down the line to virtually everyone involved. I have seen usually relaxed and amiable folk become short-tempered and irritable, reasonable and helpful characters turn into "whatever the question, the answer's no" curmudgeons. I have experienced grown men on the point of tears, mental breakdown and even potential self-harm.

Fear of failure

While anxiety regarding one's well-paid job and future career are natural concerns for any employed individual, the demands of making racing cars impact well beyond this. The amount of money that can be at stake, although varying enormously whether it's a new F4 or F1 car, a GT or an LMP1 machine, often represents similar consequences to the companies and staff relying on their success; it's just a matter of scale. Unlike many design and construction programmes where there may be some leeway on deliverables, test and race dates don't usually shift once established and this impacts heavily on those whose planning and decision-taking can make or break the season ahead. Pride, fear of failure, dread of letting down colleagues, drivers, sponsors and customers can be a crushing responsibility and it takes a strong-willed and resilient personality to deal with this.

It's not only the deadlines that create the 'cold light of dawn' panic. Rumours can filter through of a different design direction being taken by one's main rival. "Have we missed something, are we going to be blown away? Can we afford to carry out just that one more important wind-tunnel or dyno test that could show a useful gain, or will it put design freeze and thus production too far behind? Is there an area of the car or engine which still prompts niggling doubts and which could screw up the project?" Imagine the mental agonies, multiplied further if it's the first complete project for which an individual designer or production manager is responsible, or when key personnel unexpectedly leave.

Extra pressure for the car designer comes from the dreaded crash tests now being (rightly) mandated in almost all chassis technical regulations. Only so much can be prepared and tested early in the car build, certain elements can only be done when completion is near. A failure to pass at this stage constitutes a massive headache and even more stress. For the engine men as well, what appears as a small 'clarification' of the regulations may in fact require a significant re-think affecting not only the design but also the manufacture of long lead-time components.

On top of the time constraints, getting it slightly wrong can just add to the pressure on a team pre-season

Then there are the unexpected crises than can occur. The critical lines on the graphs of temperature, pressure and load can catch you out – just beneath the line and everything is OK, a very small increase of a few degrees or Nm taking the parameter over the line can prove disastrous.

An example from my previous life at Lola Cars comes to mind. One year, when the first of around a dozen Indy cars delivered to date began serious testing in February, it became worryingly obvious that, due to the increased performance of the new car, the transmission would not last the 500-plus miles required for the Indy 500 taking place in May. One simply could not sell a car to teams that would not complete the most prestigious – and financially vital – race on their calendar. Consequently a major programme to design, manufacture and deliver a new crownwheel and pinion (for this was the Achilles Heel) in the following few weeks was put in place. Not only was a new crownwheel and pinion needed; it being larger, a new transmission casing was also necessary to accommodate it. Given that this was a casting with all that that entails in process time, an almost miraculous effort by everybody involved got some 40 units done in time for the big event. For a commercial business, swallowing the cost of the redundant parts and supply of the new parts was also a very serious financial blow, but one that had to be accepted.

Perpetual problem

In these days, FEA simulation might well have identified the problem in advance of manufacture, but such is the complexity of many current racing cars other possibilities for a wrong design or manufacturing call or simply an oversight still exists. This is when the ability to respond with the right actions by the design and production team makes the difference, but such dramas add even more to the mental load on those responsible.

Ah, you might exclaim, but the latest manufacturing technologies such as 3D printing should make it easier. What happens in reality is that the engineers take advantage of the reduced prototyping and manufacturing times to extend the design deadlines and permit more research before committing to the final product, adding to the frustration of the production people.

So, while eagerly studying the latest race car and engine offerings, spare a thought for the anguish and crazy working hours involved in getting each project so far. Especially as many of them will never even win a race.

Extra pressure for the car designer comes from the dreaded crash tests

Disruptive technology

Nissan takes a typically innovative approach to LMP racing with its LMP1 GT-R LM NISMO

By ANDREW COTTON

By A N OTHER

Nissan will return to LMP1 racing this year with a front engine, four-wheel-drive car that the company says can win at Le Mans within two years. It is an ambitious claim given the strength of the opposition, and the fact that it will go up against the likes of Porsche, Audi and Toyota which each have a year of development under their belts with their technology and their LMP1 cars, but Nissan believes that the GT-R LM NISMO makes the most of regulations and can take the win.

The car certainly stretches conventional thinking, as should be expected from the designer, Ben Bowlby, who brought the DeltaWing to the global stage with Nissan at Le Mans in 2012. The team has lived up to its promise at the programme launch in 2014 that Nissan would deliver something different to the others. How different could this car be? This is the first front-engined Le Mans car since the Panoz LMP07 in 2000-2003. It has built a new 3-litre V6 twin turbo engine, based on Formula 1 architecture, but steered clear of using an MGU-H, an exhaust energy recovery system. Instead, it has a mechanical flywheel. Like the others, it is four-wheel-drive, but the engine delivers power to the front wheels, rather than the rear. Tyre sizes are different to reflect this fact. In short, the car could hardly be more different.

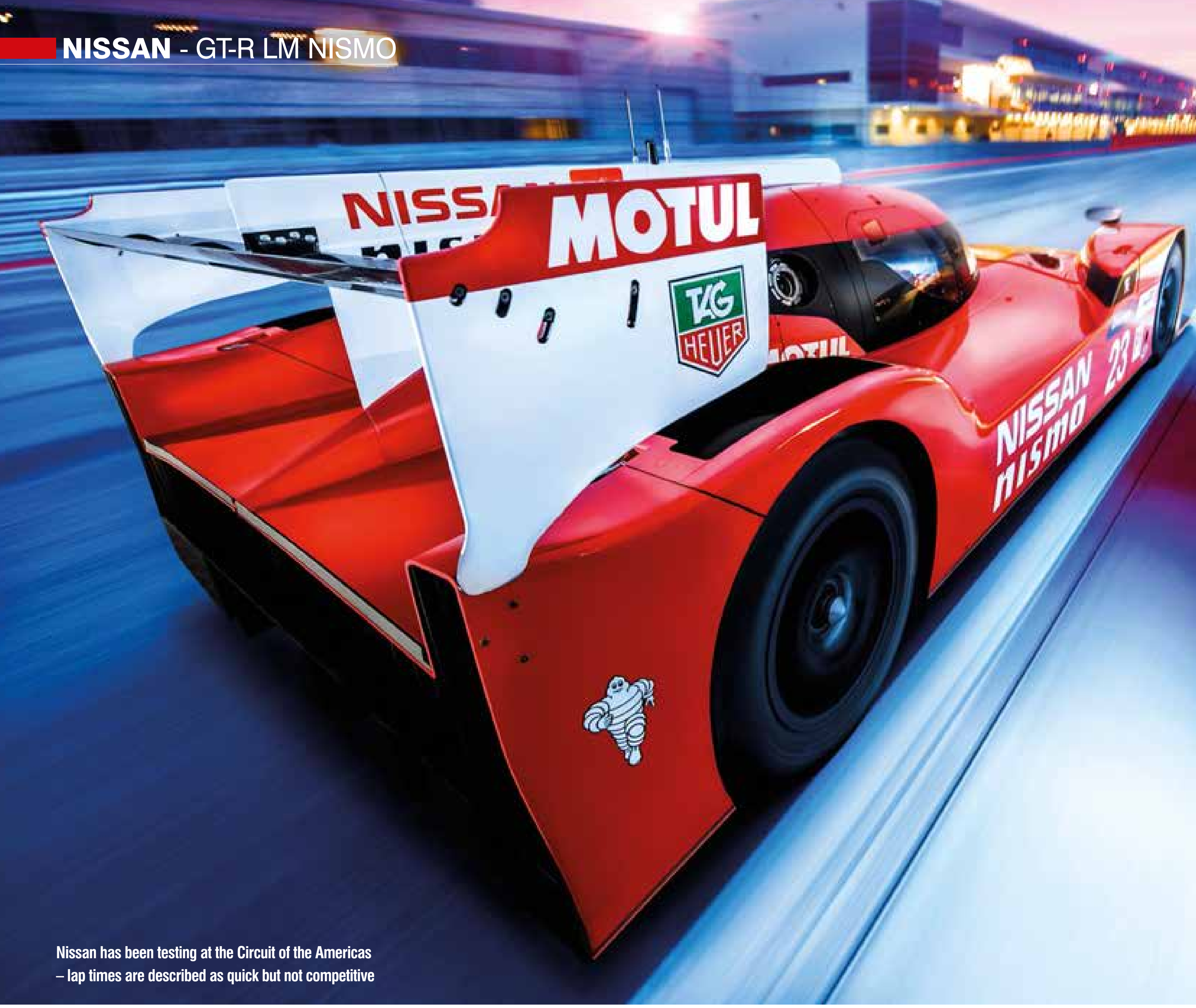
The budget is estimated to be far lower than the other teams, in keeping with Nissan's philosophy of delivering value for money, and there have been unusual steps taken to deliver this. For a start, the team is

"At first sight the LM NISMO may not appear to share much the GT-R production car, yet in concept it is much closer than might be expected"

based in Indianapolis, Indiana, rather than in Europe where the majority of mechanics and engineers with Le Mans experience would normally be found. Testing has largely taken place at Nissan's Technical Centre in Arizona, saving the team expenditure hiring circuits for on-track testing. However, the team has also tested at Willow Springs, California, and for comparison with the current LMP1 cars at the Circuit of the Americas, also in Texas, where the first video and images of the car were leaked online. However, the US base does not fit with the new WEC schedule that was announced late in 2014, which now includes a race at the Nürburgring at the end of July. That means a European schedule for four months, from Silverstone in April until the German race at the end of July, and the team is currently looking for a temporary European base.

As is to be expected of such an ambitious car, the team has not been able to put as many miles on the test car as hoped. The car has around 2000km of track testing under its belt, many without the hybrid system.

It is a far cry from Toyota's preparation in 2014, when the Japanese company completed more than 40,000km of testing before the Le Mans 24 hours, but Porsche encountered delays with its brand new 919 Hybrid in 2013, but still produced a competitive car that won the final round of the 2014 season in Brazil. Yet, the Nissan team is only at the start of its two-year programme and it believes that, with reliability, the speed is in the car, and that it will achieve its target of scoring the manufacturers' first victory at Le Mans.



Nissan has been testing at the Circuit of the Americas – lap times are described as quick but not competitive

Mechanical hybrid

The team has opted for a full mechanical system as that avoids having to deal with the complications of electric cars, including fail safes and battery management. However, even the full mechanical system has become something of a headache. In today's modern world of engineering, millions of lines of code still have to be written and interpreted.

The 2015 LMP1 regulations do not say that cars must utilise a single energy store. Instead, while usually referring to it in the singular, they seem to leave it open, but the rules only allow for two energy recovery systems to be used. Nissan has the option of taking advantage of this by using a pair of flywheels for its kinetic energy recovery system, rather than the more common exhaust gas recovery systems used by Porsche, YGK and all F1 power units.

The team could yet run a single flywheel, dependant upon which ERS category the car will run. The likelihood is that the team will run in one of the lower ERS categories, either the 2MJ or 4MJ column of Appendix B, which allows them a greater maximum fuel flow allowance.

The system is thought to be supplied by Torotrak subsidiary Flybrid Systems, based at Silverstone, England. This system is purely mechanical and directly links the flywheel to the transmission rather than via an electric motor generator unit (MGU) as seen on the Audi R18.

A cavity in front of the cockpit can hold one or two flywheels, an arrangement similar to the one used by Hope-Polevision on its LMP1 Courage at Le Mans in 2011 (the first hybrid ever to race at Le Mans). The hybrid system will drive the rear wheels, while the fronts are driven by the IC engine, giving the GT-R partial four-wheel-drive. But with only the hybrid system driving the rear wheels, the rear tyres are much narrower than are usually seen on LMP cars, and Nissan believes this will bring aerodynamic gains.

The use of flywheels for energy storage could lead to an interesting performance characteristic – unlike combustion-electric hybrids, which can be plugged in and charged in the pit garages, flywheel hybrids like this can only really be charged up out on track. This means that after a lengthy stop for repairs or similar the system won't work properly until after a hard braking session to deliver full power, reportedly as much as 500bhp.

As the primary driven wheels are also steered it suggests that Michelin has developed special tyres for the GT-R LM, as it did for the Deltawing, although if standard LMP1 rear tyres were used on the front the results could be somewhat unpredictable.

As the primary driven wheels are also steered, Michelin developed special tyres. If standard LMP1 tyres were used, results could be unpredictable

Targeting a lower ERS category and instead relying more on the engine power, the team had the option until the beginning of the year to switch to its back-up plan, an off-the-shelf super capacitor system that would have put the battery in where the flywheel sat, ahead of the driver. Given the complications of an entirely mechanical system compared to the complications of an electrical system, the engineers have opted to stick with their original plan and have used a mechanical system.

F1-derived engine

From the start of the programme, Nissan said that it would have to retain road relevance and that the GTR would form the basis of its new car. This is true only in the fact that the new Nissan is front-engined and four-wheel-drive, but the fronts are driven by a low-revving three-litre, 60 degree V6 petrol twin turbo engine.

Nissan remains coy about the exact technical specification of the car, but *Racecar Engineering* understands that its power unit is mounted 'the wrong way round' and the pictures seen on these pages back this up. The engine is believed

Nissan has placed the flywheel system just ahead of the cockpit. Then follows the engine, gearbox and radiators. The steering wheel shows a maximum of 8,000rpm. The lap time shown is not representative of the GT-R LM's pace

Nissan has challenged conventional thinking with a front-engine car. One of the two turbos is visible in the opening by the front wheel, confirming a twin-turbo layout

to share much in terms of architecture with Cosworth's unraced direct injection 1.6-litre originally designed for F1, can pump out more than 1000bhp. However, in the energy-based formula it is more likely that the engine will be scaled back to produce between 600-800bhp. With a rev limit of less than 8,000rpm, and with the efficiency formula of the World Endurance Championship, it could safely be assumed that the engine produces huge amounts of torque

The exhaust exits sit just ahead of the cockpit, and the turbochargers can be found under panels just ahead of those exits. A twin turbo engine is a departure from the engine's F1 roots, but two MGU-H turbines could not be used. In a conventional car of this type the engine is mounted directly to the back of the monocoque, the Xtrac-supplied gearbox is in turn mounted to the rear of the engine and the rear crash structure is mounted to the transmission casing. In the case of the GT-R LM the whole concept is rotated through 180 degrees, with the engine mounted directly to the front of the chassis, the gearbox to the front of the engine and the front crash structure to the front of the gearbox.

The front suspension is mounted to the gearbox casing in this area, with the dampers most likely mounted on top of the transmission and torsion bars on the flanks of the 'box (or possibly on top also), which is a common layout for the rear of a modern car. Either side of the front crash structure, which protrudes slightly from the front of the car (and also gives Nissan a handy place to fit the car's badge), sit the main radiators for the engine's cooling system, just about the only conventional part of the layout!

The rear suspension picks up on the differential and monocoque, which also carries the rear crash structure. While technical details of the car with its front bodywork were not available at the time of going to press, some interesting packaging challenges are likely to be found under the skin, such as where the brake and clutch master cylinders will sit, as well as where the power steering system will be located, and how both of those elements will be shielded from the heat of the engine and turbos.

The Xtrac gearbox is believed to be a bespoke unit for the car, developed during the dyno and track testing to suit the unusual needs of the GT-R LM NISMO.

Full frontal

The key to the design, however, is that the engine is located at the front. This makes the car front heavy, and means that the centre of gravity is far forward. Others may ridicule the concept but, as with DeltaWing, Bowlby's calculations make for interesting reading (and, as with the DeltaWing, Bowlby was happy for the discussions to take place, positive or negative, certain that his calculations were sound).

The whole concept of the ACO and FIA regulations is the limitation of downforce by reducing the size of the rear wing. The limitations of the rear diffuser are also, according to the team, restrictive. At the front, the regulations are much more free, and Nissan aims to take full advantage.

With the engine at the front, and the centre of gravity further forward than normal, it is possible to create a huge amount of downforce.

To cope with the larger forces at the front from weight and downforce, the car will run on 16-inch rims at the front, and nine-inch rims at the rear. The width of the tyres will be at the limit of the regulations. What that means is that

A twin-turbo engine is a departure from the engine's F1 roots, but two MGU-H turbines could not be used

the tyres have a large sidewall and increased contact patch when it is needed, such as under heavy braking. The car still requires downforce on the rear, hence the wing.

The car is principally designed for Le Mans, where the aero will work best on the long straights, and simulation lap times are rumoured to be in the 3m15s area, which is faster than the pole and race laps in 2014 (although the fastest qualifying times were markedly slower due to the introduction of slow zones following large accidents for Audi and Aston Martin on the Wednesday evening). Lap times in testing for the GT-R LM NISMO are yet to be fully competitive compared with the LMP1 lap times of Audi, Porsche and Toyota, with the car rumoured to be setting sub two minute lap times region at a test at the Circuit of the Americas in January, although Nissan still has to decide on the car's final configuration and start its performance testing ahead of the first race at Silverstone in April.

Open source?

With all the novel engineering in the car, and the unusual concept in thinking, it would be an obvious marketing advantage for the team to provide open-source information and allow spectators more access to the team than any team ever before. 'These cars represent the pinnacle of current racing technology: huge energy recovery systems, super fuel-efficient engines and wild aerodynamics, creating extremely fast cars for their weight and endurance,' said Nissan's LMP1 Team Principal, Ben Bowlby. 'It is all about having a fast, efficient and safe car.' Others may protest about the legality of the car (and some rivals are reportedly looking at it closely), but Nissan remains confident that this will be the car that will challenge the established contenders.

Nissan is aiming to pose questions and to challenge conventional thinking. The company's challenge now is to take that different thinking, and prove to the naysayers that it can be done for real. It is a big ask, and only time will tell if it can be done.

Slippery design offers excellent aero properties – the simulated lap times for Le Mans are rumoured to be quicker than 2014's pole

Nissan history at Le Mans

Nissan entered the Le Mans 24 Hours for the first time in **1986** and then raced in the Sarthe with both works and private entries, apart from a short break between **1991** and **1993**, until **1999**. The company returned as an engine supplier in **2011**.

In **1986**, Nissan was the third-largest manufacturer in the world. It arrived in the Sarthe with two cars. One was the R 85V chassis which in 1985 delivered a win a round of the sports car World Championship, Nissan becoming the first Japanese manufacturer to do so. The second car was an R 86V, fitted with a V6 turbo engine that was said to put out 1000 bhp. At Le Mans, the R 86V retired while the R 85V saw the flag in 16th place.

In **1987** Nissan returned with a chassis developed by March and a V8 engine. Both cars retired.

Two cars started the **1988** race, but only one finished, in 14th.

Nissan returned in**1989** with monocoques designed by Lola. The 3.5-litre twin turbo engine helped to give the three cars a top speed of over 380 km/h. One entry mixed it with the front-runners before retiring, a fate which also befell the other two cars.

1990 saw seven Nissans at the start, five of which were works entries. For the first time a Japanese car started from pole. Mark Blundell lapped in 3m27.02s, more than six seconds faster than anyone else. Kazuyoshi Hoshino became the first Japanese driver, in a Japanese car, to lead the Le Mans 24 Hours. The car finished fifth, the best result until then of a Japanese car and driver line-up.

In **1994**, two Nissan 300 ZXs that had already won at Sebring and Daytona were entered at Le Mans. The quicker of the two was running fourth with four hours to go and finished fifth overall and first in IMSA GT.

In **1995** and **1996**, Nissan was represented by customer teams. In 1995 unofficial GTs competed, one of which finished tenth. A year later, two private GTs raced, with one securing a 15th place.

Three GT1s with a twin turbo V8 installed in a carbon monocoque were potential winners in **1997**. Only one finished in 12th place.

In **1998**, three R391s took the start, the fastest secured third followed by the other two in fifth and sixth.

In **1999** two open cars, including a Courage chassis and a new 5.0-litre V8 normally aspirated engine competed. One got as high as fourth before it was forced to retire.

In **2011,** Nissan came back as an engine supplier to three cars in the LM P2 category. The Zytek Z11-SN-Nissan driven by Ojjeh, Kimber-Smith and Lombard won its category.

Nissan's modern racing era has not been conventional in that it has largely been led by a marketing department, with extensive support from Nissan in Japan. It started with an engine supply chain of the VK45DE V8 engine to the LMP2 field, and the majority of ORECAs now use Nissan engines. They have proven to be fast, reliable and affordable to the extent that Nissan finished first to fifth in LMP2 in **2014.**

Nissan also put marketing money behind the DeltaWing project, originally an Indycar proposal but which was adapted for Le Mans. The car featured Nissan engineering in the engine, but for an estimated annual budget of £4m, the return on investment was pretty impressive.

Fast forward two years, and the company was at it again, this time with the ZEOD, a 'zero emission on demand' car that set new records; the first car to reach 300km/h on electric power only, and the first car to achieve a full lap at Le Mans solely running on electric power. The car retired in the first hour after a technical failure not related to the battery.


Nissan's ZEOD managed to do a complete lap solely on electric power at Le Mans in 2014

Design for the masses

After six years, Wirth's coupé concept finally hits the track. Could this concept be part of the Daytona Prototype class in 2017?

By ANDREW COTTON

It has been six years in the making, but the Wirth Research Coupé has finally hit the track at the opening round of the Tudor United Sports Car Championship at Daytona in January. The HPD ARX-04b was debuted by the ASM team in the race.

The car was originally designed as Honda's new LMP1, and a three-year programme was on the cards before the financial crisis hit. Wirth Research continued to develop the coupé concept and it was ready to race in 2011-2012, but the 2014 change in regulations put off interested manufacturers and the project was again shelved. When the 2014 regulations were finally introduced, Wirth and HPD were working closely together again on the new Indycar programme, and so there was another delay until the two companies started to think once again about returning to the Le Mans Prototype class, and originally planned a full LMP1 programme before Honda made the decision to return to F1 with McLaren. At that time, the relationship between Wirth and HPD was strong enough to withstand the decision, and instead the two started to look at LMP2 possibilities.

'Honda was looking at the hybrid regulations, and we eventually got together again, and they liked the car,' said Wirth at Daytona. 'We started down the P1 route because of hybrid, but it got to the point where Honda was starting to think about F1, and doing two hybrid projects, with different technologies, didn't make sense.

'The other sea change that happened was that in HPD's back yard in North America, IMSA came under the NASCAR banner, and then the P1 class was killed off. The reason for HPD to do a P1 car in North America was gone so HPD said 'let's look at P2', and that is how it was born. More than any other project, this was a joint project. HPD had a limit on what they felt was right to spend on P2, and we co-invested in it, but I am very proud that HPD decided to take on the project and continue the fantastic run of results and championships that we have had.'

The 2.8-litre turbo has achieved some great successes, including victory at the Sebring 12 Hours and the 24 Hours of Le Mans

HPD had developed a strong LMP1 engine, but that was put to one side and as the team pursued the LMP2 path, it reprised the 2.8-litre engine that had been used since the ACO introduced the cost-cap in 2011 and the team took time to optimise the installation of the engine into the new chassis which was, as Wirth has now become famous for, designed entirely in CFD. 'The principle has been proven and we have won championships with these guys,' says Wirth. 'The technology is very stable – it was not on other projects – but it is in the sportscar, and was a big help in designing a car to the new rules. We are pretty happy with it.'

The ARX-04b is fully compliant with the new ACO LMP2 regulations, and exceeds the latest safety standards of the new enclosed-cockpit configuration. The 2.8-litre twin-turbo, direct injection, production-based Honda HR28TT V6 powerplant now includes a regulation compliant drive-by-wire throttle system and fresh air valve system, eliminating turbo lag and providing improved reliability and performance.

'We are very excited for our new HPD ARX-04b LMP2 Coupé to see the light of day, combining all of our successes in international sportscar racing with the very latest regulations for closed-cockpit prototypes,' said Steve Eriksen, HPD vice president and COO. 'Our production-based Honda HR28TT engine has powered all of our LMP2 sportscars since the ACO regulations set the new cost-capped direction in 2011, and since its introduction the 2.8-litre twin-turbo V6 powerplant has achieved some truly great successes around the world – including multiple engine manufacturer championships, victory at the Sebring 12 Hours and the 24 Hour of Le Mans, as well as powering the first LMP2 FIA World Endurance champion.

The ARX-04b will continue the HR28TT powerplant, developed by HPD from the production Honda "J35" series of V6 engines currently found in the Acura MDX and RLX in North America, in addition to the upcoming 2015 Acura TLX. The racing engine uses more

The 2.8-litre twin-turbo V6 powerplant uses more than 400 production parts for improved reliability – the technology is proven and has won multiple championships

than 400 production engine parts, including the engine block and heads, crankshaft, direct-injection fuel system, valve train components, drive-by-wire hardware and even the stock Honda oil filter. While there is little else carried over from the ARX-03a, the basic concept for many of the components remains the same. 'We have tried not to introduce new issues,' says Allen Miller, manager and principle engineer, Honda Performance Development.

The car features a new gearbox having switched to Xtrac's 1059 'box as that was an off-the-shelf component and the team felt that would help to keep down the cost of the car. The paddle shift system changed to Megaline, but the team uses a Shift Tech controller so that it can more easily control the ECU.

Slimline

Walking around the car, the design is more compact than the ARX-03a although the design team has worked to ensure that the car can still be worked upon easily. The front steering rack, for example, is easily accessible, and although the packaging has been brought closer to the centre of the car, there is still room to make changes where required.

'The upper plenum is flipped around, so the throttle body is now at the back of the bulkhead. It is the same airbox, whether on the Ligier or here, but it is turned around, and we have put a different fuel line to it.' With the production-based engine, weight was clearly and issue. Despite IMSA raising the minimum weight of the car (along with increasing power as part of the balance of performance measures with the Daytona Prototypes), the ARX-04b was still over the 940kg limit and needed extra work to reduce the weight. 'At the end of the year, we started to save weight going to a carbon airbox,' says Miller. 'We went to the ACO and said we needed some weight off it, there is no performance gain. They upped our power, and then upped the weight to make a balance. This is 940kg, the Ligier is 940kg, so if it has our engine it is 940kg, but the Ligier Judd is 900kg and it is pretty close in performance to where we are. The monocoque has the Zylon panels in the side [to conform to new safety regulations in the LMP classes], and fitting them was a big deal.'

As the team changed both the monocoque and the gearbox, the front and rear suspension have had to be redesigned, although they remain the same in concept. The uprights are more fabricated than previously used on the ARX-03a, and engineering firm Pankl has completed most of the work. The brakes are carried over from AP due to their reliability, and although the axle design is similar in concept, it too has had to be modified.

With so much time to think about the chassis, from concept to delivery, it is little wonder that the design appears to be both compact and efficient. 'From the chassis side, it was the opportunity, working together, to put the P1 engine to one side, put the P2 engine in there, and see what opportunities we had to optimise the powerplant and chassis to work together,' says Wirth.

'We didn't even carry the suspension over from the P2 project. The P2 project was born from the Acura programme which was competing against Porsche, so we had some quite exotic parts, but we had to get the costs down. The manufacturers of those bits had been working for so long, the tooling costs had gone, and we bought lots at once. Instead of five or ten, we bought 20 to get the unit costs down. In re doing the suspension, which we had to do because we have a new transmission and a new monocoque, so we couldn't really carry bits over. We have brought those costs down in the design, but tried to keep the benefits of the suspension. This car retails for less than many supercars on the road, and when you look at the technology it is amazing. We are very proud of the engineering in it.'

"This car retails for less than many supercars, and when you look at the technology it is amazing. We are very proud."

Good visibility

As the LMP1 and LMP2 regulations allow for the same monocoque to be used, new visibility regulations meant that the cockpit area had to be redesigned from the original concept. The

What's the
secret
about the new 911 GT3 Cup's
new brakes?
Mobil 1
adidas
GT3
It's Quicker.
PFC
PORSCHE
OFFICIAL PARTNER
PORSCHE
MOTORSPORT
PFC
BREMSE
www.pfcbrakes.com
1.800.521.8874

The distinctive twin holes in the car's nose channel air straight into the cockpit, saving weight and removing the need to fit an energy-draining air conditioning unit

roof was raised, and attention was paid to the A pillars to ensure that the drivers could see into the corners more easily than had been the case with the old LMP1 cars. Blind spots were reduced, and the HPD has a clever solution to the mirrors, hidden inside the bodywork, yet still able to be seen clearly by the drivers. 'They now don't feel any more hindered than in an open car,' says Miller.

