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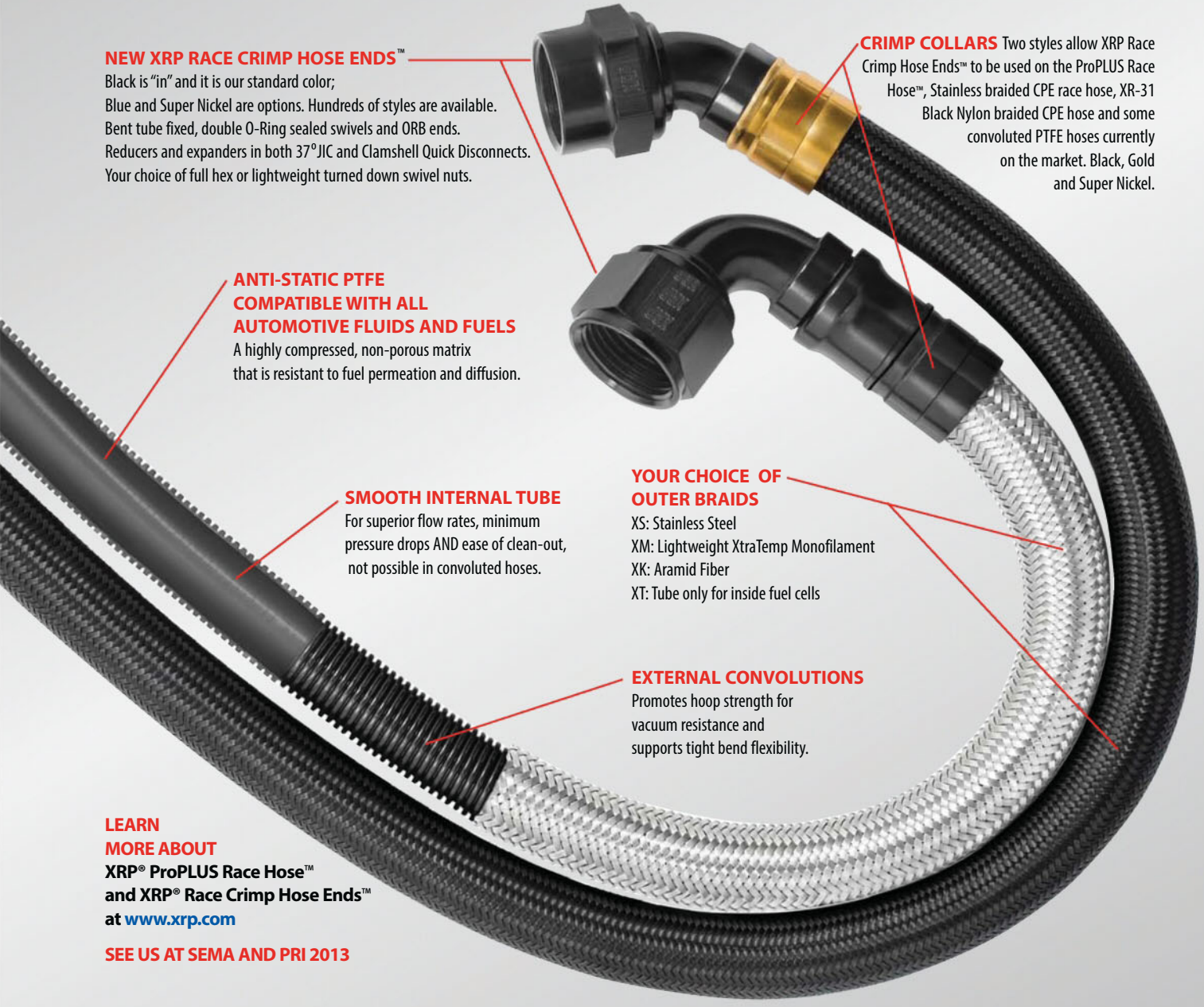

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Going against the grains

Terrain, tiredness and self-dug toilets – the singular challenges of the Paris-Dakar

Some races are a bit different, and one of my favourites is one that harks back to the stile at the start of motor racing, when we used to have the great town-to-town races like the 1894 Paris-Rouen.

Well, take away the tree-lined routes, nice green fields, general paraphernalia of civilisation and the stops at brasseries for a quick top up of andouillettes and red wine, but keep the dust and ruts, add oodles of sand, then stretch it out for three weeks with no real sleep and you have the Paris-Dakar. Ah, and turn up the thermostat.