The car has other rather natty design cues, including quick-change bodywork front and rear, and improved airflow through the nose of the car into the cockpit, as the team hopes to avoid having to use an energy sapping air conditioning system. Two holes in the nose of the car funnel air directly into the cockpit to help reduce temperatures, while indents into the bodywork behind the doors provides the exit for increased circulation. The car has also been designed to be low-drag to improve efficiency, and an innovative Honda refuelling safety interlock system is designed to reduce the potential for pit fires resulting from leaving the pit box with fuel hoses inserted (applied to all IndyCars since 2011).

As part of their after-sales support services, HPD and Wirth will provide teams with technical assistance and bulletins, as well as additional options available for purchase. Additional bespoke options include driver-in-the-loop simulator sessions, data-logging, race and performance engineering, and MuRiTyre and Apotheca software.

"If other maunfacturers want to have our chassis, they can have it. They can buy it at low cost, and build their own prototype"

Mystic Meg

One of the topics of discussion at Daytona in January was the future of the top category. Although it was pretty much written in stone that the category will switch from the Daytona Prototypes that have run since 2003 to a P2 only category in 2017, there seemed to be a challenge to that decision. A meeting was held after *Racecar Engineering* went to press to decide on the future as a plan has to be agreed among the manufacturers and presented to the FIA World Council in June for final approval before Le Mans. However, the HPD team has pre-empted that, and offered its monocoque to current DP manufacturers, including Chevrolet, to allow them purchase the chassis and run it under their own banner in the US. That gives the teams a cost-effective, safe solution to replacement machinergy for the DPs.

'None of us are comfortable, if we are doing a new car, to not do something based around a well-researched, crash-tested FIA regulation monocoque and we have a very low cost one,' says Wirth of the possibility of having Daytona Prototypes as the top class in the US. 'We have a roof on, not just for aero, but so that people like Ed Brown would not be worried about getting hit by something. We think that this is an ideal platform on which to build the new Daytona Prototype. It doesn't have to have this bodywork on it, but at the end of the day, that's what we would be interested in going forward. If our customers want to run in Europe they can run the Le Mans bodywork. It gives people options.

'HPD has taken the step to say that if other current Daytona Prototype manufacturers want to have our chassis, they can have it. They can buy it at low cost, and build their own prototype. They can use all the dollars that we have spent in R&D, and have the car. We want the series to prosper. The monocoque is owned by Honda, they bought the IP from us and we developed it, but if someone wanted to rehomologate it, I am sure that is possible if that meant that we could have these cars as a basis. What we like the idea of is that it is reliable, safe, and we understand the technology. Daytona Prototype racing is all about balance of performance. You all go to the wind tunnel, you all get adjusted, it is not like the P2 cars where we are trying to gain an aero advantage. If it makes the series prosper, safe and affordable we are all for it.'

'Chevrolet could come and take the monocoque and rename it a Chevrolet. There is not a problem with that. What is the point of Chevrolet spending millions of dollars to come up with the same thing as us?'

Return of an icon

Toyota has finally announced that it is to return to the World Rally Championship after an absence of almost 20 years

Toyota's Yaris WRC car has performed well in tests in Europe and will now head to Scandinavia for extensive snow testing and evaluation

Toyota's return to the FIA World Rally Championship, as predicted by Racecar Engineering in 2013, has now become a reality as TMG confirmed its return in 2017 with a car developed and built entirely at its Cologne technical centre.

Over the next two years TMG will continue its test programme with the Yaris WRC car, to prepare for a full return to the series in which it won four drivers and three manufacturers world championships in the 1990s.

The news was announced at the end of January by Toyota Motor Corporation president Akio Toyoda at a news conference in Tokyo, where the Yaris WRC made its public debut, complete with new launch livery.

The Yaris WRC has already completed a preliminary test programme on tarmac and gravel stages throughout Europe, establishing a promising baseline on which to build over the coming months. The car features a 1.6-litre turbo-charged, direct injection engine, which produces more than 300hp (and is featured in RCEV23N?), while advanced testing and production techniques have shaped the chassis.

With an official WRC programme confirmed, development will be expanded and the dedicated team of specialists to engineer and operate the car will be increased. Frenchman Eric Camilli, 27, has been selected as the first member of a junior driver development scheme designed with the goal of developing Toyota rally stars of the future. He will line up with Toyota's FIA WEC driver Stéphane Sarrazin, and Sebastian Lindholm.

That test programme will include several WRC venues around Europe on a variety of surfaces. Experience gained will assist Toyota

Toyota has an illustrious WRC heritage. Cars such as the Corolla WRC have delivered 43 victories

TECH SPEC

Toyota Yaris WRC

Chassis:
Type: Steel body shell
Brakes: 300mm discs on gravel, 355mm on tarmac
Wheels: 7 x 15" gravel, 8 x 18" tarmac
Tyres: Michelin

Dimensions:
Length: 3910 mm
Width: 1820 mm

Engine capacity: 1.6-litres

Type: In-line four-cylinder

Direct injection: Up to 200bar

Fuel: Petrol

Turbo pressure: 2.5bar absolute (maximum)

Air restrictor: 33mm

Power: Around 300hp (at 6,000rpm)

Torque: 420Nm

Max revs: 8,500rpm

Transmission: Six-speed sequential

Clutch: ZF Sachs

as it prepares a car for the 2017 season, when updated technical regulations are expected to be introduced.

The Yaris WRC follows a long line of Toyota cars to carry the brand into WRC and when it makes its competitive debut in 2017, it will mark almost two decades since the company's final World Championship rally, in 1999. The 1999 season marked the end of more than 25 years continuous rally activity at TMG, which began life as Andersson Motorsport GmbH, named after company founder Ove Andersson, and competed in WRC as Toyota Team Europe.

During that time, 43 wins were achieved with iconic cars like the Celica Twincam Turbo and GT-Four variants and the Corolla WRC featuring legendary drivers such as Carlos Sainz, Juha Kankkunen and Didier Auriol.

TMG returned to the rally world last year with the introduction of its GT86 CS-R3 customer rally car, designed to FIA R3 regulations.

Yoshiaki Kinoshita, TMG president says: 'It is a great honour to be asked to bring the Toyota name back to the World Rally Championship alongside our continued participation in the World Endurance Championship. To run two works motorsport programmes simultaneously is a challenge but we believe we have the expertise and determination to succeed. There is much to do as we make the journey back to WRC but to have received the support of Toyota Motor Corporation and our president Akio Toyoda is already very encouraging. We are looking forward to taking the next steps with an extensive development plan and a junior driver development programme. It is an exciting time and we are looking forward to this new challenge with great anticipation.'

World Challenger

Cadillac has built a car to European GT3 specification to contest the Pirelli World Challenge, but could take the programme to a global level

By ANDREW COTTON

GT3-spec ATS-V.R is eligible for up to 30 race series aorund the world

Cadillac had little choice but to build its first European-specification GT3 car as the American-based Pirelli World Challenge changed its regulations to accommodate the category that is prolific around the world.

The American manufacturer developed the Cadillac ATS-V for competition, replacing the now dated CTS-V, and will run the car in North America as a customer programme. However, with national series around the world using GT3 cars, and in Europe the Blancpain Sprint and Endurance series using the same cars, the opportunity to kick-start a global customer programme is also there.

With Audi, Porsche and Lamborghini all set to launch their new GT3 contenders, the Cadillac would be up against strong opposition, but the manufacturer has developed its car to be able to complete 24 hour races and could therefore take to the track in Europe's bigger races, including Spa and the Nürburgring.

'We had to build a GT3 car to continue to compete where we are in World Challenge,' says Mark Kent, director of GM Racing at General Motors. 'Our car and one other were the last two built to the old rules and now you have to have a GT3 car. What it offers us is a global opportunity with Cadillac, which is a global brand. Our near-term plan is to use this season in World Challenge to develop and validate the car to win races and championships and from there on we will spring off and go global, probably with a customer programme. If we are able to develop a capable racecar here that can be used globally as a customer car, then it is a win-win for us.'

The customer price for the car has yet to be finalised, suggesting that this is primarily a factory programme designed to show off the new car to customers in a racing environment, with the opportunity to sell customer cars as an added bonus.

'We haven't fully developed the cost, and we are looking at ways to revise the car to be more cost-effective,' says Kent. 'There are things that we have learnt that could be done more efficiently and as we develop our customer car programme we believe that we can build cars that are keenly priced against the competition. We have not estimated how many we can build, because we haven't been out to ask how many people will want them. We won't know the demand for the car until we go out and compete in World Challenge and people have the opportunity to see it.'

Ladoux testing

The car will make its race debut in March, but already it has been to the Ladoux test facility in France to be performance balanced against the other GT3 cars from the likes of Porsche, Ferrari, McLaren and the new Lamborghini. The test measures downforce, power and drag figures and cars have to fit into a performance window set by the FIA. Cadillac used its partner team, Pratt and Miller, to develop the car for the test and for racing.

'The FIA has a great process. They define the performance criteria of the car, aero, power to weight and that helps a lot with the engineering,' says David Caldwell, programme manager of the Cadillac programme. 'We knew our targets going in there and they had us run a few different configurations of aero and power. Their drivers drove the car and I was pretty impressed with the process. We don't have our BOP assigned to us and we are still working through the process.

'This car is built to GT3 specification and the biggest differences [between it and the out-going CTSV-R] come down a to a focus on aerodynamic performance. There is more aero on the car and we had to use all the tools and resources that were available to us. The other thing is the 24-hour endurance specification. We built a spec racer in the CTSV-R, and that car was sprint race capable. This is sprint and endurance capable and that led us having to do a lot differently on the ATSV-R, but we have a lot of experience in GM and at Pratt and Miller. We are still working through the validation but we are encouraged by the results.'

'The FIA gave us a distinct target of where we want to be,' says Kent. 'We have been developing the engine, and got it close to where they wanted it to be, and the same on the aerodynamics. There were no surprises, just minor adjustments but we were close from the start. The biggest thing was figuring out

"We had to go above and beyond the streetcar envelope. We don't know where our power is going to be, but 550bhp is a rough target"

the combination for the results that they were looking for. On the engine the big focus was to develop an engine to have the output that was reliable and have the power to compete in the endurance races.'

Twin Turbo

The development of the engine was one of the key components for the car, and the target was to stay close to the production unit while upping the power from 470bhp to around 600bhp before the BoP restrictions. Specific technical upgrades for the GT3-spec racecar include larger, twin BorgWarner turbochargers, increased capacity intercoolers, competition engine management and a direct, side-exiting exhaust. The lightweight aluminium block and heads are counterbalanced by a rear transaxle unique to the race car, giving the ATS-V.R a weight distribution of 49 percent front, 51 percent rear.

The car uses the same 3.6 litre V6 twin turbo engine as the road car, with aluminium block and cylinder heads that are used in the street car, but there are weaknesses in the engine that needed to be addressed as the power increased.

'On the powertrain side, one of the things that I am most proud of is that we have stayed true to the ATS-V,' says Caldwell. 'We are using the same twin turbo V6 that the streetcar uses, and we worked with the production team and race engine team. We had to go above and beyond the streetcar envelope. We don't know where our power is going to be right now, but we are sure that 550bhp is a rough target for where we need to be.

'We had to step it up on the engine and make it capable of 24 hour endurance races. There are a lot of components that are modified to increase the power and maintain durability, but the overall configuration is the same, so we have an integrated intake manifold, air cooler, heat exchanger, just like the streetcar, and the turbos are in the same location – they use the titanium aluminide turbine wheels just like the streetcar does. We stayed close to the architecture because one of the foundation reasons for racing is the technology transfer from racecar to streetcar. At the end of the day, we are validating our engine envelope around the 600bhp target. I don't think they will give us that power under the BoP, but we want a robust package nevertheless.

'The production team has taken a twin turbo programme in the works when we decided that we needed to try to race it, and we were able to learn a lot from the production team – the cylinder head flow capability and what you needed for a given amount of power, and the boost levels that you needed. There is a real harmony between the production team and race team on the engine, and there is a lot of knowledge that we were able to gain. Then we stepped it up to 600bhp and now we are feeding that back to the production team.

'There were some weak points that we were able to address, and they could take those to make the streetcar better. If you carry more power you need more cylinder pressure, and so the details of the pistons, the connecting rods, the heat transfer, the cooling capability, those are the things that we have been working on.'

Upping the power clearly leads to a change in the cooling requirements, and that brings a drag penalty. From the start, the team was conscious of the cooling requirements and worked with the production car team to speed up the process, and deliver the findings back to the streetcar. 'Cooling has been a real area of focus,' says Caldwell. 'We are using production cylinder heads. The engine uses an integrated exhaust manifold, so you don't have a header, and that puts a lot more heat energy into the cooling system. That is one of the areas that we can gain a lot of knowledge and contribute back to the production team – how to cool the engines with these integrated exhaust manifolds.'

Thanks to the larger twin BorgWarner turbochargers, a direct, side-exiting exhaust system and larger capacity intercooler, the AST-V.R's 3.6-litre twin-turbo V6 powerplant produces up to 600bhp at 7400rpm

The carbon fibre aero package features an aggressive rear diffuser, a front splitter, dive planes and rear bumper cover, all of which have been designed to fit FIA-mandated tyres and wheels

A full-length undertray directs air beneath the car to the rear diffuser, which helps create a downforce-producing effect and keeps the 18-inch racing tyres planted securely to the track

The link between race and production is key to the success of the GM programmes, started with the Corvette C5 and C5R, which fed into the C6 road and race programmes, and they fed into the C7R. 'On the engine side, all the development has been done on the inside of the GM powertrain, so we are working hand-in-hand with the production group,' says Kent. 'The same facility that does the Corvette engine does the Cadillac engine. GT3 has seen an explosion of entries. It is a great platform and I am confident over time that the sanctioning bodies will keep costs in check.'

Aero development

The ATSV may be a replacement of the CTSV, but there are only a few carry over parts, including the suspension and the transaxle layout, but the aero changes were significant as the GT3 rulebook opens up many more opportunities.

Among the many modifications performed to meet FIA GT3 specifications, the wheel arches of the ATS-V.R were redesigned to contain FIA-mandated tyre sizes. Other modifications include an aero kit that gives the ATS-V.R a strong stance, and a carbon fibre front splitter – complemented by corner-mounted dive planes – that provides frontal aerodynamics. A full undertray directs air beneath the car to the rear diffuser, which helps create a downforce-producing effect and plants the 18-inch racing tires to the track.

'On the aero, in World Challenge GT, you can really only put a wing on the car and front splitter,' says Caldwell. 'You can't engineer under the car to get aero efficiency. You can generate downforce, but you carry a lot of drag with it. In the case of the GT3 car we were able to get efficient downforce. The whole underside and topside of the car is aero. We just balanced the body surfaces on the top side of the car, and then did what we had to do under the car. The FIA did a great job. As far as I am aware we are right on target for aero downforce, drag and aero efficiency.'

Carry over

The suspension features carry over parts from the CTSV, but the design is all new. 'The suspension is something that you have to design around the tyre,' says Caldwell. 'The racecar has about a 50mm ride height consistent with the other GT3 cars, and that is nothing like a streetcar. We took the tyre and the ride height and modified the suspension around that. One of the things about the streetcar that's great is how they managed the light weight. I think that we have a good suspension package for the racecar.' The street car doesn't have an option that would work for GT3, so the team uses the Xtrac sequential box.

'The V-Series is the highest expression of Cadillac's rising product substance,' says Johan de Nysschen, Cadillac president. 'Elevating and expanding the V-Series is the next logical step in Cadillac's growth, including this new race car developed in GT3-specification, enabling us to pursue racing on a more global scale.'

TECH SPEC

Cadillac ATS-V.R

Chassis construction
Reinforced eight-point welded roll cage; carbon fibre hood, deck-lid, front wings, doors, rear fenders

Suspension
Three-way Penske adjustable shocks, front and rear independent SLA suspension

Transmission
Xtrac sequential six-speed rear-mounted transaxle; steering wheel-mounted paddle shift; no lift shift; limited slip differential with 3.13 final drive

Clutch
AP Racing

Wheels
BBS 12x18in aluminium front and 13x18in rears

Tyres
Racing tyres, front 315/680 x 18, rear 325/705 x 18, series spec

Brake system
Brembo, six-pot front with 380mm disc, four pot rear with 355mm disc; Bosch ABS M4 controls with driver-adjustable modes

Fuel system
120-litre (31.7 gallon) fuel cell

Electronic systems
Bosch MS5.1, programmable

Engine
LF4.R 3.6L, Twin-Turbo V-6 with production aluminium block and heads, up to 600 HP@7400 RPM torque 520lb.ft (unrestricted), developed and built by GM Powertrain

Turbo
BorgWarner EFR Series twin-turbochargers, boost set to FIA specifications

Weight
2,900lb /1315kg

Traction control
Electronic, driver adjustable

Pedals
Close-ratio foot pedal box, accelerator, brake, clutch

Steering
ZF hydraulic power-assisted rack and pinion steering

Aero kit
Carbon fibre five-piece aero kit including side skirts, front splitter, fascia and dive planes, rear diffuser and rear bumper cover

Other features
Motorola two-way radio; Pratt & Miller-developed side-impact-reducing crush box, carbon fibre custom-moulded cool seat and competition driver air conditioning system; Willans six-point racing driver seat belts; dash display rear view cameras

"GT3 has seen an explosion of entries. It is a great platform and I am confident over time that the sanctioning bodies will keep costs in check"

Slowing down the Camaro

How strict technical GS Class regulations forced GM to make radical changes to its racecar

By SAM COLLINS

One of the staples of North American motorsport is the long running stand off between the muscle cars of the 'big three'. This is played out most famously in NASCAR, with the Nationwide series cars currently representing the so-called pony cars. But the battle is also played out on the road courses, and here the machines used have always been largely production based, in the late 1960's and 1970's the Penske Camaros came to prominence with the likes of Mark Donohue at the wheel. It is a heritage GM is keenly aware of, and something that it is trying to keep alive.

Today the road racing battle of the pony cars is played out in the GS class of the Continental Tire Sportscar Challenge, part of the IMSA package. In this series cars start out as stock, production models and race with minor modifications. Ford races its Mustang Boss 302 in the class (which also features European cars), and GM is taking it on with its Camaro Z/28.R.

It is the latest in a line of racing products that has a direct link to the development of the production car models and throughout its gestation the GM racing engineers worked hand in hand with the road car department.

'If you look at the Z/28 production car, it is really a street legal racecar,' explains Mark Kent, director of GM Racing. 'Looking at the power and aerodynamics, what we wanted to do was bring it to the racetrack and validate its performance. We want to use the series to demonstrate to a large audience the potential of the car. The only modifications are ones that are driven by the series. There are things that we have had to take out of the production car to enable us to race the Mustangs and the Aston Martin.'

The GS class technical regulations enforce a number of restrictions on the technology used on the cars regardless of what is used on the production version and that has seen a number of surprising changes to the Z/28.R over its showroom counterpart. 'We had to go down to a smaller wheel size because of the series, and de-tune the engine to let it race here,' Kent continues. 'We have this wide range of production cars. The biggest dog has got to get tuned down a bit. It is a good programme for us to be able to race hand in hand in nearly stock condition against BMW and Mustang. Our race track competitors are the same as our showroom competitors.'

Work on the Z/28.R started in collaboration with the production car, and both competition and street car were influenced by the programme. 'It started very close to the road car, and where we could we kept everything from the production car, so we kept the engine, the suspension and so on,' says GM Racing Programme Manager Lisa Talarico. 'The brakes were a difficult one because we weren't allowed the carbon ceramic and the other performance brakes that we have don't fit inside an 18-inch wheel. We started with a six-piston caliper, and that was a big sticking point for the series so we had to switch over to a four-piston caliper for 2015. We still have the same base setup with the same base pedal box which they have allowed everyone to have. We were the first to have the pedal boxand that was a function of

"It is basically a production engine, and durability tests have shown that we need maybe two engines per season"

being the first new car to come in. It is a safety thing for our drivers and we think that it is a benefit for everyone.'

The overall shape of the Camaro was designed with racing in mind, which is normal for a GM street car of this type. 'The good thing about that is that the Z/28 does offer some aero features, mostly related to downforce,' Talarico continues. 'Having the production aero pieces is important. The team has done a lot of work on that, including the front splitter. In the production car, the rear wicker is adjustable but that is not allowed in the series, but we have found that to be a very efficient aero piece. We also have the rockers and the flares which has helped us increase the track width.'

Power on a GM competition car, especially a 'pony car', almost invariably comes from a Chevy V8, and on the Z/28 it is the seven-litre LS7 variant, but in GS form the engines are tuned to produce between 350 and 405bhp, which meant that the Z/28 had to be significantly detuned to meet with the regulations.

'It is basically a production engine, and that is important to us,' continues Talarico. 'The durability tests showed that we only really need maybe two engines per season. The production car has some difficulty cooling and we have had to do some work on that. Part of the problem is that you take a production car and remove some of the ducting, the induction system, the radiator and all that is basically what the series allows us. We have done a lot of work on positioning, sealing off the airbox, but we did spend the majority of last season working on that. By the end of the season, we were in pretty good shape. We do have some high temperature issues, but pretty much only when we are in traffic and when we have no airflow when following other cars.'

Greater production bias

That learning from the racetrack can be fed back to the GM engine engineers in Detroit to allow them to improve the cars current and future designs. 'We have got it well under control, and as far as taking what we've learnt back to the production team, it will help them because we have done a lot of work,' says Talarico. 'Everything that we do here we share with them. This is really the first GS car that we have gone all the way with. You are going to see a lot more benefit on the Camaro side.'

The brakes on the car did prove to be an issue, and had to be changed for the 2015 season, but not for performance reasons. 'This year, the second season for the car, is pretty much a carry over from last year other than the brakes,' says Kent.'

But as ever the rules are perhaps too restrictive in the GS class, and despite the fact that the production car has a number of modern features the technical regulations of the series outlaws them. 'We would have liked to have used other parts of the street car like the dampers and the brakes, but those are technologies that are not allowed in GS right now. But having said all that the series is seemingly open to new technologies, like DSG gearboxes, so in the next generation of cars we are looking to introduce a lot more production parts,' Talarico concludes.

In the first race of 2015, held at Daytona, the Camaros bested the rival Fords, but ultimately lost out to a European GT car. Beating the Mustangs shows that the improvements made to the Z/28.R have worked – the question now remains, with a new motorsports structure in place how will Ford fight back?

GM's team of engineers has invested huge amounts of time and money to make the Camaro as aerodynamically efficient as possible while using parts taken straight from the production car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Viral sensation

We get the story behind one of the internet's most watched cars – Ken Block's 1965 four-wheel-drive Ford Mustang

By SAM COLLINS

It is a competition vehicle that is more recognisable to car fans around the world than any of the 2015 Grand Prix cars, and will remain so until at least the Australian Grand Prix. It is a car that has never been seen at any public event or even entered a competition, and yet it was originally built in 1965. In the first eight weeks after it was uploaded to YouTube, Ken Block's Gymkhana 7 had been watched more than 20 million times, and his car, dubbed the 'Hoonicorn RTR', instantly gained cult status.

While Block's previous videos had used adapted rally and RX cars, initially Subarus and more recently Fords, this is the first time he has used a fully purpose-built machine.

'We wanted to re-invent things and do something different' explains Derek Dauncey, the Hoonigan Racing Division Team manager. 'We had done a few Gymkhana videos with the Fiesta and with it appearing in GRC too people were used to it. We were at a Monster event at the Santa Pod drag strip, and just chatting in a quiet period when Ken had the idea of doing something with a 1965 Mustang. He came up with three wishes – it had to be a Mustang, it had to have a V8 engine in it and it had to be four-wheel-drive.'

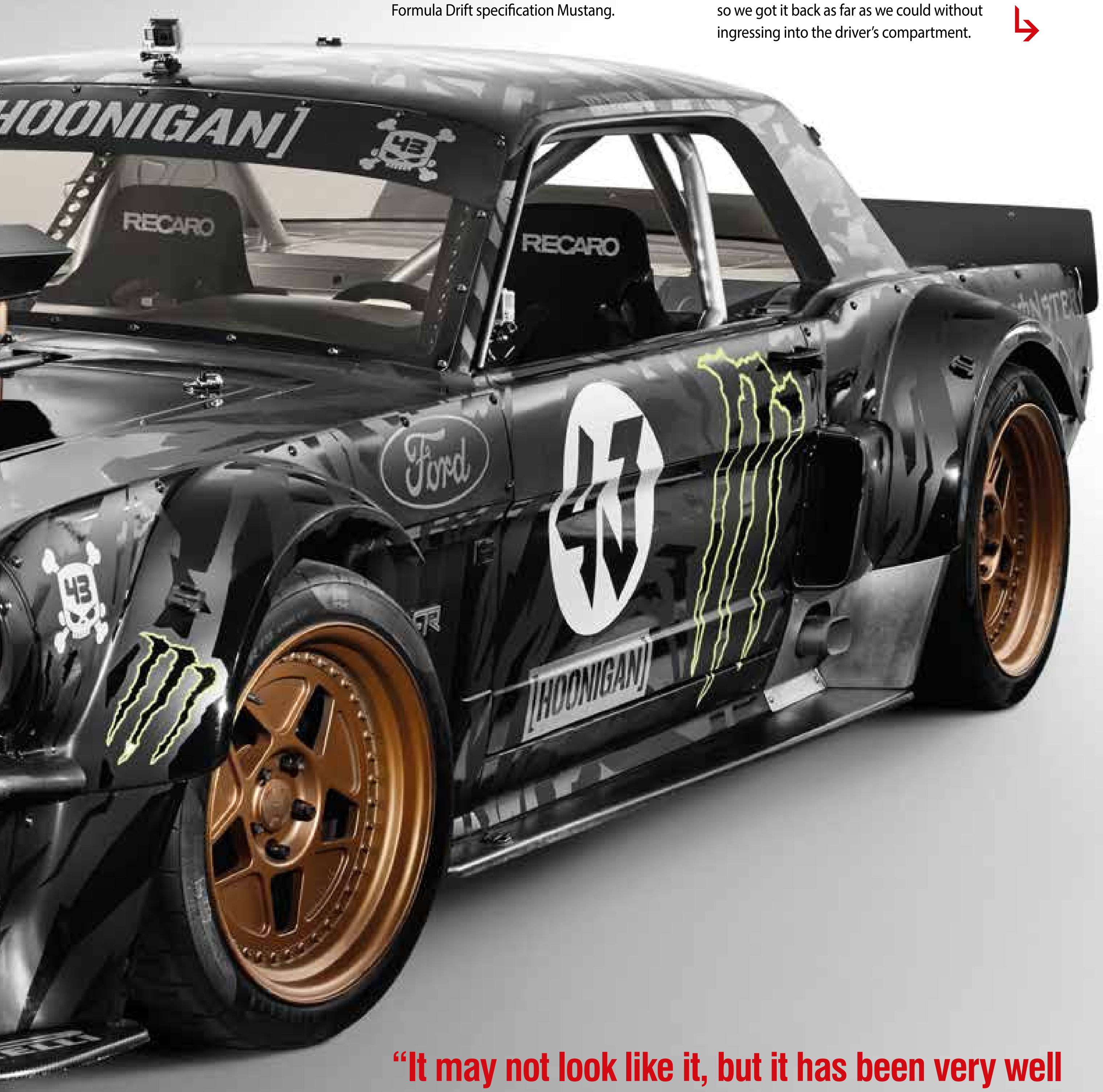
On the face of it this does not sound like a great challenge, especially when the main purpose for the car is to feature in a 10-minute online clip. But far from being some movie prop designed to perform a few stunts, this one-off Mustang is a fully-engineered competition car, according to one of its creators, Dauncey.

'We went to see Auto Sport Dynamics in North Carolina to discuss it some more and we realised we could grant Ken's three wishes and started work right then. We quickly realised it was going to be a fairly revolutionary car. We knew when the filming was over that we would do some other events and promotional work, but we wanted it to still have the capability of being used for a real competition.'

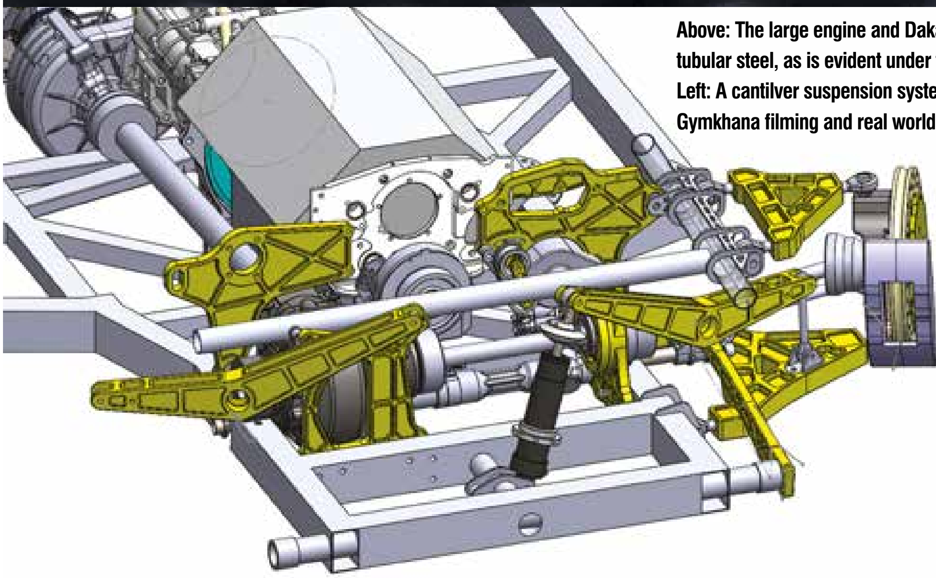
The teams at Hoonigan Racing Division and ASD had to meet Block's demands. 'Ian Stewart at ASD went out and found us the base car and the engine, while we looked into making the whole thing come together properly', Dauncey continues. Stewart turned to Ford's long-time engine supplier Roush Yates and acquired one of its small block 6.7-litre Sprint Car engines. This unit, when built to Block's specification complete with eight individual Kinsler throttle bodies and a MoTeC management system, is very similar to the one used by Vaughn Gittin Jr.'s Formula Drift specification Mustang.

Gittin was a key player in the development of the 'Hoonicorn', as he later revealed in a posting on the Speedhunters website. He had been tasked with marrying Block's description of the car he wanted with what it would actually look like, so he turned to designer Andy Blackmore to develop some concept sketches, which would also have a significant impact on the engineering side of things. It was bad news for the base car.

'Ian had come up with a nice original car so it is a shame that not a lot of it remains. One of the criteria set by Ken and the designers was that the engine had to be as far back as possible, so we got it back as far as we could without ingressing into the driver's compartment.



"It may not look like it, but it has been very well engineered to be a multi-discipline machine"



Above: The large engine and Dakar transmission saw the '65 Mustang chassis replaced with tubular steel, as is evident under the bonnet of the car. Note positioning of JRi dampers
Left: A cantilver suspension system was fitted front and rear to meet the dual demands of Gymkhana filming and real world competition

> **"We had an engine that could chuck out just shy of 900bhp, but needed something we could fit in the car"**

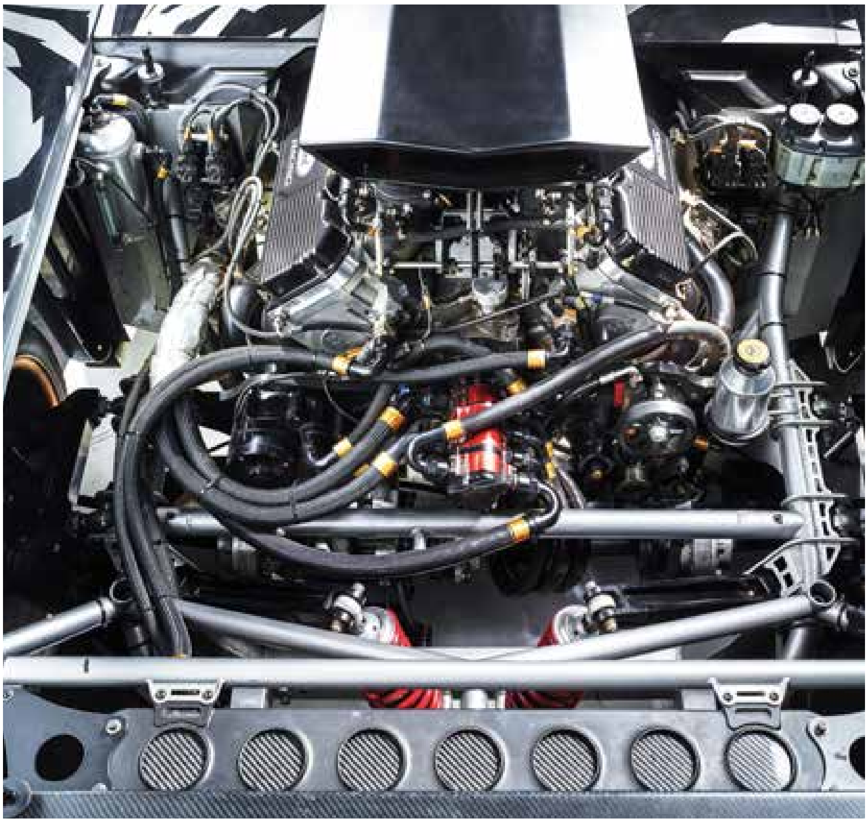
From that point it was clear that we would have to use a tubular chassis, so that was the floor gone. The rear went to install the rear diff, but there is some of the original Mustang left; the bulkhead panels, the roof, but hardly anything else.'

With the V8 and 1965 Mustang demands met, the teams at ASD and Hoonigan then had to look at ways of making the car four-wheel-drive. Dauncey knew the French engineers from Sadev from the development of Block's Rallycross Ford Fiesta, and turned to them for help. 'We had an engine that could chuck out just shy of 900bhp and 830Nm and we needed something we could actually fit in the car. There was a lot of thought about what to use and after discussions with the team at Sadev, we ended up using a Dakar style gearbox,' he reveals.

The transmission used is the Sadev SC90-24, a six speed sequential transaxle unit extremely popular with Dakar Rally competitors. 'The reason for that 'box was that, from an installation point of view, we were going north-south. When you look at the V8 it is a massive lump. You need the diff as close to the centre line as possible, and that was going to create installation problems,' Dauncey continues. 'The Dakar 'box would allow us to run a wider gear. With the way the V8 delivers its power, the demands of the filming and the way the accelerator pedal gets pumped, quite a lot is dramatic for the transmission so we needed it to be strong. The other key factor is the step off unit that goes to the front diff – you could see how it may have been the weak link in the drive train. So we wanted to be able to change it quickly.'

The transmission was not entirely standard. Block's driving style and the demands of filming meant a special hydraulic handbrake was fitted to the car which disengages drive to the rear while simultaneously locking the rear wheels. It was a system first developed for use on Block's RX Supercar. Feeding the power to the rear wheels was a greater challenge than expected, mainly for packaging reasons. 'The articulation

The 'Hoon Handle' is a specially developed handbrake which not only locks the rear wheels but also disconnects drive to the rear. It was originally developed for Block's rallycross Supercar. Note the traditional looking Auto Meter dials supplemented by a MoTeC digital dash



The huge Roush-Yates Sprint engine produces almost 900bhp and sits as far back as possible due to aesthetic demands rather than for vehicle dynamic reasons

of the joints and laying out the shafts through the car was really tough,' Dauncey explains. 'We had to drop the floor for Ken, because he is so tall his helmet was hitting the roll cage. On the other side we had to fit a passenger seat and that was really tight too. And between them you have to run the shaft. With the tight packaging at the front end we wanted to run the car as early as possible to prove the driveline. The front and rear diffs are offset slightly which is not ideal, and we had to look at the articulation of the joints through the car.

'On the shafts we worked with both Sadev and a really good company in North Carolina called the Driveshaft Shop. The shaft from the transfer box to the front was really designed as a fuse so that if massive load was heading for the box it would be that shaft that failed. The first time we ran it, it had no body panels or anything and we were not sure it would work at all. But it worked perfectly. There were no nasty surprises.'

The next major task to tackle was the suspension, which led to the use of an innovative cantilever layout.

'We wanted a car that worked for the gymkhana stuff and also one that would let us get the steering angle correct, and so in that respect it was built like a competition car,' Dauncey explains. 'It may not look like it but it has been very well engineered to be a multi-discipline machine. On the GRC Fiesta you are looking for maximum grip and weight transfer forward for turn in and small steering inputs. For a gymkhana car you need something stiff that can slide around at 15mph. It's a totally different way of looking at things. Ian Stewart suggested that we use a cantilever suspension system on the car.' The idea Stewart suggested would allow the car to have a very stiff setup where needed or something more conventional when the time comes for the car to go into competition. They ran the whole thing through CAD and the system works really well. 'If we were filming on a bumpy street we could wind the ride height up quite easily or if we were doing some static event we could quickly lower it,' Dauncey continues.

The tight packaging at the front of the car also affected the suspension design. The wheels had to be moved slightly from their original to accommodate the differential, and this allowed them to get a steering angle of up to 38 degrees while maintaining a proper Ackerman. Gittin later revealed in his web posting that the car's aesthetic demands were very significant. 'One of the biggest challenges was the overall width of the car and the fact that we required some wheel lip up front. All-wheel-drive cars work similar to front-wheel-drive cars under throttle, and you will notice most front-wheel-

"The shaft from the transfer box to the front was designed as a fuse so that if massive load was heading for the box it would be that shaft that failed"

The bodywork of the 'Hoonicorn' was orginially fabricated in metal before moulds were taken and made in composite materials, only a few panels of the orginal '65 Mustang remain. Some of the aerodynamic elements of the bodywork such as the diffuser and NASCAR style spoiler are fitted more for show, but could be reworked ahead of competition

drives use high offset wheels to create the desired scrub radius. The small scrub radius would allow this car to have great steering feel and no wheel-jerk under throttle. The target scrub radius of 850 thousandths of an inch and desired wheel profile was achieved by making custom uprights, rotor hats and using thin brake calipers.'

The small brakes are one of the few areas specced purely for the filming rather than real competition, but they are something that could be changed in the future. 'It's worth noting that, while it's a big car, it only weighs 1310kg, which is about the same as the GRC Fiesta. For the filming the brakes on the car are not actually that massive, but if we want to do something performance driven we could use a bigger disc. And while the six-pot caliper is man enough for it, it's the one area we may look at uprating overall,' Dauncey explains.

When Block first got behind the wheel of the car he was very complimentary about the way it drove, apparently claiming it to be the best car he had ever driven. 'The car is unbelievably dramatic but it's incredibly controllable', Dauncey adds. 'With the drivability of the V8 the car is much easier in. You can hold it in second or third gear and spin it – that's something you could not do on other cars. With them being turbocharged you would have to come in at a higher speed, then hit the brakes and initiate the handbrake turn before launching it.'

What the future holds for this unique car is not clear but it seems likely that it will not sit idle while the views on YouTube continue on their relentless march upwards. Dauncey and Block clearly have other competitions in mind, but the reality is that there are not many places where a machine such as the Hoonicorn RTR could compete. 'I'm hoping the car will run in some more events around the world,' Dauncey teases. 'We have some ideas what we want to do. There are definitely some things we have in mind, which we might do in future, and I'm sure the car will be out competing somewhere in the future.'

TECH SPEC

Car Name: Ken Block Hoonicorn RTR

Engine:
410 cubic inch Roush Yates V8, 8x Kinsler individual throttle bodies, MoTeC engine management system
Max Power: 845bhp
Max Torque: 720lb.ft

Transmission:
6-speed Sadev SC90-24 all-wheel drive transmission with hydraulic handbrake system, Quarter Master 7.25-inch triple-plate clutch, ST03 differentials front/rear

Suspension:
Inboard cantilever actuated JRI dampers, Eibach springs

Wheels/Tires:
fifteen52 R40 18×10.5-inch wheels, Ken Block compound Pirelli Trofeo R 295/30R18 tyres

Bodywork:
Composite and metal panels

Interior:
ASD Motorsports custom rollcage and door bars, MoTeC display, Recaro race seats, Sparco harnesses, custom Auto Meter gauges

"The car is unbelievably dramatic but it's incredibly controllable. You can hold it in second or third gear and spin it"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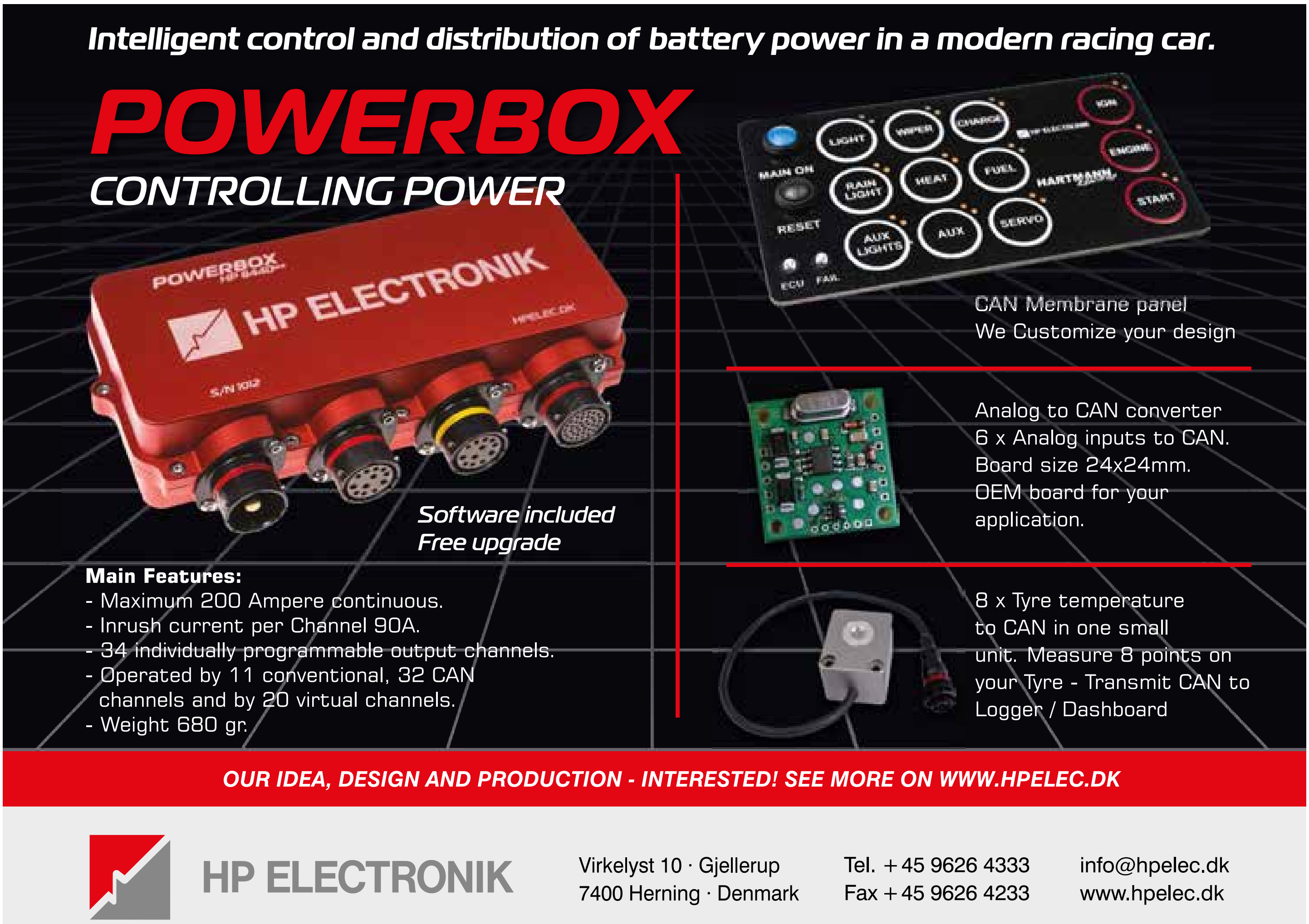
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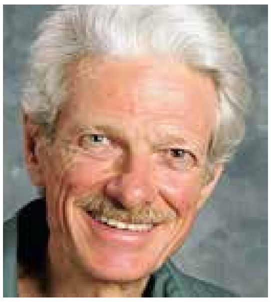

Fast and furious public trials

Anti-roll bars and steering offset investigated

Question

We build Sporting Trials cars. They have a rear mounted transaxle with "parallel" wishbones and a single transverse shock absorber with an anti-roll bar. I have noticed that the cars have good grip if momentum is maintained but are very reluctant to dig in and find grip in the mud once forward motion has ceased. Is this possibly due to the lack of anti-squat in the parallel wishbones?

The consultant says

This is the first question I've had from a trials competitor. We don't have this form of motorsport on my side of the Atlantic and I've never had a client doing it, but I'll offer some thoughts nonetheless.

Anti-squat does give a momentary increase in wheel loading when the sprung mass is accelerating upwards – that is, for a very brief time interval upon abrupt application of power. This is true whether the car is in motion or not. In some cases, the momentary increase in load will make an important difference. Ideally, in a trials car we'd like to time this to coincide with the momentary load increase from a bounce by the passenger. Anti-squat will also makes the rear of the car sit that bit higher under power. This has the advantage of raising the centre of gravity a little, and slightly increases rearward load transfer when accelerating forward or going uphill.

With independent rear suspension, assuming there aren't drop gears in the uprights, getting anti-squat depends on making the hub move rearwards as the suspension compresses. Since no drive torque is reacted through the upright, it doesn't matter how the side-view inclination of the upright changes with suspension displacement. That is, as long as we're under power and not braking it doesn't matter how long or short the side view projected swingarm is, or whether the side view instant centre (SVIC) is ahead of the wheel, behind it, or undefined.

If the side view instant centre is ahead of the wheel, it must be above hub height. This means the side view projected lower control arm must slope upward towards the front. If the side view instant centre is behind the wheel, it must be below hub height. This means the side view projected upper control arm must slope upwards toward the front. If the side view projected control arms are parallel to each other, the side view instant centre is undefined. In that case, both side view projected control arms must slope upward toward the front. So in all cases, at least one of the side view projected control arms must slope upwards toward the front, and in the majority of cases they both will.

The choice of whether to put the SVIC ahead of the wheel or behind it depends on whether one wants more or less anti-lift or pro-lift in braking, assuming outboard rear brakes. At first glance one might not suppose that braking would matter much when the main task is to climb muddy hills. However, reading the very minimal BTRDA rules (www.btrda.com/images/uploaded/66_2512249.pdf), I see that although sequential gearboxes are illegal and there is a spec for tyres, there are no rule on diffs or brakes. That would mean you could opt for a spool, but that would make the car hard to turn. Or, you could have an open diff or a non-locking limited-slip, and use a tractor brake (hand brake acting on one rear wheel or the other, either with one lever that you can push in two directions, or two levers that you can pull separately or together).

With a tractor brake, some pro-lift in braking might be desirable. When only one rear wheel is spinning, application of the brake would jack that corner up and help load that wheel. This would involve having the SVIC behind the wheel.

The idea of having a single coilover for ride springing and an anti-roll bar for roll springing is interesting. This leaves the roll mode undamped, but it does allow the system to be softer in roll than in ride, which might be useful for attaining softness in warp. A slightly more expensive alternative which would provide some damping in roll would be to use individual wheel coilovers as usual, and add either a Z-bar or a third coilover to stiffen ride.

I would expect there would be some compromise regarding how stiff to make the ride springing. Having it very compliant indeed would be best, except for getting maximum benefit from the efforts of the passenger. Adding more ride stiffness would probably assist that.

Anti-squat increases rearward load transfer when accelerating uphill

In trials the passenger can play an important a role as anti-squat in boosting grip and traction when attacking hills

Upright geometry and related considerations

Question

I am in the process of designing a universal front and rear upright. I have designed it for 10mm scrub radius when used at the front.

Then I asked myself the question: is scrub important on the rear wheels? And what should it be?

The car it will be used in is a rear-engine space frame type car (front-wheel-drive engine and gearbox moved to the back) with a target weight of 600kg and producing 250bhp.

Last night I was doing some research and discovered you can have negative scrub. So this made me question everything I was designing into my upright. So,

1. For a rear-wheel drive car, is it best to use **positive scrub** (the SAI and the centre line of the wheel crosses above ground)?
2. What is the optimal **scrub radius**? (I always thought 10mm was a happy medium between "feel" and steering wheel force).

Camber is positive when the top of the wheel is outboard of the bottom

When you have excessive scrub, whether it be positive or negative, the steering is more susceptible to road shock

3. What **SAI** should I use? We used to use the Cortina uprights (5 Deg SAI), but these were ditched in favour of the Sierra units that had an 11 Deg SAI. Now my understanding is that you create negative camber as you turn, so the bigger the SAI the more severe this camber creation.
4. How important is the **Droop = Compression/2** setup for suspension movement (working on 50mm compression and 25mm droop)? In one of your letters you explain it, but focused on oval track cars that always turn in the same direction, so they're always loading and unloading the same wheel). This is a track day car that will tackle the odd hillclimb and gymkhana.
5. Is it best to have your front **top wishbone 2/3 of the bottom?** In the picture they seem very close to equal – the same as on an F1 car.

The consultant says

First, the term "scrub radius" refers not to an actual radius but to the front-view or y-axis offset of the contact patch centre from the point where the steering axis meets the ground. The corresponding x-axis offset is called trail. In the UK, the more descriptive term "steering offset" is used rather than "scrub radius". However, in the US, "scrub radius" is the usual term.

The questioner appears to be a bit confused regarding sign conventions for both scrub radius and camber. Ordinarily, and per SAE convention, scrub radius or front-view steering offset is positive when, in front view, the steering axis intersects the ground inboard of the contact patch centre – or when, in front view, the steering axis intercepts the wheel centreplane below ground.

Until the 1970s, most cars had positive scrub radius per SAE sign convention. Before power steering and ball joints, many designers thought zero scrub radius, or "centrepoint steering" was optimal. Negative scrub radius was popularised by VW and Audi, and was touted as a selling point when the Golf (Rabbit in the US) was introduced in 1974.

Camber is positive when the top of the wheel is outboard of the bottom. Increasing front-view steering axis inclination adds positive camber when the wheels steer, on both the inside and the outside wheels.

Optimum scrub radius

In many cases it is not even possible to define a steering axis for a rear wheel, and therefore it is often not possible to define a scrub radius. When it is possible to define a steering axis for the rear, it only matters to the extent that it may influence the suspension's deflection steer characteristics. In a race car with no rubber bushings and good rigidity for all components, there shouldn't be much deflection steer.

Optimum scrub radius depends on design objectives and various practical considerations. A negative scrub radius as used by VW and others is used to minimise the effects of brake pulsation, bumps, flat tyres, and front-wheel-drive related forces upon the steering. A positive scrub radius is more common in race cars. The bigger it is, the more the driver feels bumps, brake pulsations, and so on. That's good in a racecar or performance car as the steering is more communicative.

The bigger the scrub radius is, the more jacking the steering creates when the wheels steer. The combination of scrub radius and caster makes the car roll in the opposite direction to steer. It de-wedges the car (adds load to the inside front and outside rear wheels and unloads the other two) when steering in the direction of the turn, and wedges the car when countersteering. The combination of steering axis inclination and scrub radius makes the entire front end jack up with steer, and creates a central force in the steering that is independent of ground plane forces at the contact patches. Negative scrub radius reverses all these jacking-related effects.

Given a choice of 5 degree or 11 degree uprights for a race car, I would normally go with the 5 degree. I would aim for a scrub radius anywhere from one to four inches (25 to 100mm) – more for low-speed tracks, less for high-speed.

For most applications, we don't want the suspension to either bottom out or top out. Generally, we want to keep bump and droop travel fairly close to equal. Limited droop travel can be used to free up entry and tighten exit, but topped-out suspension doesn't ride bumps well. If the track is smooth, that may be acceptable. In any case, there is no sacred ratio of bump to droop travel.

For control arm lengths, the 2:3 ratio as seen on most cars is not a bad rule of thumb, but it is not sacred. Having the lengths more unequal keeps the geometric anti-roll more consistent as the suspension moves. Having the lengths nearly equal keeps the rate of camber change in ride and the rate of camber recovery in roll more consistent as the suspension moves. Making both arms longer helps everything except control arm weight, but packaging constraints limit how long we can make them.

CONTACT

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis setup and handling queries. If you have a question for him, get in touch.
E: markortizauto@windstream.net
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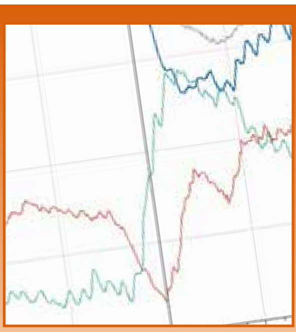

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Pulse Width Modulation

Controlling speed and reducing power consumption

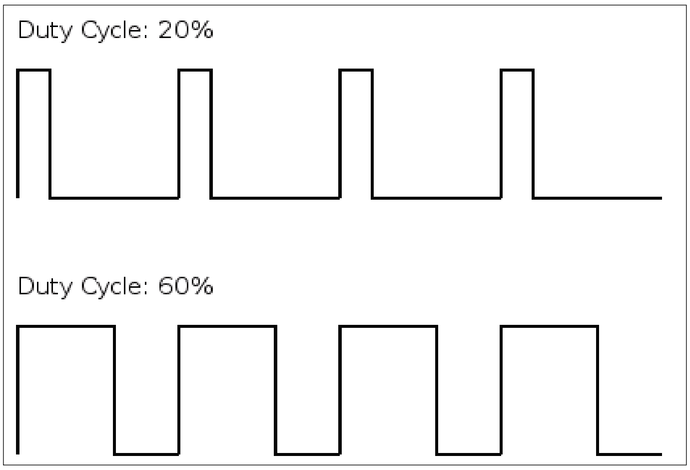

Figure 1: This shows the differences between the length of time the signal is on

Pulse Width Modulation or PWM, is a well known technique used in automotive and many different disciplines of electrical engineering. The principle is to provide a speed control, or to control the power consumption of a specific device.

Instead of driving a device constantly the PWM control supplies pulses of power to a device with a defined width to run the device at a desired speed or reduce the power consumed. The term duty cycle is used in order to quantify the time the signal is on compared with the total time of one cycle. So, if the PWM duty cycle is 20 per cent the device will be driven for 0.2sec in every one second, or whatever time is defined as one period. **See Figure 1.**

The PWM technique is useful for many things in racecars. There are plenty of fans and pumps that could benefit from not being run constantly giving the engineers more control and configurability over the car. In some cases it is necessary to drive devices that draw more current than an available PWM output can provide, in these cases a relay can be used to provide both adequate current and control.

Let's look at an example of how a power control module drives a fan through a relay with one pin providing the high power control through a switch and another providing the PWM signal.