It originally started at the Champ de Mars in the shadow of the Eiffel Tower, ending at Lac Rose in Senegal 22,000km later, with a preliminary run through France to Marseille or – later – to Gibraltar. It ran at a leisurely pace spiked with some special stages, usually in mud or slush as the early January start ensured wintry weather, across the Pillars of Hercules, narrow cliff-side roads through the Atlas mountain range and an eventful traverse of the Sahara desert, finishing with a run through rutted roads in Mali and Senegal, through beautiful baobab tree forests. You cross dunes, mud, camel grass, rocks and erg under conditions that entitle you to join Leopold Ritter von Sacher-Masoch's club.

JUST DESERTS

The tour de force was really the desert stages, including the marathon stages, where maintenance crews were forbidden on the overnight bivouac and drivers had to tend to their steeds. For me as an engineer, running in the support class meant you were in the same race, running the same route, with similar cars, though burdened with an additional 300kg of spares, driveshafts, CV joints, uprights and the tools to intervene if necessary. One year in the support trucks, class T4, more of the same – but with an over 3.5 ton mass to dig out of the sand. Centrally commanded tyre pressure controls helped with this one, as one could inflate and deflate tyres on the go to increase the footprint over soft ground. You were in the first wave to depart the bivouac, being successively overtaken by the bikes, then trucks, then the cars, as they were released behind you at staggered times, and arriving late at the next bivouac, where the support trucks were already working on the cars, they having had a relatively easier route on bridge stages through more lenient terrain.

It also meant you did not get much sleep, as work sometimes finished just before you had to depart for the next day's stage. It did not seem to matter much – being strapped into a bucket seat with a six-point harness, helmet bungee-strapped to the wire grille behind you gave ample snoozes even as you bounced from tussock to tussock or leapt over ravines, while your co-driver tackled as much of the stage as he could endure, relaying the steering back to you as fatigue coma approached. The periods became shorter and shorter as the day advanced, and the only coffee available was from vacuum flasks, rapidly exhausted. That was part of the job list for the following years, but never satisfactorily solved.

There were other hazards also. The mined stretch of the border wall between Western Sahara and Mauritania was one; the other was the turd minefield downwind from the bivouac every night – maybe bigger than the wall – as the needs of the 3500-plus people at the bivouacs was self-catered for. Heading out into the desert night with a shovel and loo paper was a grim affair. All too many headed out without a shovel, however, the mindset of which explains the environmental state of the planet. Even cats are more fastidious.

When not stuck in the sand, drivers kill their suspensions bouncing over it

Modern technology was a boon the year I was testing infrared goggles with view to using them on the rally itself, to spot and avoid bikers in the dust-clouds when barrelling on with cars. Thermal-imaging the turd field pre-empted hours of boot scraping when the offending dejecta could be seen glowing greenly in the dark.

Maybe Parnelli Jones put it best: 'Desert racing is like an all-day plane crash.' And parts of the route had other, non-natural drawbacks. Some bearded followers of the also-bearded prophet would take umbrage at the Dar al-Harb cars rumbling through their territory, and would use the vehicles for target practice. Arriving at the bivouac with bullet holes in the bodywork was far from unheard of – I don't think that has been an issue in any other race I've done, although it's been heard in the paddock that the only way to beat the Lotus 58 wing car when it appeared was to ambush it at the far corner with a shotgun to blow its tyres. (Mmm... that gives me an idea for Le Mans – could one prophesise a rash of punctures on the Audis this June?)

Arriving at the bivouac to find bullet holes in the bodywork was far from unheard of

The 350mm suspension strokes would make these 1780kg behemoths as agile as mountain goats, even chunking through the ubiquitous camel grass mounds and landing as soft as a down-filled mattress after leaping of the lee side of a dune, albeit 50 metres down the road. Much as news from the antipodes, things seemed to be serenely happening a long way away.

Running on Senegal's red earth trails, with a patterned washboard rut that could disassemble any mechanical component, the speed you ran at would define a frequency for the vibration. This prompted musings about what would be the best speed to reduce the resonance and attempting to formulate the equations to solve. By then we would be on the second week practically sleepless, and the crucial part of the modelling process in evaluation of whether or not a given mathematical model describes a system accurately would be fairly hit or miss, but amusing. Talk about fuzzy logic – everything was fuzzy.

The route would be mile-posted by the dropping screws, features and accessories pinging to the car's floor as you buzzed along. Teeth would literally itch, and eyeball jiggling de rigueur. Breton, Marinetti, Ernst, Dalí, Arp and Giacometti would be right at home with the surreal visions of writhing baobab trees in the preternatural sunlight said jiggling would produce. The accumulated

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lack of sleep, laced with strong coffee, could accentuate the hallucinatory viewing of 'Dada in the Desert.' Who needs psychoactive drugs? One Dakar is the equivalent of 50 blue pills.