In the first instance the main switch should be configured. The idea is to enable the high power to turn on the fan when the ignition

CHANNELS: Box 1

[Aux Fan Control] = choose ([Ignition] == 1 , choose ([Aux Fan Switch] ==1 , 1 , 0) , 0)

[Ignition Switch] is the channel that shows the state of the ignition switch

[Aux Fan Switch] is the channel that shows the state of the driver fan switch

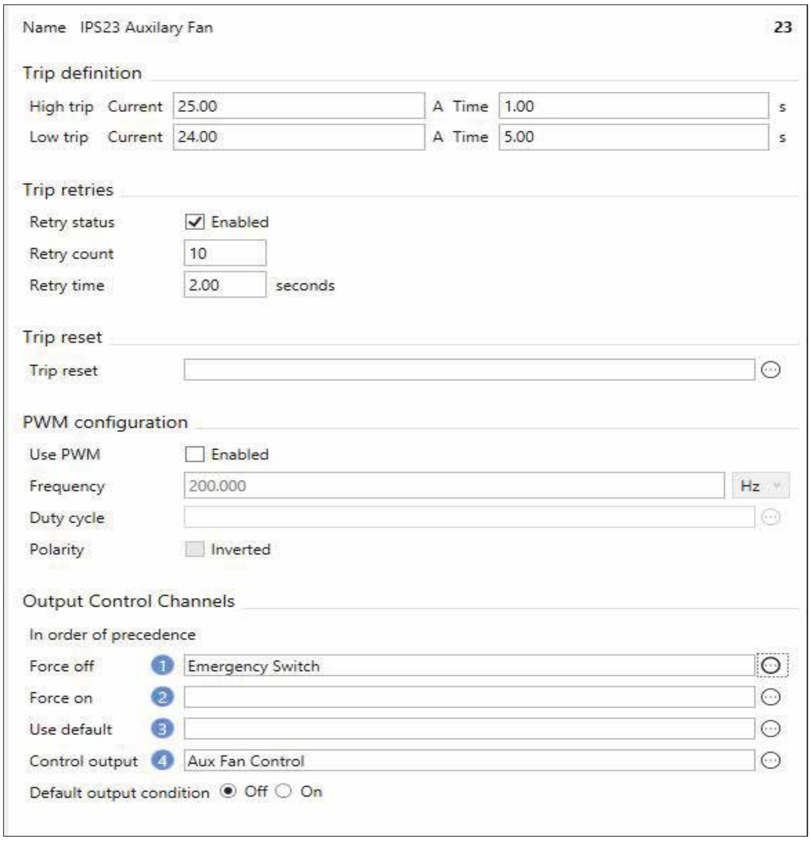

Figure 2: Parameters can be set to acheive the desired output

CHANNELS: Box 2

```
choose ( [RPM] > 4000, 65, 30) So if the RPM is below 4000 the duty cycle is 30 per cent and if above it is 65 per cent
```

CHANNELS: Box 3

```
[Fan Dutycycle] = a0     ( choose ( [Fan Current] > 16 , choose ( @a0 == 0 , 0 , @a0 -1 ) ,

                                choose ( [Fan Current] < 14 , choose ( @a0 == 100 , 100 , @a0 + 1 ) ,

                                     choose ( [Ignition Switch] == 1 && [Fan] == 1, @a0, 0 ) ) ) ) ;

              @a0
```

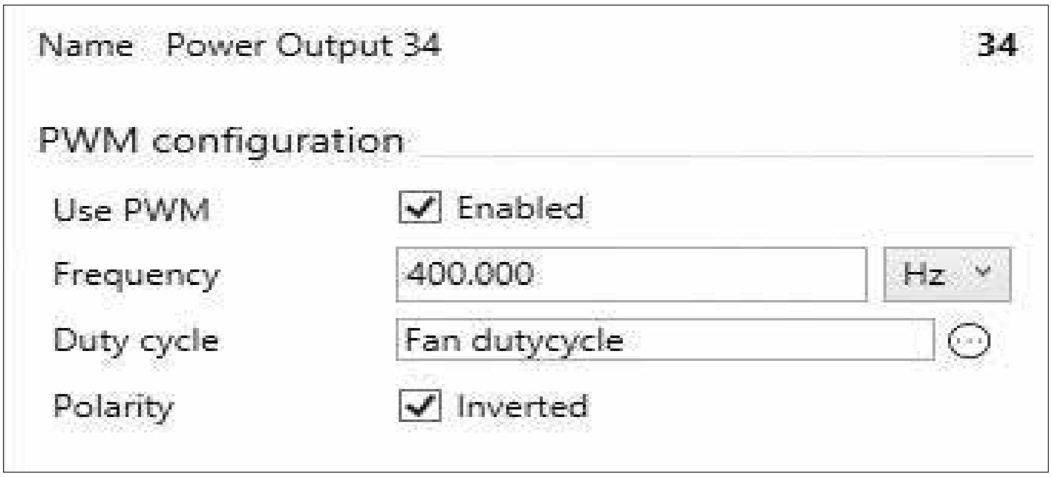

Figure 3: PWM gives technicians more control and configurability over racecars

switch is on and when the driver pushes a button. Therefore, the first condition in the control line is to check whether the ignition switch is set to one and if it is the channel goes to one when the driver pushes the fan switch. **See Channels Box 1.**

This channel can then be used as a control function for the desired output. **Figure 2** shows the configurations of the output which include the trip values for protection of both the device and wiring looms in the car. It is also possible to configure automatic or manual resets based on a maths channel or a switch. Note that this output also has PMW functionality, but in this case we are using two outputs to drive a relay so this is not configured. The auxiliary fan control channel is then set as the control output and in case of emergency the marshal's switch can force the output off.

Then we point our attention to the PWM side. For this we are using a low-powered output that requires a duty cycle in percentage as its control function. This allows us to implement various clever strategies in order to deliver the best control. One simple idea is to set the duty cycle based on rpm – this means that at low rpm the duty cycle can be low to reduce the strain on the alternator and at high rpm the duty cycle is higher. This could be done as per the definition in **Channels Box 2.**

This is a fairly crude function and does not have a great deal of sophistication, but there are ways of implementing a more accurate control. As the power device we are using reports the current draw of the fan it is possible to structure the strategy so that a set current limit is never exceeded. **See Channels Box 3.**

This channel monitors the current draw of the fan [fan current] and if it is more than 16A then it starts counting down in register a0 – if the current draw is less than 14A then the counter goes up. The duty cycle value is therefore dictated completely by the current draw. If the duty cycle is 100 per cent and the current draw is over 16 amps, the duty cycle will be reduce to 99, the counter then keeps reducing the duty cycle until the current draw is less than 16 amps.

The opposite happens if the current draw is less than 14 amps. Line 3 is there to give the fan a soft start effect, where if the switches are OFF then the register count is set to 0.

The fan duty cycle channel is then used in the PWM configuration of the power output, as shown in **Figure 3.**

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One simple idea is to set the duty cycle based on rpm – this means that at low rpm the duty cycle can be low to reduce strain on the alternator

Team Wix go with the flow at MIRA

Continuing our look at the aerodynamics of a current BTCC racer

Wix Racing (formerly Cicely Motorsport) brought Mercedes back into the BTCC fray in 2014 by fielding an A Class hatchback. Under chief engineer Paul Ridgway and his team the car showed its mettle by finishing 10th overall in the 2014 series, bagging two fastest laps and taking a race win in the season finale on the Brands Hatch GP circuit. As part of their preparation for the upcoming season Wix Racing joined Racecar Engineering in the MIRA full-scale wind tunnel during the autumn of 2014 for what proved to be a fascinating session – **see Photo 1.** With fairly restrictive rules on the aerodynamics, attention to detail was paramount, and in such a close-fought series, small improvements can make a massive difference.

In episode one last month we saw how relatively subtle changes to the shaping of the front bumper made tangible differences to the aerodynamic coefficients and balance (%front). We start this month with the next experiment on the front end, which saw the original bumper replaced with a new one that featured yet more subtle shape changes. The original 'baseline' bumper with which the car finished the 2014 season, and the modified variant we looked at last month, are shown in **Photos 2 - 4** along with the new bumper, and although the new bumper looked similar to the original, the dive-plane like devices had been removed. What would the data say?

Given that the new season is just a short time from publication of this article we are using 'delta values' only, that is, the amount by which the aerodynamic parameters changed with modifications, rather than publishing the absolute coefficients. So **Table 1** shows the effect on the aerodynamic parameters of fitting the new bumper relative to the previous configuration, where Δ (Greek letter delta) represents the change in parameters.

This was a rather curious set of results that saw a relatively large drag increase (in the context of this session) with a modest downforce increase, but with most of that downforce increase occurring at the rear of the car and just a small gain at the front. Considering that the splitter itself was

Table 1 – the effects of fitting the new bumper

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
+0.025	+0.014	+0.003	+0.012	-4.63%	+0.003

Photo 1: The Wix Racing Mercedes A Class

Photo 2: The original front bumper featured a horizontal recess above the splitter

Photo 3: Modifying the original front bumper produced gains and losses

Photo 4: The new front bumper created some surprises

Photo 5: The panel closing off the rear bumper cavity produced the expected results

Photo 6: The new rear bumper also produced surprises

Table 2 – the effects of adding a vertical panel to the leading edge of the base of the rear bumper

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
-0.006	+0.004	0.000	+0.003	-1.68%	+0.017

Table 3 – the effects of fitting the new rear bumper

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
-0.005	-0.001	+0.016	-0.019	+8.51%	+0.002

Table 4 – the effects of fitting a flat panel under the rear bumper and floor

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
-0.001	+0.020	-0.004	+0.025	-10.22%	+0.048

Table 5 – the overall changes so far in the session

ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
+0.009	+0.049	+0.044	+0.006	+1.00%	+0.108

completely unchanged during these bumper modifications, the rear downforce increase, in conjunction with a small front downforce increase, is not easy to explain other than by saying that something at the rear developed more downforce after the new front bumper was fitted. Readers are invited to submit their suggestions as to what may have caused this, accompanied by explanations of course.

Moving rearwards

Leaving the front end behind, let's fast-forward to the rear of the car. The team came to the test fully prepared to remove and fit a number of parts to the lower, rear part of the car. The first modification was to remove the vertical panel, (arrowed in **Photo 5**) which was fitted to the leading edge of the base of the rear bumper. The results in **Table 2** show the effects on the aerodynamic parameters as if the panel was fitted to the rear bumper cavity.

This was another of those seemingly infrequent occasions when the results were more or less as expected, with the vertical panels contributing to slightly less drag and slightly more rear downforce. It seems reasonable to conclude that the panels helped to prevent the inside of the bumper acting somewhat like a parachute, although the benefit of panelling off this exposed area was quite modest.

Next, a new rear bumper was installed. This featured slightly more sculpting of the rear arch behind the rear tyre but had no bottom panel, as shown in **Photo 6.** The results in **Table 3** show the effects relative to the previous bumper configuration.

This was an interesting result because the modest drag reduction was accompanied by a fairly significant loss of rear downforce and an increase in front downforce. Given the short overhang of this part of the rear of the car, and the extent of the gain at the front, this looks more like an aerodynamic rather than the mechanical effect of the rear downforce reduction. It was not possible to know if the gains and losses here were the result of the more radically sculpted rear arches or the lack of a bottom panel in the bumper. Both probably had their effects, but for the front downforce to have increased as much as it did one might surmise that mass flow under the front splitter was increased by this modification.

The next modification saw a new, larger flat panel installed under the rear bumper and rear floor of the car, extending forwards to the rear suspension sub-frame. The results in **Table 4** show the effects.

The dominant effect of this change then was a significant increase in rear downforce for, effectively, no drag change. The small reduction in front downforce was probably down to the mechanical leverage effect of the gain at the rear. Clearly there was also a significant shift in %front too. Equally clear is that for these relatively modest changes in the lift coefficients to make this big a change in balance, the lift coefficients themselves are not that huge – but then BTCC cars were never intended to be high downforce racecars.

At this point it's instructive to look at the progress achieved so far in the session by tabulating the differences in the aerodynamic numbers compared to the starting configuration, which was how the car finished its last race in October 2014, as illustrated in **Table 5**.

So although we have examined a number of modifications, some that produced benefits, some that did not, the overall progress from the start of the session was a very positive set of numbers. The ratio of the downforce to drag increases was more than five to one, representing very efficient gains, and without giving too much away the increase in the overall efficiency (–L/D) represented more than a 25% improvement.

Next month: More fascinating insights on the Wix Racing BTCC Mercedes A Class.

Racecar Engineering's thanks to James Kmieciak Nigel Rees at GSD Racedyn, and all at Wix Racing.

CONTACT

Simon McBeath offers aerodynamic advisory services under his own brand of SM Aerotechniques – www.sm-aerotechniques.co.uk.
In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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Power tool

How state-of-the-art software is revolutionising engine tuning

By NICK BAILEY

When an engine specialist as experienced as Brian Kurn is excited about a technology, others in the field tend to take notice. If they don't, they should.

Kurn is currently working at ECR Engines, a division of Richard Childress Racing and is in charge of valvetrain development together with all virtual prototyping technologies, including engine and valvetrain simulation, as well as computational fluid dynamics (CFD). In a career spanning 25 years he has worked for some of the biggest names in the sport, including Roush, Hendrick and Bill Davis Racing. Kurn started his craft building and improving V8 engines for the small dirt tracks and worked his way up to the elite series in NASCAR. He was highly-regarded for his work on cylinder heads and his ability to extract more power while retaining reliability. Today, he's a highly-respected engine developer who has plied his trade, successfully, across many racing championships – Tudor United Sportscar Championship, NHRA Pro Stock, American Le Mans Series (ALMS), Touring Cars in Brazil and Argentina, Truck-pulling, Supercross and, of course, NASCAR.

'In the good old days, so-called tuners determined the biggest valves that could be used and then they simply began to hand-port the head, believing that the more air that would flow, the more power it should make,' says Kurn.

'After spending a lot of time doing this, you took the parts to the dyno and only then did you find out if you had found a solution or just scrapped another cylinder head. It was an expensive and time-consuming way to see if your idea gained a few more horses or not. And each time you got a new head design, you really had to start again!' It was this inefficiency which drove the forward-thinking Kurn to investigate simulation technologies.

As an experienced CFD user, primarily to analyse internal flows in the engine, both stand-alone and coupled with engine simulation, Kurn is at home with state-of-the-art technology. But, in those early days just over a decade ago, CFD posed problems. 'The run-times to do the

Using trusted valvetrain simulation, we can now optimise the design to work in the real world, even in a NASCAR application

Richard Childress Racing's Austin Dillon put the engine tweaks to good use on the track

simulations took too long and when we had to create our own mesh, we really suffered with the variability between users,' claims Kurn. 'It can affect your results and introduce inconsistency, which ultimately means your trust in the data can go out of the window.'

Mix and mesh

Even today, creating a good mesh is crucial to resolve the flow. But the quest for an automatically-generated mesh never quite delivered the accuracy needed to move away from user-generated data. For years, engineers simply accepted the challenges and did what little they could to minimise the variations.

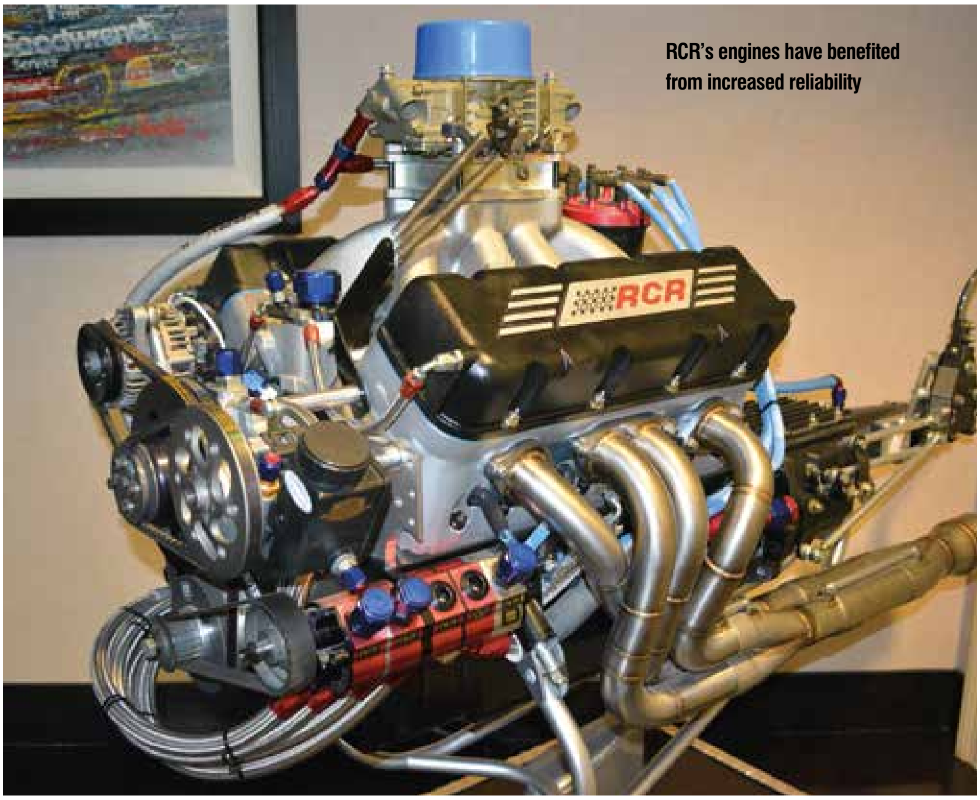
For Kurn, it was a frustration. 'I never believed that an effective automatic meshing tool would happen in my lifetime. I thought we would be stuck with the longer run-times forever,' he explains. But after learning that Converge had collaborated with engine simulation provider Gamma Technologies, everything changed.

It was there that Kurn first encountered an innovative automatic meshing solution called Converge™ CFD Software. Developed by Wisconsin firm Convergent Science Inc., it automates the meshing at run time with a perfectly orthogonal Cartesian mesh that eliminates the need for a user-defined mesh.

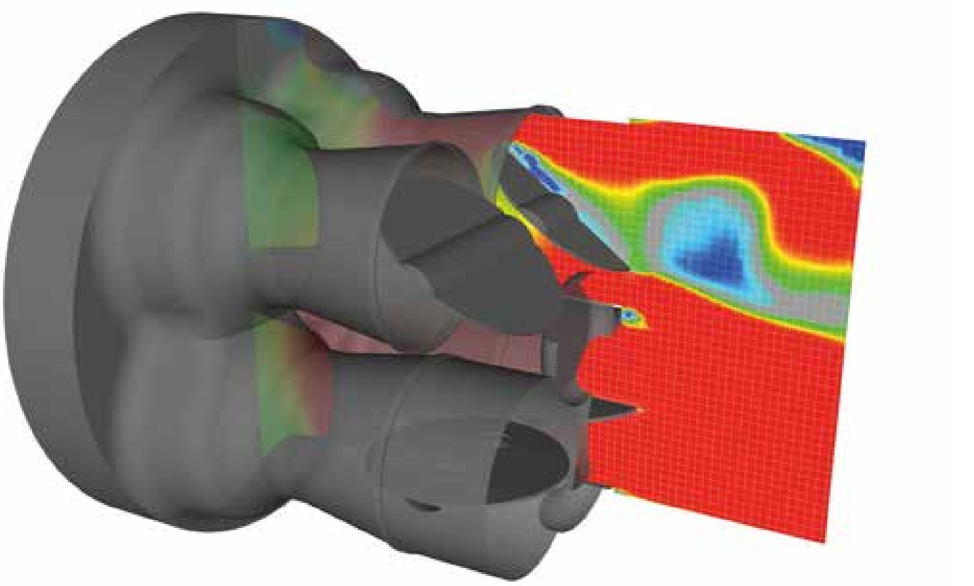
'To be honest, I'd heard it all before and I was sceptical,' says Kurn. 'Automatic meshing had been around for long time but none of the solutions I tried lived up to their claims of a completely automatic mesh that produced accurate results. But if the guys at Gamma were convinced Converge was different then I thought maybe it was worth a look. I'd always struggled with meshing, and longed for the day when I wouldn't have to predict the outcome in order to define the mesh, and I didn't want my meshing to affect the result. I ended up taking a look – the rest is history.'

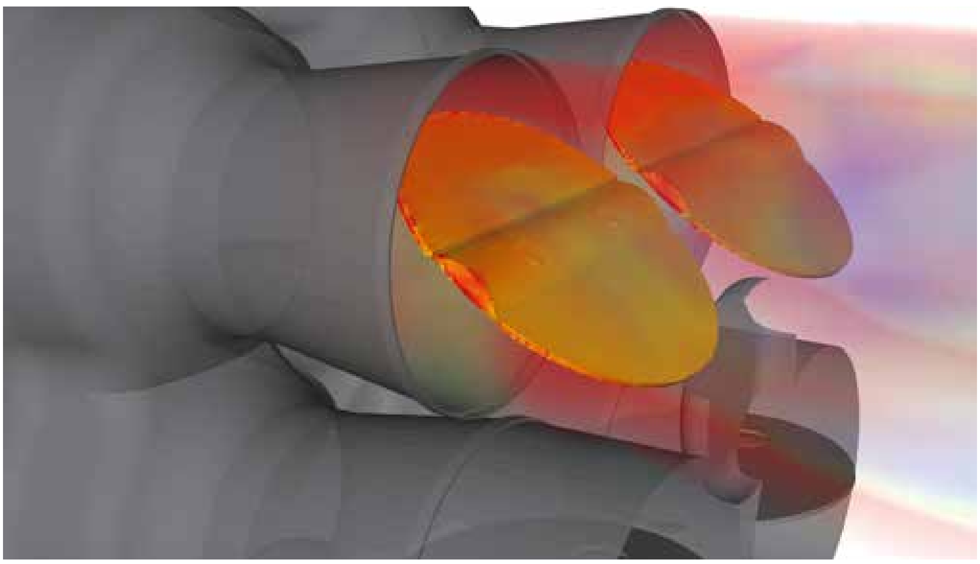
Time saver

Written by engine simulation experts to address the deficiencies of other CFD codes, Converge offers run-time grid generation and refinement



RCR's engines have benefited from increased reliability




CFD comes into its own for in-cylinder propagation as it's far more accurate than using a larger mesh

so users such as Kurn no longer need to spend their time creating meshes.

Instead, the user supplies a triangulated surface and a series of guidelines from which the Converge proprietary code creates the grid at run-time. 'They had hit on my objective; reduce the run-time while retaining the accuracy of the simulation, removing assumptions,' says Kurn. 'Testing would become more fruitful as with consistent meshing and we could test more solutions in the same time frame. Once you have the model you can keep re-running the job without recreating the case.'

For race teams, the software achieves the one thing that is hard to buy – more time – and Kurn has been astounded with the amount he's saved. 'We gained literally weeks on some developments in 2014,' says Kurn. 'On our Daytona prototype engine we got ahead of the development schedule and we were able to start testing different trumpet lengths before the engine was even ready to run on the dyno, or got anywhere near the car. This saved not only time but also the number of prototype parts produced. Knowing the exact parameters of key items such as combustion chamber, intake and exhaust ports means now when we make changes, we can accurately measure just those changes and have complete control over them. We now run a number of simulations and with the accurate data generated can select the best one or two to try on the car.'

Predictable combustion

Trumpet design is just one of the areas that Kurn is trusting to the new software. Others include the very challenging modelling of combustion, and Kurn can see the potential for using it for optimising future fuel efficiency.

Rob Kaczmarek, marketing director from Convergent Science, explains: 'Our genetic algorithm optimisation can run cases depending on design parameters such as fuel efficiency or power and is capable of thinking outside the box. Our founders came from engine simulation and struggled with CFD meshing in the early years so they focused on creating a tool that would simplify meshing and increase accuracy. To achieve this they allowed the program to automate the mesh at run-time and refine when and where it is needed through adaptive mesh refinement (AMR).'

A common area of interest where this approach works particularly well for is in-cylinder flame propagation. Kaczmarek believes non-Converge users really struggle with hard-to-define areas such as this.

'It leads them to either go to a larger-sized mesh, maybe up to 1mm, in order to save time. But doing this loses accuracy. Going to a smaller mesh increases accuracy but also leads to an increase in run-times,' explains Kaczmarek.

The good news is Converge can take care of this, allowing the programme to refine when and where it is needed at run-time for

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Richard Childress Racing has profited from adopting CFD – the perfomance and reliability gains took the team to second in the Sprint Cup Series Championships

NASCAR has no regulations governing virtual testing – pretty soon most of the paddock will be following RCR's lead

more accuracy – while keeping run times manageable. In addition, the software comes equipped with detailed chemistry and physical models to help engineers make gains.

'For example, measuring turbulence of a flame in microseconds and how it changes is very hard to do but it's crucial for efficiency,' adds Kaczmarek. 'Converge can help. It's great for transients and we saw, for example, with the use of direct injection in Daytona prototypes and other high pressure scenarios, that Converge is very effective. Even though NASCAR engines have been around for a long time, well over 40 years, some of the best tuners who think they have understood them can now really see and truly understand what is actually happening for the first time,' explains Kaczmarek.

Working at the track rather than in the garage is another area where fast and accurate simulation is helping. Kurn believes that a NASCAR pushrod engine is one of the worst case scenarios for different behaviours when fired up. 'The actual exhaust valve opening can be delayed as much as 10-15 crank degrees as a result of the cylinder pressure acting on the valves,' he explains. 'Using trusted valvetrain simulation, we can now optimise the design of the valvetrain components to work in the real world, even in a NASCAR application.'

Simplicity and support

Virtual testing is currently unrestricted in NASCAR and is becoming more and more popular as teams look for the edge over the competition. As Kurn points out: 'Track testing, save for the odd tyre test, is zero!' Despite half the teams having simulation tools, he is unsure how many are actually using them effectively. The simplicity of Converge leads him to believe anybody with CFD experience could use it – and within 10 minutes they'd have a surface modelled.

'I have found Converge to be one of the simplest and most powerful simulation tools available. And if there are any issues, there's usually a solution to hand. All we have to do is pick up the phone with any questions and together we've provided answers to many issues. I can't fault the team's support.'

Tracking the results

It is results on track that define success and 2014 was a very successful year for Converge, as demonstrated by the significant gains in power achieved in 2014.

These leaps in performance helped Richard Childress Racing (RCR) secure second overall in the Sprint Cup Series Championship standings with Ryan Newman, while more than 23 top 10 finishes resulted in Brian Scott snatching 4th in the Xfinity championship with Ty Dillon gaining a rookie victory at Indianapolis and 5th overall in the final standings. Team mate Brendan Gaughan showed the versatility of the team's development, winning on the traditional Road America circuit. ECR's engines proved crucial in the TUSCC, helping Chevrolet to win both titles. The Action Express Daytona Prototype, with an ECR engine, scored eight podiums including three victories, most notably the Daytona 24 hours. The ECR engine was reliable; the car completed every lap of competition last season. 'It was a special year for Kurn and the ECR team,' adds Kaczmarek. 'We are so proud to have been involved with the team and Brian.'

Even though NASCAR engines have been around for a long time, some of the best tuners can now really understand what is happening

Redefining design

How using Windform SP and 3D printing allowed CRP USA to explore the boundaries of design on the revolutionary DeltaWing DWC13 racecar

The Daytona 24 hours saw the return to track for the DeltaWing DWC13, a car that resonated with the general public, which qualified fifth and, in the hands of British driver Andy Meyrick who took the start, was competitive against the established Daytona Prototypes until a mechanical issue forced the car's retirement after just 42 laps.

The transition between the 2012 and 2013 season brought significant change to the DeltaWing. An entirely new operating team, crew, engine, and tyre partner made for several new elements as the team took to the track. There is very little time between races to make necessary changes to a car, and the DeltaWing Racing Cars team and Élan Motorsports were faced with having to design a new engine from scratch (See RE V23N5).

Understanding the design and time constraints, when it came to the intake manifold, design engineer Christian "Skitter" Yaeger, turned to CRP USA to assist on the design and production. The result of their combined efforts: from nothing but a Mazda head to a new running engine in 81 days, to racing at Sebring in 105 days – including a 3D printed intake manifold.

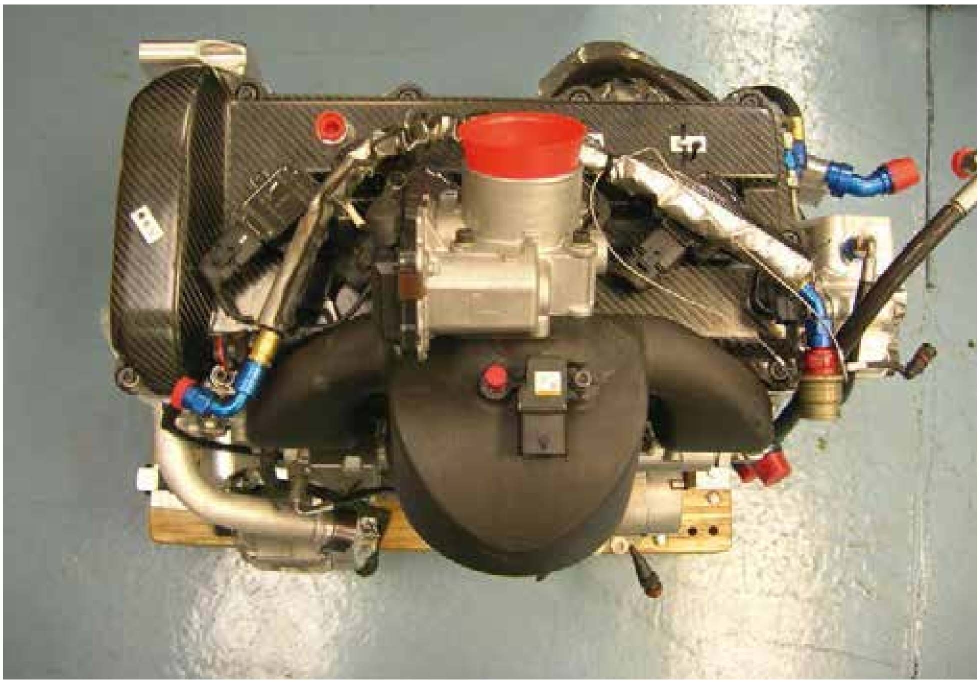
The introduction of the DeltaWing in 2010 brought a radical change to conventional thinking. The philosophy of half the weight, half the fuel consumption was not new, but in the design of the car, it got people to think differently. When the DeltaWing took to the racetrack, the engineering team behind the project pushed the boundaries of conventional design and launched a truly revolutionary approach in motorsports.

Yet it is the new DeltaWing, that took to the track in 2013, which is pushing the boundaries of efficiency, technology and innovation. Engineers at DeltaWing Racing Cars, working with CRP USA and Windform, created a component that is fully functional

The DeltaWing DWC13 was holding its own in the race until it was forced to retire with transmission issues

Since its introduction, the DeltaWing has become more familiar and is now an established crowd-favourite

When the DeltaWing took to the track, the engineering team behind the project pushed the boundaries of conventional design



The BorgWarner turbo allows the four-litre engine to produce 350bhp at 6800rpm

Engine sports many parts created using 3D printing

(3D printing) technology with Windform SP for its construction, to operate under boost utilised in race conditions.

The resulting component has been campaigned by the team since March 2013, gaining positive results and showing the tremendous potential for utilising advanced materials technologies in partnership with 3D printing. 'We could not have made this motor if we couldn't produce parts directly from CAD files,' said Yaeger, design engineer for DeltaWing Racing Cars. 'The biggest benefit is being able to print exactly what you need. We have eight odd-shaped ports in the head, and CRP USA was able to match them perfectly, with a knife-edge in between.

'With the coupé version, we went slightly less wild and a little more conventional in our design. Over the past two years, the 3D printed manifolds have covered more than 12,000 testing and racing miles, along with six hours per unit running on the dyno.'

Material strength

Prior to the production of the intake manifold, Windform materials were used on the DeltaWing to produce several different components such as electronics enclosures and transmission seal covers with integrated, pressurised oil feed passages.

As the engineering team began the redesign of the intake manifold, a high performance material was required to handle the heat and tension placed on the part. CRP USA introduced Windform SP to the DeltaWing engineering team for consideration – Windform SP is a state-of-the-art composite polyamide-based carbon-filled material.

Windform SP has excellent mechanical properties and the added advantage of increased resistance to shocks, vibrations, deformations, and most importantly, it's resistant to absorption of liquids and moisture.

'The packaging constraints required by the location of the engine within the chassis requires some creative design,' said Stewart Davis, Director of Operations, CRP USA. 'The runner lengths attach at the base of the plenum and form a complex structure that would be extremely difficult to build without using additive manufacturing. Windform SP's toughness and heat deflection temperature allow the part to be built and then raced in the endurance series. The engine is run under boost, so it sees pressure variation in addition to the vibration, shock and temperatures changes associated with racing. The work done by Skitter and the DeltaWing/Élan Motorsports team is a great example of the application of Windform SP for a complex problem, and utilising additive manufacturing to push the boundaries in racing.'

Since its introduction in March 2013, the technology has raced in the 2013 American Le Mans Series and, after the merger with the Grand Am series, now competes in the combined Tudor United Sportscar Championship. The intake manifold has covered 12,000 racing and testing miles. www.crp-usa.net - www.windform.com

The expertise of CRP Group and Windform materials

The CRP Group (www.crp.eu<http://www.crp.eu>) is comprised of: CRP Engineering, CRP Meccanica, CRP Service, CRP Technology (www.crptechnology.com<http://www.crptechnology.com>), CRP USA and Energica Motor Company (www.energicasuperbike.com<http://www.energicasuperbike.com>). With its emphasis on customization, high-end technologies, a broad range of applications and customer service, the CRP Group maintains a strong relationship with client companies and entrepreneurs in the fields of the automotive industry and motorsports, design, aerospace, Unmanned Aerial Systems (UAS), the marine, entertainment, and packaging.

The development of the Windform materials is due to the need to introduce in the market more performing Additive Manufacturing and 3D Printing materials with properties able to distinguish them as the main SLS materials. Windform XT2.0, Windform SP, Windform LX2.0 and Windform GT have passed outgassing tests that have been carried out at NASA. The result states: Materials were tested in accordance to the ASTM E-595-07 standard and are considered passing.

Furthermore, all Windform materials can be CNC machined and processed with tooling machines if necessary, for example to obtain plans and seats with narrow tolerances. To this purpose CRP Meccanica (www.crpmeccanica.com<http://www.crpmeccanica.com>) is equipped with CNC centers that embrace the industry's latest CNC technologies and practices. Top level metal alloys and Windform materials are processed by CRP Meccanica to manufacture accurate parts for the motorsports, automotive, aerospace, and marine industry.

The manifolds have covered 12,000 testing and racing miles

Fuelling the future

Pressure on fossil resources means that, despite the recent drop in fuel price, the need for alternative fuels is still critical

By GEMMA HATTON

Biofuels are more environmentally friendly than electric powertrains, more sustainable than fossil fuels and are substantially cheaper than oil. If the technology continues to advance at its current rate then more and more race engines will be powered by biofules. And where motorsport goes, the mainstream automotive sector follows. This is the future...

Recent price drops in crude oil have re-ignited the discussion regarding the need for an alternative to our current transport demands. However, the inescapable fact is that the infrastructure currently in place is using fossil fuels faster than they are being made, and that consequently they will run out. It is a question of when, not if, and with more than 900 million cars already on the world's roads, a change in how we fuel our vehicles will make a difference.

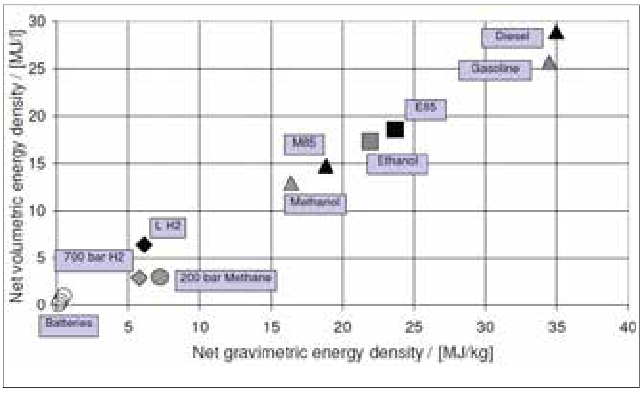
One problem is that there are government incentives for electric vehicles, with lower road tax and lower emissions at vehicle level. However, the creation of electricity means that the problem is pushed further up the supply chain. This phenomena of 'electrification' is largely in response to the EU's 2021 emission targets, that demand automotive manufacturers achieve a fleet average of 95g/km of $C0_2$ emissions, or otherwise be fined. Although electric cars are 'zero emission', on a global scale there remains a fundamental flaw – the majority of them still use some form of energy from fossil fuels. Add that to the carbon footprint of actually producing an electric car and implementing the necessary infrastructure, and suddenly electrification doesn't seem to be the best answer.

Racecars are increasingly turning to hybrid technology, but these come with a weight disadvantage that is hidden or accommodated in the regulations. The message from the manufacturers is clear – make better use of energy that is otherwise thrown away. However, there is another option that is increasingly becoming an option; biofuels, and the best way to develop these is through motorsport.

Biofuels

A biofuel is defined as a fuel which has been derived from recently dead organic matter such as biomass, and so contains energy from 'carbon fixation' where carbon dioxide is converted to organic compounds by living organisms (e.g. photosynthesis). They can either be first generation; which uses the food component of a feedstock (raw material used for an industrial process) such as sugar and starch, second generation, which uses the non-food parts of crops and waste biomass, or third

Drayson Racing was quick to embrace biofuels. It ran an Aston Martin Vantage GT2 ALMS car on second generation E85 produced from waste wood in 2008, and a flex-fuel Lola



Both ethanol and methanol give on board gravimetric energy storage capacities that are up to 15 to 20 times greater than the most sophisticated batteries

generation; which is produced from extracting oil out of algae. Similar to the fuels of the automotive world there are diesel and gasoline equivalents in the form of biodiesel, and various compositions of ethanol, methanol and gasoline.

The concept of biofuels is not new. Their potential was discovered as early as 1900. Governments pushed towards this technology in the 1970's and again in 2006, but with the original feedstocks such as corn invading agricultural land, (40 per cent of US corn is used for biofuels), this led to an increase in food prices (an estimated £460 million per year for the UK alone) which damaged public opinion of this technology. Nevertheless, countries such as Germany have implemented laws that ensure 10% of their transport energy comes from renewable sources which is mainly biofuels.

A revolution in evolution

The principle of biofuels is based on natural processes where the only requirements are the sun, water (even dirty water) and space. Using this principle, 2009 saw a revolutionary approach when the company Joule Limited combined engineering and chemistry to develop a range of patented bio-organisms that act as catalysts; each optimised for the production of a particular end product without the need of biomass or feedstocks (see Peter Wright's article featured in *RE* V23N7). As these catalysts can be individually 'designed', this process can generate a wide range of infrastructure-ready ethanols, hydrocarbons for diesel, jet fuels and gasoline.

Essentially, Joule uses a SolarConverter array that takes up around 1000 acres and is composed of many different modules, each containing the catalyst, untreated water and micro nutrients. Waste $C0_2$ from industrial processes is pumped into each module, which keeps the catalysts mobile and thus maximises their exposure to sunlight for photosynthesis. After one week of growth, the catalysts have been designed in such a way that there is an internal biological 'switch' which stops further growth, and reproduction and instead enables the catalysts to deploy their solar energy into the liquid medium for another eight weeks, therefore wasting no energy on unnecessary growth and thus achieving almost 100 per cent efficiency. This liquid is then filtered and the end product undergoes a final separation, while the module is flushed and reinoculated.

With a staggering 80 per cent of a car's emitted carbon life cycle coming from the fuel consumed, Audi was quick to realise that the actual carbon emitted from an IC engine using carbon neutral synthetic fuel would be far less than an EV powered by renewable electricity. So in 2011, a partnership between Audi and Joule Limited formed Joule Fuels securing Audi's exclusivity to this automotive technology.

Essentially, the biochemists can make an evolution that takes one million years within just four weeks in a laboratory and the development will be to create more fuel from a smaller area. Joule claims that at full-scale commercialisation, it would only take a 10,000 acre plant to produce a reserve value of 50 million barrels – matching the same as a medium-sized oil field. The equivalent of 10,000 sports fields still seems like a large amount of space, but because this process can be effective in areas such as deserts, it is not competing with food, so aside from the initial implementation of the infrastructure, this really is environmentally friendly. In fact, Joule say that with their technology, just five per cent of the USA's desert would meet all the transport fuel needs of the entire country.

The astounding efficiency of Joule's chemical process also means that this fuel can meet and beat the price of fossil fuels. Even with the recent dramatic fall in crude oil price, Joule still tops the tables supplying its Sunflow-E at \$50/barrel compared to current crude oil prices of \$65/barrel (the lowest since May 2009).

Biomass Limits

Joule's approach is in effect increasing the 'biomass limit' of the fuel, because it is not dependent on one bio-derived crop. 'The biomass limit is basically the logic behind making a biofuel. Take corn for example, which is a very popular feedstock for biofuels. Now if you were to run all the cars on the planet on corn based biofuel you would have to have something like 12 new planets to grow enough of it – that is what theoretically is called a biomass limit,' explains Edward Goossens, owner of Gutts Fueled by Nature and the man behind the motorsport-renowned GEM Fuel. 'If you then combine multiple feedstocks into one type of fuel or combine two types of fuel into one litre of fuel, you theoretically increase the biomass limit because you are not dependent on one type of feedstock.'

GEM fuel is a ternary blend of 36 per cent gasoline (G), 21 per cent bio-ethanol (E) and 43 per cent CO_2 derived methanol (M). It offers higher power output complimented with lower greenhouse gas emissions, but with current E85 alternatives utilising 85 per cent ethanol and only 15 per cent gasoline, what is the benefit of GEM Fuel? It's all to do with sustainability.

FFV's are 'flexible fuel' or 'dual fuel vehicles' and are vehicles with an internal combustion engine that can run on a binary fuel blend with a stoichiometric AFR (air fuel ratio) between gasoline (14.7:1) and E85 (9.7). Essentially then, fuels blended with either methanol or ethanol.

There are currently 22.6 million of these vehicles on our roads today, most of which are suited for bioethanol blends such as E85. The US has demanded that a total of 31 million US gallons of bio-ethanol should be produced by 2022, half of which will be first generation. This biologically made ethanol however, does have a finite biomass limit and therefore is not only unsustainable, but relies on energy crops which compete with food production.

Although electric cars are 'zero emission,' on a global scale there's a fundamental flaw – the majority of them still use energy from fossil fuels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The Junior World Rally Chamionship is the first series to approve the use of biofuels. Expect it to be rolled out to other championships as more teams see the fuel's performance potential

Methanol can be synthesised from almost any feedstock containing hydrogen and carbon and therefore theoretically has no 'biomass limit' – providing a better alternative, without the need to modify engines. 'Originally, GEM fuel was developed as a more sustainable and better performing substitute for E85. Lotus Engineering played around with the percentages and replaced a certain percentage of the ethanol with methanol while still maintaining the performance of the fuel in a flexfuel car,' explains Goossens. 'Their goal was to achieve an equally technically performing fuel as E85 but with an increased sustainability profile by getting rid of ethanol, replacing it with methanol and thus, increasing the biomass limit. This was purely a laboratory exercise by Lotus and as a company we decided to turn the formula into a race fuel.'

Racing biofuels

Biofuels have already been utilised in motorsport to a certain extent, an example being Drayson Racing's Aston Martin Vantage GT2 ALMS car in 2008 which ran on second generation E85 produced from waste wood. More recently, the potential for biodiesel is being investigated, and this fuel has the advantage of reducing engine wear. 'The bio part of biodiesel is derived from normal vegetable material so they convert it into a fatty acid known as FME (fat methyl ester),' explains Martyn Mann, technical director of Millers Oils. 'It has a very high lubricity function which makes our additives more slippery to help protect the valve seat of the engine and other components. This chemical barrier is only microns thick and it's constantly being worn away and replaced as the engine uses the fuel.'

This is another area where Audi has been exploring potential. The racing team has run a single cylinder diesel simulation on the fuel without a problem, once the high wear rate was addressed with a small additive.

As ever, motorsport pushes everything (and everyone) to the limit, so one concern may be the energy density of these biofuels. However, for SI engines, these 'light' alcohols are ideal due to their high octane numbers, high latent heat and low stoichiometric AFR. As you can see from the Figure on the previous page, both methanol and ethanol give on board gravimetric energy storage capacities that are two or three times greater than hydrogen and up to 15 to 20 times greater than the most sophisticated batteries.

Furthermore, these higher heats of vaporisation and lower AFR actually results in cooling of the cylinder charge as the fuel evaporates, increasing the intake charge density. Theoretically, this cooling effect of methanol could prove to be invaluable as Goossens explains: 'Methanol is basically an alcohol that extracts heat from any material it touches, especially metal. So, if you were to run methanol or ethanol as a fuel in pure form, in an engine you would require significantly less external cooling. Therefore, potentially and theoretically you could actually reduce the drag of a racecar and achieve some interesting speeds particularly in endurance racing applications.'

A consequent result of a cooler intake charge together with the high octane numbers of these fuels is reduced engine knocking. This in turn, makes these fuels even more suitable for the downsizing trend seen in both motorsport and automotive, where gasoline is restricted to low compression ratio in pressure charged engines to avoid excessive knock.

Overall, it seems that the potential is there, the technology is there and with recent developments, now the sustainability is there, but as ever, progress is somewhat hindered by regulations, but that did not stop GEM Fuel. 'Our big breakthrough was in 2012 when we convinced the FIA to allow our fuel to be used in the Junior World Rally Championship,' explains Goossens. 'It took more or less a hundred pages of reports, research, certificates and discussions but eventually they approved it and since 2013 we have supplied the Junior WRC.' This long process was not down to the FIA being stubborn, the challenge was to not only ensure that safety standards were met with these new fuels, but also component standards.'

'You have to understand that for centuries now, the world has defined fuel as an oil derived product, so all fuel lines, fuel pumps, fire extinguishers etc are all aimed at preventing anything happening with an oil-derived fuel,' explains Goossens. GEM fuel contains a larger percentage of alcohol and that requires different types of rubbers and polymers –even the type of foam inside the fire extinguishers needs to be changed. So the FIA had to redefine and update all the safety rules, and be persuaded that the road car market trend is towards biofuels and that they are a viable option.'

For biofuels to work in both the automotive and motorsport worlds, the regulations need to be amended on two scales: 1) the minute scale, where all the millions of component standards are amended to suit alcohols rather than crude oil and 2) on a global scale where the 95g/km of $C0_2$ legislation for automotive, includes the reductions using biofuels. Biofuels mean that we can continue to use our cars as we currently do, and they provide carbon-neutral motoring (the carbon taken from the atmosphere is equal to the emission of a car).

'As a company, we work within the renewable fuel industry throughout all sectors and the rate of innovation is staggering, for example there are more than 6000 ISCC certified fuels or fuel feedstocks in Europe,' explains Goossens. 'We aim to push these innovations and turn them into race fuels and use motorsports as the proverbial 'catwalk' for the automotive sector, demonstrating the smart way forward.

'There is definitely the potential for F1 and LMP1 to capitalise from such technologies. All cars should be able to run on any fuel that a customer or a country has available and you should not be hindered by the fact that a rubber component in your fuel pump is not alcohol resistant. This is slowing down innovation in motorsport and we need to get to a more sustainable form of transport in daily life.'

'The inescapable fact is that our infrastructure is using fossil fuels faster than they are being made, and that they will run out'


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What dampers are telling you

Understanding the dark art of damping will give you a much better understanding of your racecar's true performance

By DANNY NOWLAN

One of the things that continues to astound me about this business is how race and data engineers really don't look into damper data enough. The reason it blows me away is there is so much good information in there about what the car is doing. In particular, the big thing that is overlooked is that your dampers are load cells, and in this article we'll be discussing how to extract this information.

A big reason we are doing this is that while technically, on paper, load cells make this redundant, the reality is not so clear cut. The first problem you'll run into is that not many race cars will have load cells fitted to them. Consequently you really need to keep on reading if you want to determine your loads from race data. Also load cells are not bulletproof. Consequently what we'll be discussing here is a great sanity check.

The bottom line is that once you have your loads you can start to determine a lot about what your car is doing. So let's get started.

Before I bombard you with equations it might be a good idea to understand why your damper displacements are load cells in the first place. To get a good appreciation of this let's consider the beam-pogo stick model of the racecar that is illustrated in **Figure 1**.

I've left off the third springs and roll bars. Here is the huge take away. If you do a free body diagram of **Figure 1**, the forces on the springs will be the sum of the aero loads and, in a static situation, it will give you the tyre loads. I'll leave you to figure that bit out (university students and young data engineers, this means you). To begin working this out we need to get a few definitions out of the way first. These are summarised in **Table 1**. For brevity I'll also define the relevant F3 parameters we will use.

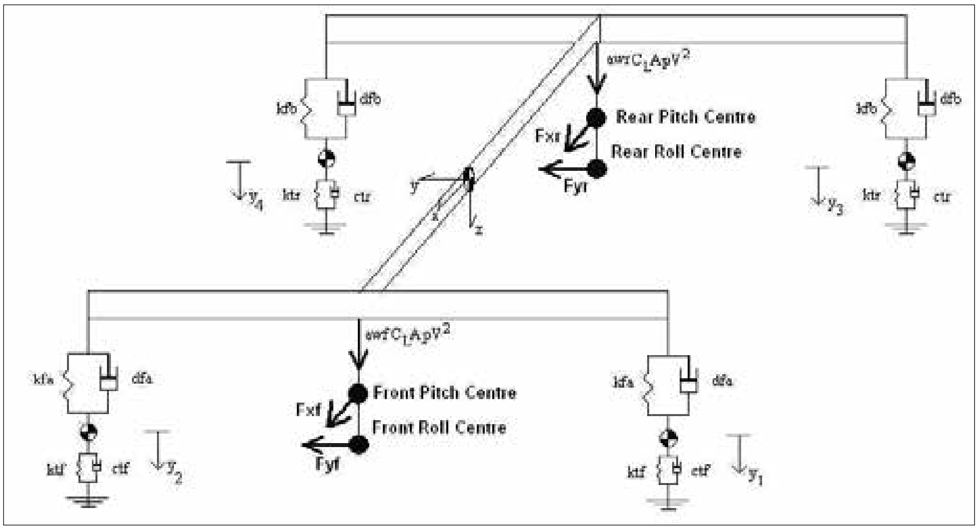

Figure 1: Beam pogo stick of a race car

Table 1 – Definition of terms and parameters

Description	Symbol	Value
Front left damper movement	ma	n/a
Front right damper movement	mb	n/a
Rear left damper movement	mc	n/a
Rear right damper movement	md	n/a
Front spring function/rate	kfa	157.6 N/mm
Front spring damper function/rate	dfa	n/a
Front main spring motion ratio (damper/wheel)	MR_F	0.8842
Front bar rate	krbf	2096.7 N/mm
Front bar motion ratio (damper/wheel)	MR_{BF}	0.815
Rear spring function/rate	kfb	122.6 N/mm
Rear spring damper function/rate	dfb	n/a
Rear main spring motion ratio (damper/wheel)	MR_R	0.7698
Rear bar rate	krbr	678.6 N/mm
Rear bar motion ratio (damper/wheel)	MR_{BR}	0.55

The bottom line is that once you have your loads you can determine a lot about what your car is doing

EQUATIONS

Equation 1

$$L_1 = MR_F \cdot \left(kfa(ma) + dfa(m\dot{a})\right) + \frac{MR_{BF}^{\ 2} \cdot \left(krbf \cdot (ma - mb)\right)}{2 \cdot MR_F}$$

$$L_2 = MR_F \cdot \left(kfa(mb) + dfa(m\dot{c})\right) - \frac{MR_{BF}^{\ 2} \cdot \left(krbf \cdot (ma - mb)\right)}{2 \cdot MR_F}$$

$$L_3 = MR_R \cdot \left(kfb(mc) + dfb(m\dot{c})\right) + \frac{MR_{BR}^{\ 2} \cdot \left(krbr \cdot (mc - md)\right)}{2 \cdot MR_R}$$

$$L_4 = MR_R \cdot \left(kfb(md) + dfb(m\dot{d})\right) - \frac{MR_{BR}^{\ 2} \cdot \left(krbr \cdot (mc - md)\right)}{2 \cdot MR_R}$$

Here the extra terms are,

- L_1 = Sprung mass load on the left front (N)
- L_2 = Sprung mass load on the right front (N)
- L_3 = Sprung mass load on the left rear (N)
- L_4 = Sprung mass load on the left rear (N)

Equation 1a

$$L_1 = 0.8842 \cdot (157.6 \cdot 2.63) + \frac{0.815^2 \cdot \left(2096.7 \cdot (2.63 - 1.35)\right)}{2 \cdot 0.8842} = 1459.7N$$

$$L_2 = 0.8842 \cdot (157.6 \cdot 1.35) - \frac{0.815^2 \cdot \left(2096.7 \cdot (2.63 - 1.35)\right)}{2 \cdot 0.8842} = -905.2N$$

$$L_3 = 0.7698 \cdot (122.6 \cdot 6.4) + \frac{0.55^2 \cdot \left(678.6 \cdot (6.4 - 1.59)\right)}{2 \cdot 0.7698} = 1245.3N$$

$$L_4 = 0.7698 \cdot (122.6 \cdot 1.59) - \frac{0.55^2 \cdot \left(678.6 \cdot (6.4 - 1.59)\right)}{2 \cdot 0.7698} = -491.3$$

Equation 2

$$L_1 = MR_F \cdot \left(kfa(ma) + dfa(m\dot{a})\right) + \frac{MR_{BF}^{\ 2} \cdot \left(krbf \cdot (ma - mb)\right)}{2 \cdot MR_F} + F_{yf} \cdot \frac{rc_f}{tf} - F_{xf} \cdot \frac{pc_f}{a}$$

$$L_2 = MR_F \cdot \left(kfa(mb) + dfa(m\dot{c})\right) - \frac{MR_{BF}^{\ 2} \cdot \left(krbf \cdot (ma - mb)\right)}{2 \cdot MR_F} - F_{yf} \cdot \frac{rc_f}{tf} - F_{xf} \cdot \frac{pc_f}{a}$$

$$L_3 = MR_R \cdot \left(kfb(mc) + dfb(m\dot{c})\right) + \frac{MR_{BR}^{\ 2} \cdot \left(krbr \cdot (mc - md)\right)}{2 \cdot MR_R} + F_{yr} \cdot \frac{rc_r}{tr} + F_{xf} \cdot \frac{pc_r}{b}$$

$$L_4 = MR_R \cdot \left(kfb(md) + dfb(m\dot{d})\right) - \frac{MR_{BR}^{\ 2} \cdot \left(krbr \cdot (mc - md)\right)}{2 \cdot MR_R} - F_{yr} \cdot \frac{rc_r}{tr} + F_{xf} \cdot \frac{pc_r}{b}$$

The additional terms in equation 2 are

- F_{yf} = Total front lateral force (N)
- F_{yr} = Total rear lateral force (N)
- F_{xf} = Total front longitudinal force (N)
- F_{xr} = Total rear longitudinal force (N)
- a = Distance from front axle to c.g (m)
- b = Distance from rear axle to c.g (m)
- tf = Front track (m)
- tr = Rear track (m)
- rc_f = Force based front roll centre height (m)
- rc_r = Force based rear roll centre height (m)
- pc_f = Force based front pitch centre height (m)
- pc_r = Force based rear pitch centre height (m)

Equation 3

$$F_{yf} = wdf \cdot m_t \cdot a_y \cdot g$$

$$F_{yr} = (1 - wdf) \cdot m_t \cdot a_y \cdot g$$

To keep this discussion simple I'm using a main spring F3 car with linear motion ratios. I realise that strictly speaking this will not be accurate for non-linear cars. However, the principles we are about to discuss also apply to non-linear cars. I'm just using a symmetric linear car as a teaching tool. We will assume all damper readings are positive in bump.

The first step in this process is to calculate the loads on the sprung mass. This is simply a combination of the spring forces on the sprung mass and the roll bars. This is given in **Equation 1**.

Mid-corner forces

The dots in the damper terms like $m\dot{a}$ denote velocities. Also note all damper displacements are defined at the damper as if you are reading them off the data. Also note the roll bar term note that we are dividing by two times the main spring motion ratio. Firstly we are after the differential movement of the bar. The reason we divide by the main spring motion ratio is we need to get the bar movement back to wheel movement before we can convert it to what it is doing at the bar. It's why you see the squared term in there for the bar ratio because we need to calculate what the bar is seeing at the damper before we multiply it by the bar motion ratio. This also illustrates why I always work my motion ratios as damper/wheel. For me it's much more intuitive when you start calculating forces.