And we had it easy, compared to the bikers. Why they would embark on this expedition always puzzled me. Having to stand up on the foot pegs for practically the whole day, when not continuously falling in soft sand, throwing chains, repairing punctures, breathing dust thrown up by the cars and trucks and being narrowly avoided by the other, much bigger competitors seems to me foolhardy. The sight of one biker arriving at the bivouac around midnight, rolling into the middle of the bedouin tents erected for the food, stopping by the coffee urn, but just falling over as the legs gave out before a steadying leg could be put on ground – like a fallen, beetle-like medieval knight in his armour – haunts me to this day, mainly for the blank look in the eyes, denoting no conscious thought behind them. But maybe there was none there at the start.

One of the alternate routes – taken after the threat of fundamentalists, necessitated the airlift of the whole caboodle over Mauritania – took the Dakar from Marseilles to Sharm El-Sheikh, on the Sinai, passing through Libya. Parts of the Libyan leg ran through over 800 miles of absolutely flat, featureless desert, the whole universe consisting of a straight horizon bisecting blue sky and white sand. Running on it for two hours with no referential, vibration or sense of movement made you slip into the hallucination that you were motionless, even though running at 170kph.

No description can convey the feeling of awe, running through and on 300-foot high dune fields under a million-star studded sky with the knowledge that there were few other human beings around. These dunes took over a million years to form, wind sculpting the identically-sized sand grains painstakingly into soft pillowy dunes. A lesson in time and relative size, too often nature gets crowded out in city life. And we have vacuum cleaners too.

The course conditions also changed over time. Early morning running on the thinner, harder dew crust of sand needed a given speed to practically speedboat on the surface. Slow down and you would rapidly find yourself chassis-deep in sand, bogged down in fine powder. Digging yourself out with the obligatory shovel and using the sand ladders could give a very temporary respite, as you could bog down a mere car-length further on. Sisyphus redux. Reading dune types and sand surface conditions was an acquired skill, to be honed after several years of shovelling your way across the desert.

On some stages you could find yourself in a gaggle of bogged-down competitors, all shovelling away with some still-moving car warily threading its way through the pan, only to find another dustpan a bit further along. Ropes and sturdy nylon straps were useful for dragging cars out of the pans by the lucky ones on firmer ground, and even if no such case existed one could almost envisage making a noose and ending it all. I will never, ever, build another sand castle by the seaside. Other days you would see no-one, either because you were thoroughly lost, or out of the group because of a delay – only vast expanses of sand. And sun shining on sand. Some wind sometimes, moving sand. If a strong wind, you didn't see anything, except sand, of course.

Sand in the food, sand in the drink, sand in the engine, sand in the minutest nook and cranny of anything you have, including your body. I still find sand at home on some gear years afterwards. The sand saga was capped the year we broke a cam on a stage, having to replace it on the lee side of a rock outcropping amid a howling sandstorm, pulling the head, replacing the offending item and re-timing the cams wearing goggles, sand trickling down the back of the neck and into the sump and internals of the engine. No need to burnish the valve seats, everything inside the engine had a thorough scouring by abrasive particles, to no apparent immediate harmful effect.

Just out of shot: a gang of locals sizing up the Chevvy truck for target practice

Navigation, even when GPS were de rigueur, provided moments of hilarity, when the choice of which canyon to take through the barren mountains, supposedly recced by satellite photos and plotted in your road-book, was rendered moot by the sight of an opposing competitor whizzing by at 180deg to your bearing, causing quizzical looks of enquiry towards your navigator. Turning around and heading back if in doubt would often bring the sight of the very same opposition whizzing by you again heading for your late course, as they, too, were unsure.

The drivers one had also stood out. When the news was announced that I would have the great Colin McRae as a driver, one had a rash of commiserating calls from friends in rallying, predicting our early retirement through mechanical failure or, euphemistically 'impacting a natural obstacle'. The maestro had form, as his emblematic motto 'If in doubt, flat out!' attested, but one other legend that pedalled my car was characterised by a story Colin would tell: 'On the Manx Rally, Ari Vatanen had a massive accident. Afterwards, Fred Gallagher asked his co-driver Terry Harryman: "'When did you know that it was all over and you were going to have a big accident?" and Harryman replied, "Scrutineering!"'

You'd have sand in the food, sand in the engine... I still find sand on some gear, years afterwards

ARI KARI

On one of the Dakars, Ari retired my car by hitting the only tree in a 500 mile radius, but my admiration for his press-on abilities was recompensed by his 50th and last Dakar stage win with us. And any doubts about his virtuosity and coolness will be dispelled by watching the 'Climb Dance' video of the Pikes Peak with the iconic Peugeot 405 T16. No ABS, automatic gearbox, EPS or guard-rails overlooking 600ft drops on a gravel strewn climbing mountain dirt road. Look it up on YouTube for 5m15 of awe-striking images, with Ari the epitome of cool as he drives one-handed up the final stretch shielding the eyes from the sun with a gauntleted hand, one wheel over the abyss.