Let's now work through an example. For simplicity we are going to assume the damping velocities here are zero. Also the dampers are zeroed on the ground. For our F3 car the parameters are as in **Table 2.**

Table 2 – F3 parameters

Parameter	Value
ma	2.63 mm
mb	1.35 mm
mc	6.4 mm
md	1.59 mm

Working through **Equation 1** we come to **Equation 1a.** Since the damping velocities are zero, you'll note I didn't include the damping term in working **Equation 1**. The first thing to note here is how L_2 and L_4 are negative and the left loads look small, since we have zeroed on the ground the loads are zeroed on the ground. To get to absolute loads we just need to add in the static corner weights. Humour me for a moment – we are going to leave this as is and you'll see why in just a bit.

On the surface what we have done seems ridiculously trivial, however what I've shown you is incredibly powerful. Here is the deal – I've just given you the ability to interrogate your own data so you can actually see what is going on. This cannot be underrated; you now have the tools to quantify the effects of aero and jacking forces mid-corner. This will go a long way to help you truly classify what your car is up to.

The next question that comes up is 'can we include the effects of suspension geometry?' The answer is a resounding yes, and it will look as per **Equation 2.** Note that lateral force is positive to the right of the car and longitudinal force is positive forward. One thing to note is that **Equation 2** really illustrates the power of the force based roll centre and pitch centre approach that I have discussed in previous articles. The big payoff is calculating tyre loads from race data, which is what we are doing right now.

One question that has to be asked is that as great as **Equation 2** might be in theory, how do we derive the lateral and longitudinal forces if we haven't logged them. Again, the answer's not as hard as you think. The lateral results are presented in **Equation 3.**

Dialling in drag

Here a_y is lateral acceleration in g, g is acceleration due to gravity in m/s^2 and wdf is the front weight distribution as a factor and m_t is the total mass in kg. The longitudinal results are a bit more tricky but not that difficult. Under acceleration we have **Equation 4**.

Under brakes we have **Equation 5.**

I can appreciate that a lot of you are reading this and saying 'the lateral case isn't too bad, but what do I do about the longitudinal case?' Here ChassisSim is your best friend, because if you get basic correlation ChassisSim returns the applied lateral and longitudinal force and will help you dial in the drag.

Let's now go through a worked example of **Equation 2** with the roll centre effects. The parameters are presented in **Table 3.**

Table 3 – Roll centre and Force parameters

Parameter	Value
Front roll centre	-28mm
Rear roll centre	63mm
Front lateral force	5014 N
Rear lateral force	6071 N

To makes things simple I'll assume the front and rear tracks are 1.5m each. Crunching the numbers we see **Equation 6.**

Again, this in itself isn't earth shattering but I've just given you the tools to approximate information that you would not otherwise have.

So now that we have loads we can now calculate ride heights. Here's the pay off from using dampers zeroed on the ground. The ride heights from race data are shown in **Equation 7**. So taking the example we just worked through let's say the front ride is 27mm, the rear ride height is 40mm and the front and rear tyre spring rates are 200 N/mm. The dynamic ride heights will be **Equation 8.**

So we have a dynamic ride height of 25.6mm at the front and 38.1 mm at the rear. Again, this by itself is very trivial but it is

EQUATIONS

Equation 4

$$F_{xf} = t\_split \cdot T(rpm) \cdot \frac{gr}{r_t}$$

$$F_{xr} = (1 - t\_split) \cdot T(rpm) \cdot \frac{gr}{r_t}$$

Where,

- t_split = Torque split at the front (1 = Front Wheel Drive, 0 = Rear Wheel Drive)
- T(rpm) = Engine Torque at the given rpm (Nm)
- gr = Current gear ratio (measured as engine speed/wheel speed)
- r_t = Rolling tyre radius (m)

Under brakes we have:

Equation 5

$$F_{xf} = br \cdot (|m_t \cdot a_x| - Drag)$$

$$F_{xr} = (1 - br) \cdot (|m_t \cdot a_x| - Drag)$$

Here we have:

- br = Factor of braking force applied at the front (1 = all braking at front, 0 = all braking at rear)
- Drag = Current Drag of the vehicle in N

Equation 6

$$L_1 = 0.8842 \cdot (157.6 \cdot 2.63) + \frac{0.815^2 \cdot (2096.7 \cdot (2.63 - 1.35))}{2 \cdot 0.8842} + 5014 \cdot \frac{-0.028}{1.5} = 1366.1N$$

$$L_2 = 0.8842 \cdot (157.6 \cdot 1.35) - \frac{0.815^2 \cdot (2096.7 \cdot (2.63 - 1.35))}{2 \cdot 0.8842} - 5014 \cdot \frac{-0.028}{1.5} = -811.6N$$

$$L_3 = 0.7698 \cdot (122.6 \cdot 6.4) + \frac{0.55^2 \cdot (678.6 \cdot (6.4 - 1.59))}{2 \cdot 0.7698} + 6071 \cdot \frac{0.063}{1.5} = 1500.3N$$

$$L_4 = 0.7698 \cdot (122.6 \cdot 1.59) - \frac{0.55^2 \cdot (678.6 \cdot (6.4 - 1.59))}{2 \cdot 0.7698} - 6071 \cdot \frac{0.063}{1.5} = -746.3$$

Equation 7

$$rh_f = rh_{f0} - \frac{L_1 + L_2}{2 \cdot ktf}$$

$$rh_r = rh_{r0} - \frac{L_3 + L_4}{2 \cdot ktr}$$

Here we have,

- rh_f = Current front ride height (mm)
- rh_{f0} = Static front ride height (mm)
- rh_r = Current rear ride height (mm)
- rh_{r0} = Static rear ride height (mm)
- ktf = Front tyre spring rate (N/mm)
- ktr = Rear tyre spring rate (N/mm)

Equation 8

$$rh_f = 27 - \frac{1366 + -811.6}{2 \cdot 200} = 25.6$$

$$rh_r = 40 - \frac{1500 + -746.3}{2 \cdot 200} = 38.1$$

You now have the tools to quantify the effects of aero and jacking forces mid-corner

particularly significant if you don't have laser ride height sensors.

While the examples we have discussed have all had the damping at zeros, if you really want to nail down what is going on with the car you have to include it. To illustrate this let me show you the effect of a lap time simulation comparing smooth to actual data. Since this is off actual customer data I have blanked out all scalings. The results are shown in **Figure 2.**

The smooth simulation is coloured, the black is information represents bumps. As we can see looking at the rear dampers (4th plot) and the rear pitch, the difference between the pitches is night and day.

The reason comes down to the biggest suck you see when looking at smooth simulation and/or pseudo static simulation. On paper you expect it to come to the static results, and in most cases it usually does. However this is not always the case. The reason for this comes from studying the sprung mass equations of motion. This is summarised in **Equation 9.**

If you want all the terms you can buy my book *The Dynamics of the Race Car.* However the give away here is that **Equation 7** is a time-based differential equation. By the time we start integrating all these terms to understand what the car is doing and we throw in some bumps, there is no guarantee we'll hit the static condition. This is particularly apparent if we have big values of damping in both bump and rebound.

Don't get me wrong, most of the time you will hit the static condition, but it is not always the case. This particular example sucked both me and my customer in, so if you've been in this situation you are in very good company. The moral of the tale here is that if you want to get accurate answers from your data, you need to include a look-up table for your dampers. It also underscores the importance of why I went down the fully transient road with ChassisSim.

It is clear that we can tell a lot from what the dampers are doing. We have outlined in detail how you can use damper data to calculate loads and, by tying this in with basic suspension geometry data, we've explored how we can use this to approximate ride height data. We have also discussed the importance of putting in damper data. The next step is down to you – go through your suspension data and start doing load calculations. The results will be revealing.

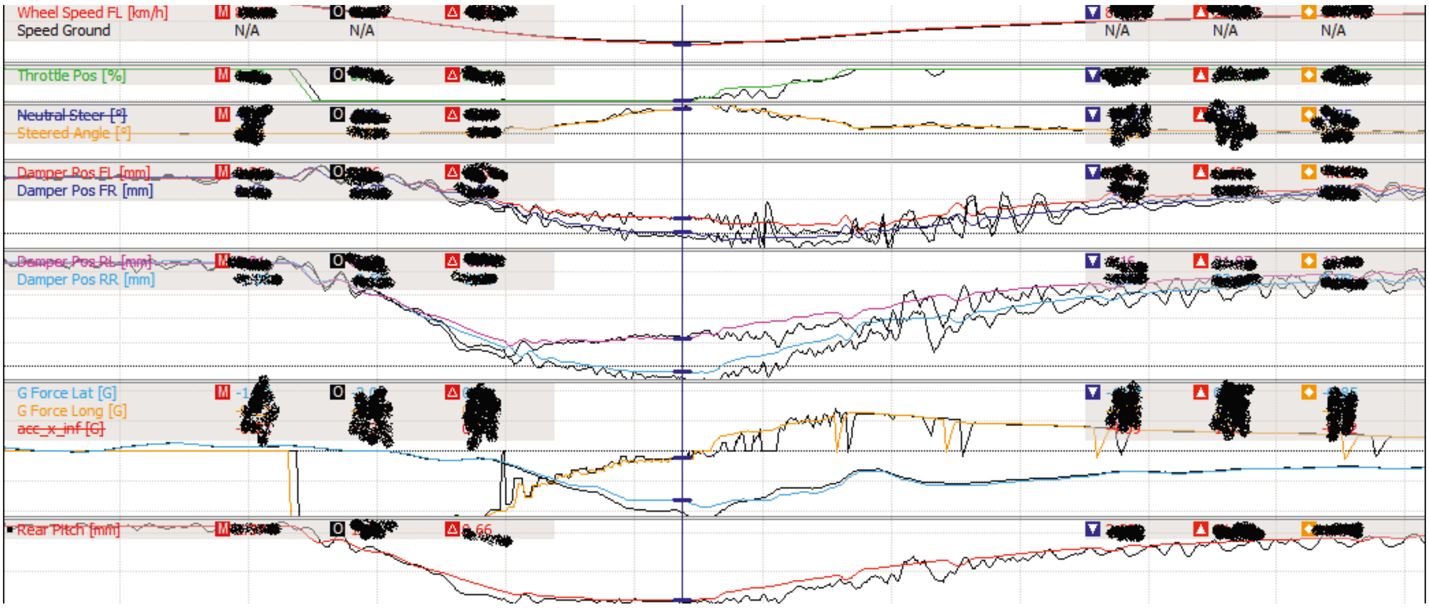

Figure 2: Smooth vs bump simulation

EQUATIONS

Equation 9

$$m_S z'' = Faero\_f + Faero\_r + msg - kfa(ma) - kfa(mb) - dfa(ma') - dfa(mb') - kthsf(mthsf) - dthsf(mthsf') - kfb(mc) - kfb(md) - dfb(mc') - dfb(md') - kthsr(mthsr) - dthsr(mthsr')$$

$$I_y\theta'' = a.\,(kfa(ma) + kfa(mb) + dfa(ma') + dfa(mb') + kthsf(mthsf) + dthsf(mthsf')) - b.\,(kfb(mc) + kfb(md) + dfb(mc') + dfb(md') + kthsr(mthsr) + dthsr(mthsr')) + b.\,Faero\_f - a.\,Faero\_r + F_{XF}.\,(h - pcF) + F_{XR}.\,(h - pc_R)$$

$$I_x\phi'' = 0.5.tf.(kfa(ma) - kfa(mb) + dfa(ma') - dfa(mb') + 2.krbf.mrbf) + 0.5.tr.(kfb(mc) - kfb(md) + dfb(mc') - dfb(md') + 2.krbf.mrbr) - FYF.(h - rc_F) - F_{YR}(h - rc_R)$$

$$\begin{aligned}
m_{tf}\, y_1'' &= ktf(z_1 - y_1) + ctf(z_1' - y_1') - (kfa(ma) + dfa(ma')) + 0.5(kthsf(mthsf) + dthsf(mthsf')) - frbf) + F_{YF}..rc_F/0.5*tf - 0.5*F_{XF}..pc_F/a \\
m_{tf}\, y_2'' &= ktf(z_2 - y_2) + ctf(z_2' - y_2') - (kfa(mb) + dfa(mb')) + 0.5(kthsf(mthsf) + dthsf(mthsf')) + frbf) - F_{YF}..rc_F/0.5*tf - 0.5*F_{XF}..pc_F/a \\
m_{tr}\, y_3'' &= ktr(z_3 - y_3) + ctr(z_3' - y_3') - (kfb(mc) + dfb(mc')) + 0.5(kthsr(mthsr) + dthsr(mthsr')) - rrbf) + F_{YR}..rcR/0.5*tr + 0.5*F_{Xr}..pcr/b \\
mtr\, y_4'' &= ktr(z_4 - y_4) + ctr(z_4' - y_4') - (kfb(md) + dfb(md')) + 0.5(kthsr(mthsr) + dthsr(mthsr')) + rrbf) - FY_R..rcR/0.5*tr + 0.5*F_{Xr}..pcr/b
\end{aligned}$$

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Great expectations

Simpler, lighter, stronger, faster, better – Volkswagen makes the most of the new WRC rules and gives its Polo a weapons-grade overhaul

By CHRIS EYRE

With the 2015 World Rally Championship beginning, Volkswagen Motorsport has unveiled the second-generation version of its all-conquering Polo R WRC. Back in mid-2013, aside from the five technical 'jokers' allowed, all WRC teams agreed a budget-driven homologation freeze to defer WRC car updates from 2014 into 2015. So, only now do we see the second homologation of the Polo R WRC.

The Hannover team of Willy Rampf, technical director, Francois-Xavier 'FX' Demaison, WRC project manager and Dr. Donatus Wichelhaus, head of engine development, have distilled all of their technical nous from two years of WRC experience at the top. Strategically maximising their use of WRC testing allocations, works drivers tested the revised car from mid-2014, more than 5000km on all surfaces. Test and development driver, Dieter Depping, did the majority of that testing, having also done the same for the first generation car.

Following a principle of evolution, a large proportion of components were scrutinised to capitalise on 'simpler, lighter, and stronger' opportunities, as well as 'optimising centre of gravity, load and function'. Mechanics' input was also received, such as reducing the variation of fasteners used on the entire car and servicing accessibility.

But with six world championship titles in two years, was there any need to raise the bar? In any cold light, the original car rarely came up short in two seasons of world domination. Demaison is unequivocal: 'Maintaining the status quo is taking a step back in motorsport.'

Aerodynamics

New and old, side by side, there are subtle bodywork changes to 'increase aerodynamic efficiency', indicating that the Wolfsburg wind tunnel facility has played its part. The squared-off outer edges of the front wheel arches are obvious and the arches are two centimetres higher than before. Coupled with a more ramped front wing surface area, flattened upper surfaces and re-shaped trailing edges, it's clear where these efficiencies start. Outer front bumper areas have also had detail revisions, an area of critical aero importance in the absence of unpermitted horizontal front splitters.

Metal matrix components and other similar materials have been banned from use for the pistons, rods and crankshaft

Weight has played a huge role in improving the engine – the 315bhp powerplant now sits bang on the 81.5kg weight limit

A revised 3kg carbon spoiler fine tunes the rear aero package and the differences are intriguing. In a throw-back to the early 2012 Polo prototype, the two inner vertical supporting structures of the Capricorn-supplied wing have gone, leaving a less supported upper wing. So, structurally it's been previously over-engineered or is now compromised and targeting other less obvious gains. The lower wing plane also appears to have a reduced Gurney rise at the trailing edge.

Taken in total, the aerodynamic improvements are described by Volkswagen Motorsport as 'extremely effective.

Engine

The engine package sees many largely-unspecified detailed improvements. The FIA Appendix 1.6-litre I4 turbo is now lighter and more powerful. Output is quoted as 318bhp, up from 315bhp, and torque is 430Nm, up from 425Nm. The aluminium unit, whose head and block are manufactured by Spiess Motorenbau, now sits at the FIA revised minimum weight of 81.5kg, down by 1kg. Both bore and stroke remain unchanged.

'Performance, drivability and weight are always at the very top of the specifications,'

notes architect Wichelhaus. 'In the case of the first two areas, we were pretty close to the limit with the first version for the 2013 and 2014 seasons. Naturally you implement what you have learned over the past two years, you know which parts work well and don't change them.'

There are much smaller detail changes in the rules, in the past all bolts used in the engine had to be made from a ferrous material unless they were the original components used on the base production engine. As the Volkswagen is a bespoke motorsport engine it meant that it had to use ferrous fasteners. In 2015 that rule has changed and aluminium alloy bolts can now be used throughout while nickel based alloys can be used to make the cylinder head bolts.

Meanwhile ceramic bearings have been outlawed and all rolling elements must be made from an iron-based alloy. However valve seats, guides and bearings may be made from alloys containing beryllium, they can also use metallic pre-forms infiltrated with other phases which are not used for reinforcement.

Metal matrix composites and other similar materials have been banned from use on the piston, rods and crankshaft.

Transmission

An exception to the evolution concept is the transmission. Volkswagen was keen for pre-2011-spec steering wheel paddle shifters to return to the WRC, to mirror the steering wheel-mounted ergonomics sold in production vehicles. Now permitted across the WRC, furious sequential gear lever changing again gives way to paddle push-pull serenity, while a clutch pedal remains.

Reflecting on its development cycle, Demaison noted: 'The new semi-automatic gearbox is a complex hydraulic system. The whole gearbox is a completely new development, which we worked on with Xtrac. We also developed a completely new gearbox casing. We started work on this project back at the start of 2014.'

Given the standardisation of WRC transmissions, it is all down to the margins and optimising the electronics. From Wichelhaus' engine perspective, 'the way that the gears are changed doesn't really make any difference to the engine. The regulations also set strict limits here, such that there wasn't much room to

Volkswagen's engineers have overhauled the Polo's chassis in order to increase aerodynamic efficiency. As well as new trailing edges on the front wings, which are now about two centimetres higher, the most striking change to the new car is a new rear spoiler

Volkswagen was the only manufacturer to fully exploit the rule changes

manoeuvre. The trick was to use the little that is permitted to get the maximum out of the gear-changing performance. And it took a few iterations before we technicians and the drivers were satisfied. The gearbox also needs to suit each driver's driving style.'

Chassis

When Jari Matti Latvala joined the team in 2013, he found a car developed and setup to Sebastien Ogier's preference and it took the Finn a while to adjust it to suit. The revised Version 2.0-designated chassis has wider range of set-up options over the 1.1 version, used since its 2013 debut. With the three Volkswagen drivers having different driving styles, unspecified revisions will allow the Volkswagen engineers to achieve greater freedom when it comes to set-up for their respective drivers.

Feedback from race technicians means the car is easier and quicker to work on. A gearbox can now be changed in 12 minutes, while brakes pads and discs can be replaced in just three minutes

Wichelhaus simply states: 'We've had the best chassis in the WRC for the past two years'. And Volkswagen has had plenty of practice: seven prototype and test Polos were built before the first one turned a wheel in competition, with CP Autosport supporting through chassis and suspension fabrication. With 24 cars now built, wheelbase and disclosed suspension travel remain unchanged.

Another development goal for the 2015 Polo was to make the whole car more user friendly. The three Volkswagen drivers have different driving styles, and adjusting the chassis components has allowed the Volkswagen engineers to achieve greater freedom when it comes to the set-up for their respective driver. Volkswagen will not be drawn on exactly how this has been done but a new specification damper from ZF is thought to be part of the package. Requests and suggestions from the mechanics were taken into consideration, in order to make it easier to access the components during services, which are subject to strict time restraints in the World Rally Championship. An example of this is that the new car uses the same-sized screws wherever possible, rather like IKEA furniture.

On the 2015 car only 66 different tools are required to carry out all the event servicing, that number includes everything from tape measures, replacement blades for cutting tools and wire brushes to more crucial items like screw drivers and torque wrenches. To build and prepare a Polo for a rally only requires an additional 15 tools.

Looking ahead

At the start of the Monte Carlo Rally, Citroën had updated its DS3s with a new engine, revised suspension and a paddle shift but it plans to bring more updates for its cars as the season progresses. These will include a new aero kit in the spring and a second evolution of the suspension in the latter part of the year.

M-Sport had modified the gearshift on its Fords for the opening round of the WRC but hopes to introduce a new engine, gearbox and paddle shift at Rally Portugal. Meanwhile Hyundai has only made minor updates to its cars but will introduce an all-new World Rally Car during the season.

Volkswagen was the only manufacturer to fully exploit the rule changes for the 2015 season and ran a fully updated car at the first round, the Monte Carlo Rally in January. The result was clear – the new Polos came home 1-2-3 after the challenge of a Loeb-driven Citroën fell by the wayside.

New superlicence system could hit race team income

GP2 has been graded below non-existent Formula 2
XPB

The new F1 superlicence system has been challenged by Renault and questioned by team bosses because of a perceived bias towards FIA-backed championships which could hit team revenues in other series.

Under the new system, which comes in this year, a driver will need to score 40 points in selected championships over the previous three seasons to qualify for the superlicence which would allow him/her to compete in Formula 1. There is also a weighting on each championship, so more points can be gained in some series than in others.

However, the weighting of the new system has come under fire, with some apparent anomalies, particularly when it comes to the ranking of Renault-backed championships. For instance, Formula Renault 3.5 is worth fewer points than the FIA Formula 3 European Championship, while Formula Renault 2.0 is graded below the FIA-backed national F4 series.

Meanwhile, GP2 has been graded below the FIA-backed F2, a category that does not even exist yet. A driver coming third in F2 would get the requisite 40 points to graduate to F1, yet the same result in GP2 would mean just 20 points – although these would be added to points gained racing in the previous two seasons.

Renault has now written to the teams contesting its championships to say it has contacted the FIA about the new system, which was announced after many squads had already committed to their 2015 campaigns. The FIA had initially said it would not bring in a new system until 2016.

Some team bosses are worried about the new system, as their businesses rely on the budgets brought in by ambitious drivers for whom F1 is often the ultimate goal. Mark Burdett, who runs cars in NEC Formula Renault under the Mark Burdett Racing banner, told *Racecar Engineering* that he was hoping Renault would be able to convince the FIA to change the rating on FR 2.0: 'From our business point of view, yes, because we're committed to Renault. We're still talking to drivers, we're still trying to finalise things. This doesn't help. We've already decided our line-up for this year, so it's too late to change anything. But it might affect what we look to do in the future.'

While the FIA has not given a reason for the new system it's believed the much-hyped graduation of 17-year-old Max Verstappen to F1's Scuderia Torro Rosso team after just one year racing in F3 cars was the catalyst.

NASCAR on the hunt for new Cup sponsor

NASCAR is searching for a new backer after Sprint, the long-time sponsor of its Cup division, announced that it is to end its association with the motorsport series.

The telecommunications giant will end its title sponsorship of the Cup when the current agreement expires in 2016. Sprint has held the naming rights to the Cup since it merged with Nextel, which had replaced former sponsor, cigarette company Winston, in 2004.

NASCAR is seeking a new backer following Sprint's decision to withdraw its sponsorshop of the Cup

The decision comes following a change in management at Sprint, which was sold in 2014. NASCAR said that it understood Sprint's reasoning and that it was confident a new backer would be found. Brett Jewkes, NASCAR senior vice president and chief communications officer, said: 'NASCAR and Sprint have enjoyed a long and productive partnership that has returned significant value to both parties. We understand significant changes within Sprint and the highly competitive business environment it is in has led to a decision not to extend its Cup Series entitlement position following the 2016 season.

'The NASCAR Sprint Cup Series is a unique, premium sports marketing platform with strong momentum behind it, so we are very confident of moving forward in 2017 with an outstanding new partner.'

Yet, while NASCAR remains optimistic that it can attract a new sponsor to replace Sprint at the end of 2016, it could still prove to be a tall order to find a company willing to spend an estimated $70-$75m per year, the figure said to be the outlay of Nextel/Sprint on the series, and because of the large amount of money concerned, there are probably as few as 50 companies that could afford to sponsor the Cup.

Nevertheless, sports marketing experts in the US are tipping top consumer brands to take over, with Subway, Burger King, Coca-Cola, Unilver, Panasonic and LG already being talked about as replacement backers.

NASCAR's most recent sponsorship deals for its two top championships – Cup and Xfinity (formerly Nationwide) – have both been long-term agreements, typically for seven or 10 years, and it is highly likely NASCAR will be looking for a similar lengthy commitment from any new commercial partner.

Audi announces €24bn investment over next five years

XPB

Audi could spend some of its planned €24bn investment on motorsport

In a move that's likely to have a positive impact on its motorsport programmes, Audi has announced that it is to invest a staggering €24bn between 2015 and 2019.

The investment represents a €2bn increase on the previous five-year planning period and will largely be sunk into new models and technologies – around 70 per cent of it is earmarked for these two areas. Much of this new technology could be proven in motorsport, although no mention of competition programmes was made when the news of the investment was released.

More than half of the planned investment will take place at the German sites in Ingolstadt and Neckarsulm, but Audi also plans to create additional production capacities worldwide and is pushing ahead with the expansion of its global production network.

Axel Strothek, Audi's CFO, said: '70 per cent of all our investment in the next five years will flow into new models and innovative technologies.' But he added: 'Despite the growth in total investment, we will keep a watchful eye on the upcoming challenges and exercise the required cost discipline.'

Audi CEO, Rupert Stadler, said investment would be made in technologies including the development of electric cars and technology and the use of lightweight materials. 'We place top priority on sustainable growth,' he said. 'That's why we are making large investments in the innovative areas of electric mobility, connectivity and lightweight construction.'

Worldwide, the Audi Group's workforce has now grown to 80,000 employees while Audi reached the mark figure of 1.7m cars delivered in 2014. Audi's current top level motorsport programmes are in the World Endurance Championship and the DTM.

Marussia collapse costs sport industry millions

Companies operating in the motorsport industry have been hit hard by the collapse of F1 team Marussia, with the former backmarker team owing trade creditors – the biggest of which is Ferrari – more than £30m.

Marussia went into administration in October. Since then a buyer for the team has not been found and FRP Advisory LLP, the team's administrator, has now said: 'Despite extensive discussions, no satisfactory offer or strategy has been offered to presently allow racing to continue.'

The extent of its debt has also been revealed in a summary of liabilities that was submitted to the High Court by FRP.

On top of charges of £13m owed to banking group Lloyds TSB, motorsport companies have also been hit hard. The three biggest creditors in the sector are engine supplier Ferrari (owed £16.6m, the largest creditor of all), McLaren (£7m for wind-tunnel and simulator services) and tyre firm Pirelli (£1m).

Other motorsport companies listed include Penske Racing Shocks (£220,000); AP Racing (£107,000) and Magnetti Marelli (£97,000). The FIA and some F1 circuits also appear on the list.

FRP's statement also explains that Marussia's assets of £6.3m are only likely to raise £2.2m. The team's remaining assets were due to be sold off as *Racecar Engineering* went to press, but the auction was cancelled for undisclosed reasons. Geoff Rowley, managing partner at FRP, said that there was now 'insufficient property to enable a distribution to be made to unsecured creditors'.

The estimated total owed to all creditors is £62.3m, with £31m owed to trade creditors.

Marussia's ninth place in the constructors' championship last season would have put it in line for £30m in prize money for 2015, but the team would have to race in order to claim the prize fund.

Meanwhile, Gene Haas has now bought Marussia's base in Banbury, which he intends to use as a European HQ for his new Haas F1 Team, set to hit the track in 2016.

The Haas cars, which are to pack Ferrari power units, are expected to operate out of the Banbury base.

New management team takes control at Silverstone

British Grand Prix venue Silverstone has completed a major shake-up of its management structure.

Patrick Allen is now managing director of Silverstone Circuit Limited (SCL), the company that operates the venue on behalf of the BRDC, stepping in to fill the position vacated by Richard Phillips. Phillips was suspended in October 2014, along with fellow directors David Thomson and Ed Brookes. All three are no longer with the company.

While an investigation into the running of Silverstone took place BRDC chairman John Grant and BRDC board director Lawrence Tomlinson – better known as the boss of Ginetta – took on interim roles to help run the venue. Allen's previous experience is in sales and marketing. He will be backed up by Stuart Pringle, the former BRDC club secretary, who is now sporting director at SCL. Pringle will be responsible for circuit operations and event management.

Allen said: 'Silverstone has great potential to become the ultimate entertainment venue and with the support of the team I believe we can make it the place to go. I want our customers to know that they can visit the circuit any weekend of the year and be guaranteed an amazing value for money experience – whether that is to watch motor racing, visit a music concert or enjoy a food festival.'

The BRDC says that Phillips, Brookes (finance and resources director) and David Thomson (legal and estates director) have left SCL to pursue other opportunities.

Top car executives see engines and emerging markets as priorities

Those holding the purse strings at major automakers across the world are likely to favour motorsport championships that focus on efficient conventional engines and have rounds in emerging markets, says a new survey that was released in January.

The influential KPMG Global Automotive Executive Survey, which is based on interviews with leading executives in the industry across the world, revealed that since 2013 the top priorities have remained unchanged.

Market growth in emerging countries was one of the top priorities for 56 per cent of participants in the 2015 survey (in 2014 it was 52 per cent), while the optimisation of the internal combustion engine was also a major priority, according to 49 per cent of those approached (40 per cent in 2014).

The results show a leaning towards short-term thinking, says UK head of automotive at KPMG, John Leech. 'The executives involved in this year's survey have prioritised near-term market issues over longer-term technological innovations. The focus on emerging markets is understandable as three-quarters of the expected growth in new car sales is forecast to come from these markets.'

Leech added that engine optimisation is being driven by the green agenda, though this could be at the expense of other technologies, such as lightweight construction: 'The drive to optimise the internal combustion engine is fuelled by growing environmental pressures. In the UK, manufacturers are principally focused on the EU CO_2 rules which set targets for vehicle manufacturers that correlate with vehicle weight. This means that CO_2 saving solutions that also add weight, such as direct injection, are favoured over lightweight solutions like the use of aluminium.'

The survey also found that most executives believed that the day of the electric car is still far in the future, with less than one in 20 of all cars produced in 2020 expected to be equipped with electric drivetrains.

SEEN: Ford GT

The car that many believe will be the weapon of choice for Ford's return to international endurance racing has broken cover. The all-new GT was unveiled at the Detroit Motor Show. It's a carbon-chassis, mid-engine supercar and it will go into production late in 2016, hitting the road in select global markets to celebrate the 50th anniversary of Ford GT racecars scooping the first three places at the 1966 24 Hours of Le Mans.

The Ecoboost-branded engine is a 600bhp twin turbo V6, while the car also features a seven-speed dual-clutch transaxle-mounted transmission, torsion bar and pushrod suspension, and carbon ceramic brakes. It will be built at Ford's technical centre in Charlotte, North Carolina, which opened last May.

While Ford would not be drawn on its motorsport plans for the GT, it is known that the blue oval has been evaluating a race programme in GTE, which would also mean a return to Le Mans, and it has been working with Multimatic with this in mind for the past year. The last version of the GT raced at Le Mans as recently as 2011, but a works squad has not been present at Le Sarthe since the early '80s, when the Ford C100 car raced in the 24 Hours in 1982.

IN BRIEF

Name change

The McLaren Group has changed its name to the McLaren Technology Group. McLaren says the change represents an ongoing shift at the group, which is increasingly developing into a diversified hi-tech company, now involved in industries such as oil and gas and aviation and financial services, on top of its core motorsport and automotive activities.

BRC for 4wd

The British Rally Championship (BRC) will be open to four-wheel-drive cars for the first time since 2011, when it returns in 2016. The BRC was shelved for this year after International Motor Sports (IMS) – the commercial arm of UK governing body the Motor Sports Association – took control of the championship in readiness for a re-launch in 2016. The top class in next year's all-new BRC is now to be for R5 cars, such as M-Sport's Ford Fiesta R5, Citroën's DS3 R5 and Peugeot's 208 T16.

Pirelli for F4

The BRDC F4 Championship has signed a tyre supply deal with Pirelli. All BRDC F4 cars will run on bespoke Pirelli P Zero-branded tyres from 2015, moving the championship to the same tyre supplier as GP3, GP2, and F1. BRDC F4 creator and promoter MSV said it had selected Pirelli because of the proven excellence of its competition tyres and the comprehensive service it provided to teams.

Cross coden

Experienced sportscar squad JRM is to branch out into rallycross this year with a brace of Prodrive-developed Minis. JRM has bought the Mini RX project – including all intellectual property and a complete spares package – from Prodrive, which adapted a Mini WRC for rallycross competition in 2013.

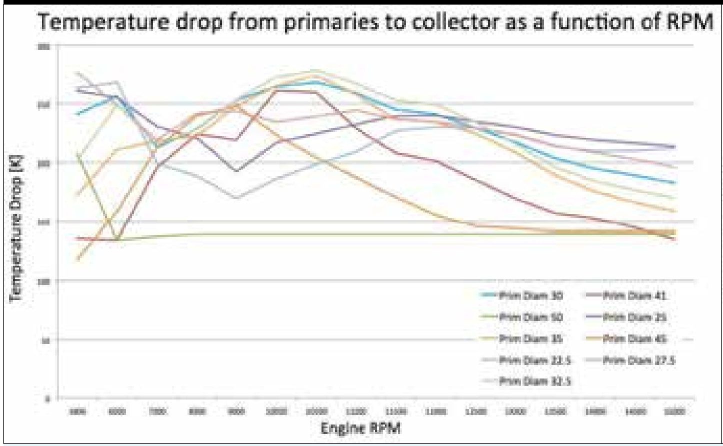
Auto GP to merge

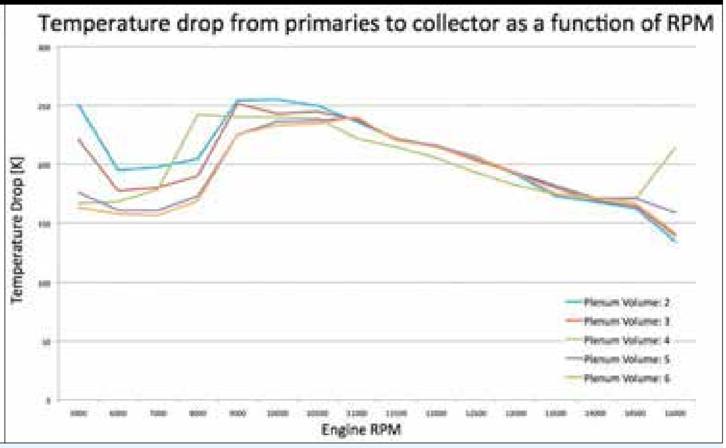
Struggling European single seater categories Auto GP and Formula Acceleration 1 (FA1) are to combine for this season in a bid to boost grid numbers across both series. Both Auto GP and FA1 use the same Lola-Zytek cars, originally raced in A1GP until the end of the 2008 season, but last year each struggled to attract entries. The move to combine the two championships should guarantee fields of 18 cars this year, those behind the merger believe.

Ferrari secures America Movil deal

Ferrari has announced a major sponsorship deal with Mexican telecommunications group America Movil, which will include its principal brands Telcel, Telmex and Claro. The deal comes after the Scuderia signed America Movil-backed Mexican racer Esteban Gutiérrez as its reserve and test driver for the 2015 season.

CORRECTION: Good recovery





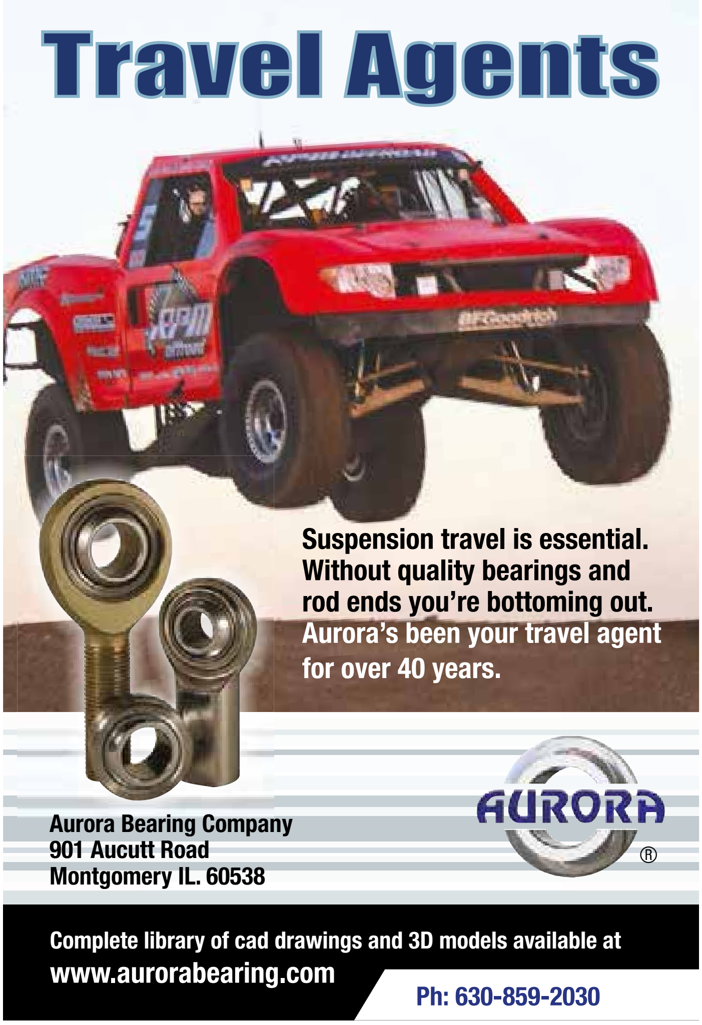
In Racecar Engineering V25N1, we printed the same graph twice and are happy to print the corrected graphs, above. The graph on the left shows temperature drop from primaries into the collector as a function of RPM for an equal length manifold, on the right for a log-type manifold.

SEEN: Porsche 919 Hybrid

Porsche has released the first pictures of its 2015 919 Hybrid, taken at its test track in Weissach in December before the car was shipped out to Abu Dhabi to continue its test programme.

'It is an evolution of the car, the concept stays pretty much the same, but it is a new car because every component is new,' says Technical Director Alex Hitzinger. 'It is all about optimising weight, stiffness, robustness, setup options, and of course further improvements in efficiency in aerodynamics and engine – it is optimising every component without changing the concept.

'There have been some clarifications over the course of the year in terms of the regulations that we have to react to for bodywork, aero, brakes and the skid blocks under the car. We already had some form of brake compensation for ERS, but the regulations have changed quite a lot and opened up. It can't be policed, so you open it up, meaning there is a lot more potential which we didn't use before because we thought that it was illegal, and now it is legal.'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INTERVIEW – Michel Nandan

Heart and Seoul

Hyundai's motorsport boss explains why the Korean car giant is in World Rally and just what it takes to set up a bespoke competition department from scratch

By MIKE BRESLIN

"At the moment we are fully concentrated on WRC, but Hyundai is quite keen to do some more motorsport activity"

Growing up in Monaco there would be a fair chance you would end up either loving or loathing motorsport, such is the way its two major events – the Grand Prix and the Monte Carlo Rally – take over the principality each year. But for one Monegasque, the outcome was definitely the former, and a certain Korean car giant is surely glad of that.

Michel Nandan hooked up with Hyundai in 2013, and since then he has been a very busy man indeed. Not only has he overseen the development of Hyundai's first WRC car since 2003, there has also been a team to build and a state-of-the-art motorsport facility in Alzenau, Germany, to establish.

Nandan cut his teeth in the 1980s in touring cars and rallying in Italy, and went on to enjoy a successful career on the technical side of the game, the highlight being his design of the championship-winning (2000, 2002) Peugeot 206 WRC.

But after a spell as a technical representative with the French motorsport federation Hyundai came calling and Nandan made the switch to the role of team principal, his first task being to set up its competition department.

'I've always been involved on the technical side, so it's the first time as a team principal,' Nandan says. 'But when you start from scratch you can organise the team from the ground up. The first job is to find the right people and to fill all the key positions. With a good group of people it's much easier to do. From there it's a step-by-step approach: build a factory, build a team, and so on. It's true that I'm further away from the technical side. It's a different job, but quite interesting as well.'

Focus on performance

Nandan says he still has a say on technical issues – working with chief designer Bertrand Vallat – but his main role has been implementing Hyundai's motorsport strategy. In terms of sales, the Korean car giant is currently the fifth biggest car manufacturer in the world, yet it has very little in the way of a performance pedigree. This, says Nandan, was the reason it returned to the WRC for the first time since 2003 with cars run by Motor Sports Development.

'Hyundai is really behind this activity, because they want to change their image; for more sporting cars, or high performance cars,' says Nandan. 'It wants to use this activity to show what is possible to do in terms of motorsport, and also to use this image for the development of a new high performance car, which is something which it is working on.'

It helps that the WRC is also home to some of Hyundai's main market rivals, such as VW and Ford. Yet matching and beating these acknowledged giants on the special stage is all well and good, but it means nothing if potential customers are not aware of Hyundai's successes. It's no wonder then that there are some frustrations about the championship's coverage. 'There's still some work to do, but it's true there have been improvements. For sure, it's not enough, but I would say wait a bit because the [WRC] promoter has started to do its job.'

Another frustration is the geographical spread of the championship, with no rounds currently being staged in some of Hyundai's key markets. But Nandan tells us the WRC has made a significant step in putting this right. 'China will probably feature in the championship in 2016, so this is going in the right direction,' he said.

This will be good news for all the manufacturers in the championship, including Toyota, which confirmed its programme in January (See p22). There had been speculation that the Japanese car giant was holding out for a significant change in the technical regulations – due to be overhauled for 2017 – but Nandan dismisses this, and says as far as he knows the regulations will not actually differ too much from the current offering, or at least that's what the teams are hoping. 'From our point of view, and also the point of view of the [other] manufacturers involved in the championship, we would like to keep at least the engine regulation quite close to what it is, which is understandable because it costs a bit of money to do it. The four-cylinder 1.6 engine regulation is not too bad for Hyundai. If the FIA wants to have a bit more freedom in the regulation, I think this discussion is open – I'm talking about maybe more freedom on transmission and suspension.'

Nandan also dismisses talk of hybrids in WRC. 'The manufacturers were not too keen to have it on rally cars and I have to say that even Toyota agrees. In terms of packaging it's

XPB

not so easy on a rally car – we also have to consider that the car is going on normal roads, not on circuits, so if there is an accident it's more difficult to handle the system. And I think that to do something really quickly for 2017 with hybrids, if we want proper hybrids, is not so easy.'

In the meantime Hyundai has a brand new rally car to think about and the second iteration of the i20 has already started its test programme. 'We are still development testing. The car we have been running is really a prototype. The first real car with the proper bodyshell should be ready for us in February, but we will still test with the car we have at the moment and we need to run it and sort out all the problems before taking any decision to enter it. We don't want to rush the new one like we did on the first i20, because there were a lot of compromises, and when you start to compromise it's not so good for performance.'

Kia to compete in touring cars?

That said, the first car was not so bad, after all Hyundai was the only manufacturer to break VW's hegemony in the WRC last year, even if its one-two on the Rally Deutschland was a tad fortuitous, Thierry Neuville picking up the top spot after his rivals had slipped up on treacherously slick stages. But then a win is a win, as they always say.

But what about winning in some other category? 'At the moment we are fully concentrated on WRC. It's true that we are looking to do some other things in the future, but nothing has been decided yet. But Hyundai is quite keen to do some more motorsport activity.'

This will not necessarily be badged as a Hyundai campaign, though, says Nandan, for Kia is also part of the company, and there have long been whispers about it becoming involved in touring cars. If that move should come to pass there is a fair chance Alzenau will have an involvement. 'At the moment I know there is some discussion in Kia,' Nandan reveals. 'We have not been approached yet concerning this. But if you want to be logical and they are doing some sort of touring car championship, it's true that we can share some of the development with the WRC programme.'

Perhaps it's a future of both rallying and racing for Nandan, then? Should feel just like home for a Monegasque …

Nandan masterminded Hyundai's winning return to WRC

RACE MOVES

XPB

Well-known NASCAR crew chief **Todd Parrot** is now Xfinity Series competition director at Richard Childress Racing. Parrott, who most recently led Tommy Baldwin Racing's No. 36 Sprint Cup Series set up, brings a wealth of experience to RCR, having spent 20 years as a crew chief at Cup level.

Jorg Zander, the former F1 technical boss at Williams, BMW-Sauber and Honda/Brawn, is now working as Audi Sport's head of technology. Zander left F1 in 2009, although he was linked with the technical director role at the HRT F1 team in 2011 before the deal fell through.

Stewart-Haas Racing's **Daniel Knost**, who crew chiefed for **Danica Patrick** in the final three races of the 2014 NASCAR Sprint Cup, is to continue to serve as her crew chief throughout the 2015 season.

Veteran crew chief **Donnie Wingo** is now in charge of **David Gilliland**'s No.38 Front Row Motorsports entered Ford in the NASCAR Sprint Cup. Wingo has worked for Wood Brothers Racing for the past four seasons.

IndyCar team Andretti Autosport has hired **Rob Edwards** from Schmidt Peterson Motorsports. Edwards takes on the post of director of race operations and engineering, and will help fill the void created by the departure of long-time team director **Kyle Moyer**.

Bob Osborne has returned to crew chief duties with Roush Fenway Racing to oversee the No.6 Ford of Trevor Bayne in the NASCAR Sprint Cup. Osborne stepped down from crew chief work in 2012, but remained with RFR as part of the engineering team.

Jock Clear, formerly the performance engineer for **Lewis Hamilton**, has been signed by Ferrari to replace **Pat Fry** in the role of engineering director. Fry, chief designer **Nicolas Tombazis**, and tyre analyst **Hirohide Hamashima**, have all now left the Scuderia.

Paul Leech is to run the new single seater arm at JHR Developments. Leech, a former F1 chief engineer at both Arrows and Minardi, will be responsible for JHR's campaigns in MSA Formula and BRDC F4 this season.

Jim Morton, who entered cars in the Australian V8 Supercars development series – as well as the main championship on occasion – has died after losing his battle with cancer. Morton was known as a mentor for young drivers and gave many stars their start in Australian touring cars.

Michael Faust, a crew member in the NASCAR Camping World Truck Series, has been indefinitely suspended from NASCAR after violating the sanctioning body's strict substance abuse policy.

Grant McPherson has left Australian V8 Supercar outfit Ford Performance Racing, where he had been **Mark Winterbottom**'s race engineer. McPherson, who played a key role in the team's engineering department, was with FPR for eight seasons.

Dave Allen has been named president of Auto Club Speedway by the the track owner, the International Speedway Corporation. Allen, 41, who served as the two-mile track's vice president of sales and marketing, replaces **Gillian Zucker**. He spent one year working at Mazda Raceway at Laguna Seca before coming to Fontana in 1999.

Oliver Schwab is now manager of the Porsche Supercup, taking over from **Jonas Krauss**. **Alexandre Gibot** has taken on Schwab's old role as manager of motorsport at Porsche China. Gibot had previously been manager of the Porsche Carrera Cup France.

Mark Cornell, who has more than 16 years of experience designing and manufacturing wiring harnesses for F1, IndyCar, Le Mans and the WRC, has now joined DC Electronics. Cornell previously worked for BF1 systems.

OBITUARY - Brian Lister

Brian Lister, well-known for a succession of successful front-engined Lister-badged sports racers in the 1950s, has died at the age of 88.

Lister started his engineering career at the family firm, George Lister and Sons, as an apprentice in 1942, going on to do his national service with the RAF just after the war. He then rejoined the family business in 1948.

A lifelong interest in cars brought him to the race track in the early '50s following the purchase of the second Tojeiro to be built. After finding the tricky machine a bit of a handful he handed over driving duties to good friend Archie Scott-Brown while he began to concentrate on his new goal of becoming a racecar constructor.

Lister asked his father to fund the development of a car bearing the family name, which Scott-Brown subsequently raced, driving it to a debut win. The Lister car evolved rapidly, powered initially by Bristol and then Maserati engines, and then, in 1957, the Lister-Jaguar appeared. Out of the 14 races entered that season it won 12. Naturally, on the back of this success there was plenty of interest from customers wanting to buy the 'Lister-Jag' as well as a Chevrolet-engined version of the car for the American market.

In 1958, in the wake of the death of Scott-Brown after an accident at Spa, Lister considered getting out of motor racing. But he continued for another year until the deaths of drivers Ivor Bueb and Jean Behra – although neither at the wheel of Lister cars – finally persuaded him to quit the sport. However, he did continue to support Lister customer efforts into the 1960s.

Brian Lister 1926-2014

Williams reorganises F1 technical team

The resurgent Williams F1 team has reshuffled its technical personnel and has also added new names to its roster.

Dave Robson, formerly Jenson Button's engineer at McLaren, now fills the same role on Felipe Massa's car at Williams, with Massa's previous engineer, Andrew Murdoch, moving up to a new role of senior performance engineer. Jonathan Eddolls continues as Valtteri Bottas's engineer.

Williams said of Robson's hiring: 'Andrew will lead the performance group at the factory, developing new techniques and processes within the engineering team to ensure continual performance improvements are brought to both cars throughout the season.'

Meanwhile, Steve Nielsen is now the team's sporting director, having left the same post at Toro Rosso. Nielsen has held a variety of senior roles at F1 teams through a long career, including team manager at Tyrrell and Arrows, and sporting director at Benetton/Renault.

Within the team Williams stalwart Carl Gaden has been promoted from chief race team mechanic to senior car systems engineer, with Mark Pattison – previously Massa's chief mechanic – now taking on the chief race team mechanic role.

Chief technical officer Pat Symonds said: 'Off the back of a great 2014 campaign, Williams is determined to continue this positive momentum into the new season, and these recent changes show our commitment to that goal. We are proud to be able to promote our existing talent to help strengthen every area within our engineering team.'

But Symonds added that the team would also still recruit from outside the company if required: 'We will continue to invest in new talent where necessary to ensure we have the support and resources to achieve our on-track ambitions throughout 2015 and beyond,' he said.

Williams achieved nine podium finishes last year, a vast improvement on its 2013 campaign when it scored a meagre five points and finished ninth in the standings.

Dave Robson has moved from McLaren to Williams as part of an engineering shake-up

RACE MOVES – continued

XPB

Graham Watson is now the team manager at Italian F1 team Toro Rosso, where he will take on a wider role following the departure of **Steve Nielsen** to Williams. Watson was previously with Caterham, but left the team last year and joined Toro Rosso in September.

Shelly Shafer Cates is now event manager in the US for the Masters Historic Racing series. Cates started her career in motorsport 18 years ago with IndyCar team Tasman Motorsports before she was signed up as director of promoter operations at Championship Auto Racing Teams (CART). She will work closely with the series' UK office.

Michael Tatoian has been promoted to the post of president at Dover International Speedway. He will also retain his previous roles as COO and EVP of Dover Motorsports Inc, where he continues to report to president and CEO Denis McGlynn.

The Renault F1 engine operation has enlisted **Mario Illien** and his company Ilmor to help it with its F1 power unit, which proved a disappointment in its debut season under the new regulations last year.

Lisa Noble, president of the Sports Car Club of America, has won the 2014 Women's Sports Foundation Project Podium Leadership Award. The award was established in 2008 and has previously been won by NASCAR president **Mike Helton** and former director of Ford Racing **Dan Davis**, among others.

Scott Elkins, managing director of technical regulations at US sportscar body IMSA, has joined the Mazda Road to Indy programme as race director to both the Pro Mazda and USF2000 single seater championships. Elkins' role at the TUSCC will be taken by **Geoff Carter** as Series Manager, reporting to IMSA Managing Director, Racing Operations, **Simon Hodgson**.

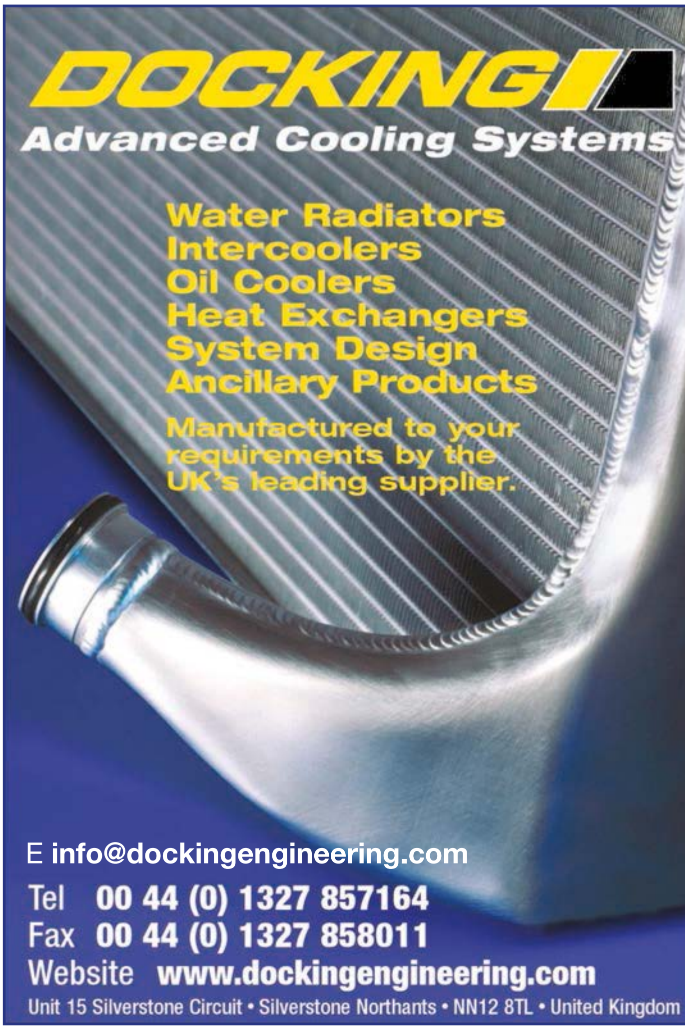
Following the closure of Turner Scott Motorsports and the subsequent legal battle, Chip Ganassi Racing has formed a partnership with **Harry Scott Jr** and will field one full time XFINITY Series team under the HScott Motorsports with Chip Ganassi banner in 2015.

Keith Barnwell has re-joined NASCAR XFINITY organisation TriStar Motorsports as executive vice president of motorsports for 2015, while **Ricky Viers** has joined the team in the role of general manager.

Bruce Cook has departed HRE Motorsports and will replace **Wes Ward** as crew chief for the No.8 Toyota Camry, while Ward takes on the role of shop foreman.

Jay Guy has joined second year team JGL Racing as crew chief for the No24 Toyota Camry in the NASCAR XFINITY Series, Guy was formerly crew chief at Sprint Cup team Front Row Motorsports.

◆ Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect. Then email with your information to **Mike Breslin at bresmedia@hotmail.com**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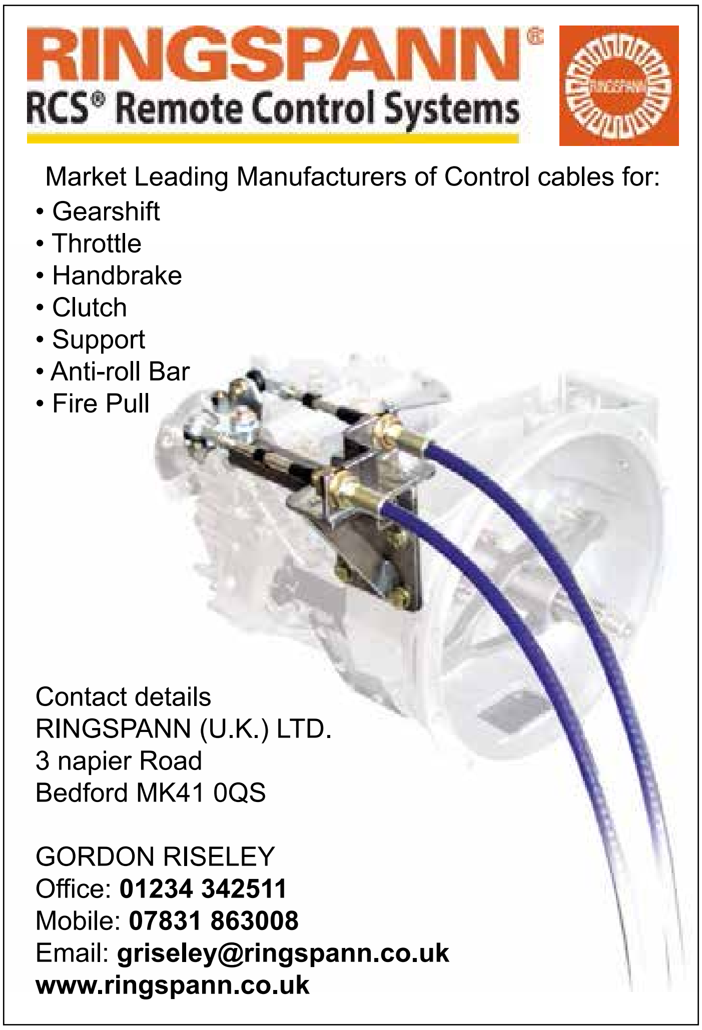
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Transmission
Xtrac P1202 gearbox

Xtrac has launched a new, cost effective rally transmission, the P1202 gearbox, which has been designed for all-wheel-drive cars competing in the World Rally Championship support category WRC2 under the newly introduced FIA R5 price capped regulations.

'We started to design and manufacture transmissions for the World Rally Championship in 1987. Since then we've helped our customers to win 19 driver world titles and 15 constructor world titles,' says development director Cliff Hawkins. 'Six of the seven teams and 10 of the 13 drivers competing in the top class RC1 category this year – one of whom will be crowned world champion at the end of the season – will be in cars equipped with Xtrac transmissions. And we soon expect to see other cars built to the R5 regulations entering the WRC2 category with our new P1202 transmission, which will join the Super 2000 cars and WRC Regional Rally cars that already use our P532 and P633 transmissions.

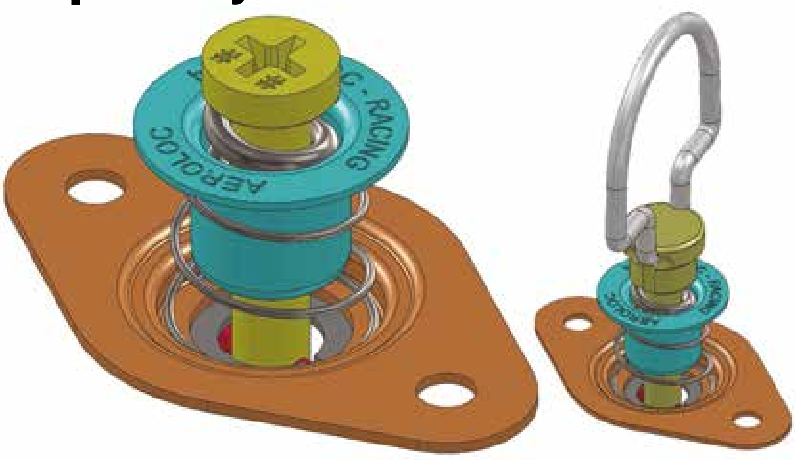
'We've optimised the P1202 transmission to meet the FIA's weight, durability and cost targets,' says technical director Adrian Moore commenting on the five-speed gearbox designed specifically for R5 turbocharged cars up to 1600cc. 'It incorporates Xtrac's well proven plate differentials, and the gear-change mechanism is the latest overlapping type on all five gears giving a class leading, fast, accurate and very precise manual gearshift. For almost 30 years we have supplied transmissions for the main world rally championships and have used that experience to develop this class leading transmission.'

Xtrac stipulates high strength L169 aluminium alloy for the casings, which are sand cast to the regulation minimum wall thickness of 5.5mm. Normally specified for critical aerospace applications, L169 provides the required toughness and durability. The similarly high specification rear disconnect unit is Xtrac's patented passive hydraulic system, which has been proven in WRC and Super 2000 rally cars since its introduction in 2007.

'The P1202 is the most highly optimised transmission available for the R5 category,' says Moore. 'It has been homologated with the FIA and will be a popular choice for car manufacturers for 2015 and beyond.'

www.xtrac.com

Fasteners
Specialty Fasteners AeroLoc



Almost every form of motorsport makes use of the Dzus turnlock fastener and it has, in its 80-year history, become a household name. The new AeroLoc from Specialty Fasteners aims to replace the Dzus. The key to its improvement is the use of a cross-head stud, which all but eliminates the risk of damaging expensive body panels, and a hold-out spring, which makes panel removal much easier.

The new AeroLoc self-ejecting fastener is interchangeable with the Dzus EHF series and is more secure when fastened, thus negating the occasional need for tank tape to keep it in position. This means that retro-fitting is not only possible, it has actually been designed in.

A cam receptacle replaces the usual spring receptacle and locking is not only made more positive but is also quicker, both attributes that race engineers will appreciate in the frenetic atmosphere of qualifying and pitstops.

Although AeroLoc is not due to be available until the Spring, Specialty Fasteners already offers CAD models for engineers to evaluate in relation to their own applications. Sales manager for Specialty Fasteners, Graham Leo, has no doubt that his company are on to a winner: 'We have had the product under test for some while now and the results have been conclusive enough to convince us that AeroLoc will be a game-changer in the area of panel fastening, in much the same way as our AeroCatch shear pin latch has been.'

To complete the line up, Specialty Fasteners will also be offering AeroLoc in a bail handled version for hand operation, where use of a screwdriver is difficult.

www.specialty-fasteners.co.uk

Lightweight cable protectors
DEI heat protection

DEI's new lightweight heat protection for cable lines, wire and hose is the latest addition to its heat protection range – the MA stands for Molten Aluminum (or aluminium if you prefer).

DEI has developed a unique process that impregnates molten aluminium into a tightly woven core fabric. Ultra Sheath MA withstands direct heat up to 600degC and is more than 40 per cent lighter than foil covered sleeving.

This thermal protection product from DEI provides the most advanced protection for cable lines, wire and hose as it is more flexible than standard foil or bonded aluminium products, and easy to trim to desired lengths for a quick and easy installation, even in hard to reach locations.

Ultra Sheath MA can be purchased in various ID sizes and lengths as well as in bulk including: ½" ID x 3' (#010230), ½" ID x 15' (#010231), ¾" ID x 3' (#010232), and 1-¼" x 3' (#010233).

www.designengineering.com

Oil catch can
Mishimoto compact can

With years of oil catch can research and development time, Mishimoto has created what it believes is the most effective compact oil catch can on the market. The Mishimoto Compact Baffled Oil Catch Can was designed to separate oil particles from the PCV/CCV air that would normally have just been routed back to the air intake. The internal air diverter roughs up the air for longer and ensures all the oil sinks to the bottom of the can, leaving nothing but clean air to pass through the 50 micron bronze filter to the intake. An internal baffle keeps the collected oil from splashing around under race conditions. This oil catch can features two ports, one inlet and one outlet, for easy installation.

The 100 per cent billet, 6061 aluminium can features 3/8" NPT threads at the inlet, outlet, and drain area and includes two black nylon fittings to make installation effortless. For maximum fitment options, the top mounting setup allows the can to be mounted from multiple angles. To make maintenance easy, the drain plug can be removed to allow for a return to the oil pan. The can is also washable, unlike many other cans that require you to replace your filtration system.
www.mishimoto.co.uk

Brake fluid
Lucas synthetic DOT fluid

Lucas DOT 3 is a high quality blend of polyethylene glycol ethers and additives which meet or exceed the industry minimum dry boiling point of 401degF. It meets the Federal Motor Vehicle Safety Standards (FMVSS) No. 116 and SAE J1703 specifications. The same company's DOT 4 Brake Fluid is also a blend of polyethylene glycol ethers and additives which meet or exceed the industry minimum dry boiling point of 446degF. Both are claimed to prevent seal hardening or softening, protect against rust or corrosion, provide excellent lubrication compatible with all brake system rubber components and other fluids.
Lucasoil.com

Fuel pumps
DeatschWerks DW350oiL

DeatschWerks has added to its range of fuel pumps with the new DW350iL. This high flow, 350-litre per hour fuel pump is DeatschWerks' first externally mounted in-line fuel pump. Flowing 350-litres per hour@ 40psi and more than 300 litres per hour at 70psi, it can support more than 700hp.

Roller-vane technology allows a flatter flow curve, which means more flow at higher pressures which is important for turbo and supercharged applications.

Along with higher flow rates, the DW350iL comes with -8 AN ORB female fittings on the inlet and outlet for connection to larger fuel lines, an anodised aluminium body, two T-bolt mounting brackets with rubber isolators, and rubber boots to protect the power terminals.

The DW350iL has been engineered to fit Bosch 044 surge tanks, which provide reserve fuelling capacity and dual pump capability.
www.deatschwerks.com

Laser leveller
B-G Racing's laser kit

B-G Racing's new Laser Levelling Kit is an effective way to accurately level scale pads, roll-off pads or drive-on set up platforms to ensure the corner weight readings are consistent. The kit consists of four CNC precisely-machined aluminium targets for placing on each scale pad and a 360 degree rotating laser unit with three adjustable levelling feet. A black plastic protective carry case is included with the kit.
www.bg-racing.co.uk

Showtime

The Autosport show celebrated its 25th anniversary this year and as the ever there was plenty of new technology to savour

By GEMMA HATTON

Renault showed off its RS01 in public for the first time

The Graham Jones Award

IS Motorsport's Simon Swatridge accepts the Graham Jones Award for the most innovative product. The trophy was kindly donated by previous winners Versarien.

It is not just speed on the track that helps win races, but speed off the track is crucial too, which is leading to some of the fastest pit stops seen to date. However, there are also those pit stops that don't go quite to plan – where miscommunication can lead to drivers jumping out of the car while still attached to some electronics or the car leaving the garage with the data engineer's laptop still connected. These are just a few of the scenarios that iS Motorsport's Mantis Quick Lok Micro Magnetic connector can avoid.

'When rally drivers have a puncture they have to fix it

Reventec

After only a couple of years in business, Reventec is already bringing revolutionary sensing technology to the market. One example is the non-contact AD-015 linear position sensor, which is capable of sensing through solid metal walls.

The MagnetoResistive technology used in this sensor can sense the position of a magnetic target over a 150mm measurement range. Most impressive, however, is the fact that the sensor can still operate with a 40mm gap between the sensor and the target, even if there is a chunk of aluminium, steel or carbon fibre in the way with no effect on output or accuracy. This has huge potential within motorsport as it means engineers will no longer have to compromise on the location of sensors.

Reventec is also in partnership with Mikina Engineering and Polyhedrus Electronics, forming Sentronics which is developing a new alternative to the controversial fuel flow meter for F1 and LMP1. 'The ultrasonic time-of-flight principle is best for measuring fuel flow on board a racecar, and with our second-generation sensor we've let the demands of the motorsport application have a greater influence over the design,' explains Neville Meech, Reventec's founder.

The FlowSonic weighs 250g, less than half the maximum specified by the FIA, and offers a competitive solution at a lower cost. It may make its competition debut on track as early as this season.

Infiniti supports paras

This year's BTCC grid is not only going to see a pair of new cars in the form of the NGTC Infiniti Q50, but also a new team with a new approach – to raise awareness for SUPPORT OUR PARAS, a the charity for the Parachute Regiment.

The team arrived at the Autosport show with two exciting revelations: the first was the reveal of its spectacular livery, and the second was the news that it had employed its first injured paratroopers.

'The number one aim is recruiting at least eight injured paras this season to be a part of the team. The second objective will be eventually to win,' explained Jerry Hardcastle, Infiniti's general manager for performance and innovation.

'We understand that, during this first season that's going to be a challenge, but we're here to race competitively and we will make progress. We're also here to build the brand of Infiniti, to develop our relationship with the UK – it's almost back to race on Sunday, sell on Monday – we want to show that the Infiniti Q50 and the 'coming soon' Q30 are attractive cars for potential customers.

'I hope what we are doing will send a great message to all the injured ex-Parachute Regiment soldiers,' ex-colour sergeant Darren Fuller said. 'Not only can you still achieve great things despite your injuries, but we as a team will be out there week-to-week raising awareness and funds for the Support Our Paras charity, which exists to help and support our wounded, financially and otherwise for years to come.

'We want to get to a level where there's not one person from the Parachute Regiment who doesn't know where to turn if they need any support, no matter how big or small their issue is."

Hexagon Metrology

There will be a new addition to this year's pit lane – Hexagon Metrologies brand new Leica Absolute Tracker AT960 will be used by Red Bull Racing at every F1 race for the first time.

"The ultrasonic time-of-flight principle is best for measuring fuel flow"

themselves, so they don't want to start pulling plugs and unclipping connectors,' explains Simon Swatridge, marketing manager for iS Motorsport. 'With our Mantis Quick Lok connector, the magnets disconnect after a certain amount of force has been applied, so if the driver forgets to disconnect, it's not an issue and it also allows quicker disconnect. We took the concept to the teams and after a while of trying to twist it, they found out that it was magnetic and all they had to do was pull it – they thought it was excellent.'

The small circular magnets are located either side of the pin arrangement, and due to their polarisation, it is impossible to connect the wrong way round. As well as being easy of use, this leads to further advantages of blind mating, which can help when sockets are in awkward places, such as headlamps.

However, initial research suggests that the main demand for this design is for download leads and headsets, which resulted in the first iteration being developed as a shell size 9, with 8 pins to allow Ethernet connection. 'We're not just looking at this size though, if someone wants a shell size 12 with 10 pins that disconnects at a particular force, then we'll go back and look at the strength of the magnets required. The whole idea is that people come to us with a niche application and then we adapt the concept to that requirement.'

The challenge is to achieve the right balance between having magnets that are strong enough to remain connected under certain loads, but weak enough to disconnect when required. 'It is a fine line,' agrees Swatridge, 'but it's something we have been working on.' Another danger is the potential for interference caused by the magnets on cables. However initial testing has proved that this is not a concern.

The AT960 is an ultra-compact laser tracker which offers accurate high-speed dynamic measurements in six degrees of freedom for probing, scanning, automated inspection and reflector measurements.

The probe can measure up to 1000 points per second, including 'hidden points' on any surface and any material.

Weighing in at only 14kg and featuring wireless communication, this new design is portable and easy to use; not only for measurements around a car, but also for flying around the world.

Base Performance

Nominated for the MIA Business of the year award, Aston Martin works driver and former McLaren F1 test driver Darren Turner's team of three will have an exciting year ahead with its GT and single seater simulators. With Aston Martin Racing launching its new young driver 'Evolution Academy' programme, base performance simulator sessions come as part of the package 'as standard'. At the show they also hinted towards some interesting developments to be revealed later in the year.

Quaife

The transmission masterminds at Quaife are ensuring the company celebrates its 50th anniversary in style with an important product launch – the all new Quantum ultra compact 6 and 8 speed sequential transmissions.

This new design is suitable for applications up to 1000 bhp and utilises patented technology that delivers eight forward speeds from just five pairs of EN39 steel gears (or six speeds from just four gears), reduces weight by approximately 6kg and achieves a greater spread of gears and reduced rev drops between the ratios. The 'quick-change' drop gears , temperature and position sensors, an oil level sight glass and an internal oil pump are included in the Quantum range, which offers solutions to the smaller teams without the price-tag.

Stand awards

Tony Tobias presented the Best Small Stand award to Newton Equipment

Machine tooling company XYZ won the Best Manufacturing Technology Stand

Wirth Research scooped the Best Overall Stand gong

Highlights package

The Autosport International show was as big and popular as ever as crowds flocked to the NEC to soak up the very best motorsport has to offer. Here are just a few of the highlights from 2015

Noble presented its new time attack model dressed up as a frog. We asked our marketing executive Ebba Jacobsson to give the car a kiss, but it didn't turn into a handsome prince. It still looks to be a pretty cool car though

Racecar Engineering's Ebba Jacobsson with the brand new Graham Jones Award trophy, kindly donated by Versarien

The Autosport Engineering Show, held in association with Racecar Engineering, had a scintillating display of old and new technology on display. With all the talk of F1 going back to wider wheels, Racecar staff wondered about current lap times with slick tyres

TE showed off its new 118 way size 18 double density connector at the show. It has been suggested that a competition should be held among the loom shops of the motorsport industry to see how quickly one of these can be built up 'although they may go mad if they attempt it' one observer quipped. It requires no new tooling

Racecar Engineering's new stand achieved critical acclaim. Central to the display was a wooden desk reflecting the full scope of our 25 years in-depth coverage of motorsport

Jenvey's new internal combustion powered laptop was on display complete with fully functional electronic throttle control

We weren't sure exactly what was going on at the Ginetta stand, but we were surprised that Alex the Lion decided to show up and feature in the picture. The engineers seen here were keen to discuss the new GT3 and GTE regulations

MG's DTM entry remains unfinished but there are suggestions that it may struggle to meet the current regulations

Pirelli staff were on hand to discuss the construction of the new F4 rubber as well as F1 tyre degradation rates

Alex the Lion was also spied on the Ford stand taking in the new Myagle FIA F4. It could just be that our photographer has a thing about lions. Or Ginettas and Fords

British stockcar racing was well represented in Birmingham. One of its best drivers, Tom Harris, made an appearance at the show before heading off to the Chilli Bowl

Donington Park was the worthy winner of the Service to the Industry award, sponsored by Goodridge. CEO Jon Hourihan presents to Donington Park MD Christopher Tate

Tim Griffin, CEO of Dell UK, hands over the New Markets award and a bottle of bubbly to Forward Composites managing director Paul Jackson

Daniel Chilcott, managing director of SS Tube Technology, is handed the PRI Export Achievement award by Francisque Savinien, PRI's director of global sales and marketing

Andy Bell, Mercedes High Performance Powertrains head of purchasing received the Technology and Innovation award from Ricardo's Steve Sapsford

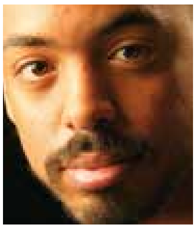
Mercedes HPP also won the Teamwork Award, sponsored by Grainger & Worrall. Pictured with the gong are Phil Ward, sport executive manager, and Geoff Willis, technical director

Quentor won the Business of the Year Award for companies with annual sales below £5m. The award was sponsored by the Northamptonshire Enterprise Partnership

Grainger & Worrall won the Business of the Year for companies with annual sales over £5m. The award was sponsored by Xtrac and received by MD James Grainger

MIA celebrates a season of success for UK companies

The MIA's annual awards evening on Thursday night has become something of a fixture during the weekend of the Autosport International Show. A glittering dinner, a speech from CEO Chris Aylett and a comedian who targeted Alan Gow and the MIA's Chairman Jim Morris were the highlights of the evening, as were the awards. British engineering has enjoyed a stellar year in 2014, with the industry rising to the considerable challenges of hybridisation of top flight racing, recovery from a deep recession and a strong vision for the future. Worthy winners accepted their awards in January, 2015, but there is more to come this season.



Trading places

Why motorsport's two biggest winter shows are still great places to do business

When winter comes, the motorsport industry mostly spends its time stripping down, rebuilding, redesigning and optimising, but the lucky few get to switch from the chilly climates of Oxfordshire, England, and North Carolina for two even colder places, namely Cologne, Germany, and Indianapolis. The reason for this is the two trade shows which have become essential parts of the motorsport industry calendar.

Professional Motorsport World's annual Expo, held on the banks of the River Rhine, is the newest and smallest show on the scene. What it lacks in scale, it more than makes up for in the quality of not only its exhibitors but also its attendees. Despite the fact that the F1 season had yet to reach its conclusion when the show took place in mid November, many of Grand Prix racing's key suppliers and buyers were doing business. Much of that business took place after the show had officially concluded – PMW has rapidly built up a reputation for a being a rather boozy event, and it is in the bar of the Radisson hotel where much of the business is done. The MIA has long been aware of this (and its staff join its members in some alternative fuelled networking at the Radisson) and organises a slightly more formal event in the old town. Its Bierkeller Boxenstopp evening is simply not to be missed and key contacts are made there every year.

The event itself has grown substantially, which took many by surprise – in the past it had been possible to walk around the show in a day, but the 2014 event was impossible to navigate in less than two days – a great statement about the current state of the European motorsport industry.

The aisles of the Indianapolis convention centre were packed with serious buyers and race teams

Tucked away on one booth at PRI was the design conecpt for the new Elan NP1 built for a new NASA Series

Destination Indianapolis

Just days after the PMW show closes its doors, all of the top companies in Europe get on transatlantic flights heading for various destinations on the Eastern seaboard of North America; mainly because you cannot travel directly to the 'International' airport at Indianapolis from anywhere outside of the USA, other than Toronto.

But the convoluted journey is worth it, as not only does it provide the opportunity to drop in at places like Mooresville, but it also means you end up at the biggest trade show in motorsport, PRI.

Attendance at this show has long been almost mandatory for any serious company in motorsport but its relatively recent return to Indianapolis has increased not only the show's size but also its importance. The variety is mind boggling, from endless sprint cars and midgets (prepped for the Chilli Bowl) and the companies that supply them, to the latest F1 and WEC technology, it is all on display in the vast convention centre.

Even though the show is held over three days, you'll struggle to get round all the stands in that time. One aisle that is highly recommended for readers of this magazine and definitely should not be missed is officially known as the High-Performance Computing & Testing Technology Zone, and it is populated by the likes of Aerodyn, Carsim, Chassis Sim and the Michelin Proving Grounds. 'This part of the show is perhaps only relevant to 10 per cent of the attendees here,' one exhibitor told me, 'but with this many people 10 per cent is a hell of a lot of people and being in Indianapolis we know it's serious business.'

One weakness of the show is the lack of focus for the post-show networking; the MIA International reception is a must-do event but is busy, a bit too short and a bit too formal. The Slippery Noodle is fun, but too loud to have any serious conversation (it's all about the music there, and good it is too). Rumours of other venues are beginning to filter out as the British contingent explore the city a little more but it is the only area where the show is found to be wanting.

Even though PRI is held over three days, you'll struggle to see everything

Chassis conundrums

Our rather sage columnist Ricardo Divila wrote some months ago about nationality and how that is reflected in motorsport. He veered into the touchy subject of moustaches for a while and while I don't expect this column to head into that kind of territory, I have to say that he was insightful.

The announcement by IndyCar's Will Philipps that the series would open up the chassis regulations means that the dominance of Dallara is about to be broken in the North American market. Although at *Racecar Engineering* we support the idea wholeheartedly, I do wonder if it hasn't come a little too late. Chassis manufacturing has taken a significant hit in the last 15 years, with the loss of Lola and Reynard in the UK, and with them has gone a vast amount of knowledge, learning and teaching capabilities. Counter to that, the likes of Mygale has announced that it is to do a Formula 3 chassis for 2016, and Formula E will eventually go to an open chassis formula too.

At the Daytona 24 hours, there was a rumour circulating around the paddock that the Tudor United Sportscar Championship would not, after all, adopt the European-style LMP2 chassis regulations and instead would continue to pursue the Daytona Prototype model. The decision was taken after *Racecar* went to press, but the conversation in the bar was still the same; does the American series actually need the European regulations and chassis manufacturers, or are they perfectly capable of producing their own?

> **If IndyCar does go open chassis, the US has the capability to cater for its own market**

Certainly the likes of Brumos Racing were very comfortable with the whole scenario as their race shop is pretty much on the other side of the road to Crawford Composites, and so building a Coyote carbon chassis would sit quite nicely for them.

There are other companies in the US that are capable of producing carbon tubs, and with the production costs coming down, it is hard to see the carbon tub not being adopted in US prototype racing. However, the European perspective is that the North American market is important as the manufacturers over here have to have a market. Yet, the point is that there may not be a market there at all.

There are, according to one source, eight manufacturers interested in building LMP2 cars, and each would have to probably sell around eight cars each to make them financially viable – a market of 64 cars. Even with the European Le Mans Series, the Asian Le Mans Series, TUSCC and the WEC there is simply not that level of demand.

HPD has built an LMP2 tub, as has Jacques Nicolet under the Onroak banner, and as far as Nicolet was concerned, the decision to adopt P2 or not in the US makes no difference – he built the Ligiers based on the assumption that they would not be able to race in the US until 2017 anyway, yet at Daytona in January one of his cars set the pole position time. The market is already there, he thinks. With ORECA opening up a base in North Carolina, it seems that Hugues de Chaunac also sees opportunities in the US.

Clearly the American public responds well to the competition of Chevrolet and Ford in the TUSCC, otherwise they wouldn't continue to race there. However, what's the plan? Chevrolet has confirmed that it will not make a P2 car, and its most likely course of action, should the decision be to adopt P2, is to install an engine. That means that, should the decision be taken to go to Le Mans, it would have to sell a customer car (factory cars are not welcome in European LMP2), a customer driver (all-professional line-ups are not permitted), and it will only be competing for a class win. Chevrolet already does that with an all-professional line up with a production-based product, the C7R, so why would it need to do P2? Likewise, if the rumours surrounding Ford and Multimatic turn out to be true, the Blue Oval has the opportunity to go to Le Mans to contest a class win with an all-pro team.

There is a strong argument to suggest that the American chassis manufacturers are more than capable of looking after their own market, while it is far more important for the European manufacturers to have the US market in which to sell. The US manufacturers don't *need* the link to Le Mans; that is purely an emotional, or romantic, sentiment. Let's not underestimate the power of that, but that is very different from an actual 'need'.

If Indycar does go open chassis, it has the capability in-house to cater for its own market, and that could easily hurt the European dominance of chassis manufacture. The globalisation of racing business is not an absolute requirement and the Europeans should be very careful not to assume that they are the only ones who can service the industry. Competition is strong, and British and European companies are doing well in the US. But the world can change in a heartbeat. I wonder if the IndyCar, and the IMSA decisions will facilitate that change?

ANDREW COTTON Editor

The International Journal of Motorsport Technology
Racecar engineering

PIT CREW

Editor
Andrew Cotton
@RacecarEd

Deputy editor
Sam Collins
@RacecarEngineer

News editor
Mike Breslin

Design
Dave Oswald

Chief sub editor
Simon Toyne

Technical consultant
Peter Wright

Contributors
Nick Bailey, Mike Blanchet, George Bolt jr, Ricardo Divila, Chris Eyre, Gemma Hatton, Simon McBeath, Danny Nowlan, Mark Ortiz, Peter Wright

Photography
James Moy

Deputy managing director
Steve Ross
Tel +44 (0) 20 7349 3730
Email steve.ross@chelseamagazines.com

Head of business development
Tony Tobias **Tel** +44 (0) 20 7349 3743
Email tony.tobias@chelseamagazines.com

Advertisement manager Lauren Mills
Tel +44 (0) 20 7349 3740
Email lauren.mills@chelseamagazines.com

Advertisement sales executive
Lucy Caller, Stewart Mitchell
Tel +44 (0) 20 7349 3745
Email lucy.caller@chelseamagazines.com

Marketing manager Will Delmont
Tel +44 (0) 20 7349 3710
Email will.delmont@chelseamagazines.com

Publisher Simon Temlett

Managing director Paul Dobson

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

Advertising
Racecar Engineering, Chelsea Magazine Company, Jubilee House, 2 Jubilee Place, London, SW3 3TQ
Tel +44 (0) 20 7349 3700
Fax +44 (0) 20 7349 3701

Subscriptions
Subscriptions Department
800 Guillat Avenue, Kent Science Park
Sittingbourne, Kent ME9 8GU
Tel +44 (0) 1795 419837
Email racecar@servicehelpline.co.uk
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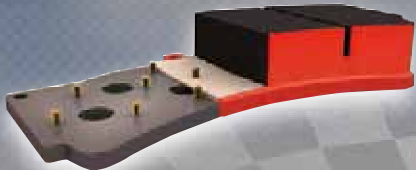

PAGID RST

Double DTM Champion Mattias Ekström has clinched his first-ever FIA World Rallycross Championship victory after a flawless drive in the Audi S1 EKS RX in Holjes, Sweden. In his RX campaign, Mattias relies on the supreme stopping power of PAGID RST racing brake pads – high initial bite, constantly high friction over temperature with excellent modulation over the whole temperature range. With the highest degree of braking performance, PAGID RST racing brake pads deliver the competitive edge that successful drivers demand.

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