Ari is The Man, four times Dakar winner, Rally World Champion and also being an accomplished raconteur, wryly humorous and erstwhile European Parliament member. Civilised too, being the owner of a winery in the south of France.

My first Dakar with McRae gave a week of all-nighters before he fractionally slowed down to cut down on the massive rebuilds every night. The one-man tent I had in the back of my car never had to be used, and we were breaking parts theoretically stressed to 10G impact loads, including his co-driver seat brackets, not gentlemanly of his part as it implied a bit of avoirdupois on her part. Sorry Tina!

All that, plus the healthy, spartan energy-laden food and the continuous isometric exercise by being shaken daily for 15 hours brought you to the end of the marathon in pristine physical shape, and looking at my profile now, one must do another soon. Just a shame about all the bloody sand.

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Formula 4 reformed

The FIA is giving long overdue direction to junior single-seater formulae

The proliferation of categories over the past couple of decades is acknowledged as having diluted the size and the quality of the numerous starting grids, muddying the waters in defining the best way up the single-seater ladder and making it increasingly difficult to measure the most talented young drivers against their peers. As a result, the wrong call may have spoiled many a worthwhile career.

According to FIA president Jean Todt: 'One of the missions of the Single Seater Commission is to clarify the career progression of young professional drivers. The first step was to reposition Formula 3 at the heart of the ladder leading to Formula 1. We then needed to come up with a category that could bridge the gap between karting and F3. It is with this in mind that we have now created Formula 4.'

While the concept of a cost-restricted formula bridging leading to F3 is hardly new, what stands out is the understanding by the FIA of the need to do more than dream up or sanction yet another category. FIA F4 – no relation to the existing Formula 4 – appears to be much more than that. The provision and mandating by the Federation of an all-embracing set package – or 'toolbox' – to ASNs concentrating on the key elements of common technical and sporting regulations, organisation style and effective modern marketing and communications initiatives is intended to establish a consistent pattern and identity. So, through multiple national championships F4 could effectively become a worldwide brand, opening the doors to the participation of global commercial and media partners to cement its future. It is imaginative and it's proof that the Federation that controls our sport – and effectively much of our industry – is aware that it needs to be pro-active, engaged and practical in ensuring a healthy future for both from grassroots upwards. This has not traditionally always been the case, and it is encouraging.

According to the regulations, each national F4 championship must designate a single engine partner. However, the ASNs may individually decide to authorise one or more chassis types. Therein lies a matter of particular interest to the racecar constructor industry and beyond.

Rendering of Dallara's proposal for use in the new F4 series

While the philosophy of one-make engine and chassis formulae presents a strong argument for controlling costs and providing the 'level playing field' on which competitors can fairly be judged, my hope is that the ASNs will instead look to the massive success of F-Ford 1600 in its (near 30-years!) heyday and be persuaded to follow that same route of fixed-engine but open-chassis concept. It's to be hoped that the FIA will encourage this. But why, when categories such as F Renault have been so successful, over a long period?

Well, I have expressed before my concerns about the limitations of one-make chassis in developing not only young drivers, but also designers, engineers and teams as a whole, and the long-term negative effect this has had, typified by some of the failings of F1 as we see it now. A counter-argument has been the overall support that a major automotive manufacturer brings by attaching its brand to not only the engine, but the car and series as a whole. However, if the FIA is successful in its F4 gameplan and as a result – via strong commercial partners – replaces the car manufacturer in this role, then the importance of this connection is to a large extent negated.

Driver aside, the significant performance elements of a racecar built to strict regulations are tyres, engine and chassis, and the latter is the one that permits the most scope without creating a big performance differential. Therefore the remaining arguments in favour of one-make chassis are the cost savings of volume manufacture that can be reflected in the lower price of hardware to competitors, plus the level playing field for drivers.

If the FIA is as determined to make F4 succeed, as it appears to be, the potential scale of sales worldwide should create sufficient business for more than just one car constructor, even in each individual country. Certainly enough potential to justify nascent racecar companies investing in the design of their own chassis and putting this forward for homologation and into the marketplace. Plus, any industry needs new blood, and competition is healthy in developing this. A choice of chassis promotes ingenuity of the Ben Bowlby kind, not seen at this end of the sport for many years.

STANDING OUT

Regarding a level playing field, it's not just sheer speed that should define the best drivers. The ability to help develop and setup a car is of equal importance if the stated ultimate objective for a winning F4 driver – F1 – is attained. Best to learn this right at the start in an open chassis category not totally constricted by the regulations. Drivers wringing headline performance out of unfashionable chassis soon stand out. Constructors needing to showcase their product will inevitably step forward with offers of support – a real push up the ladder for under-financed drivers that never happens with one-make chassis formulae and has been absent for far too long.

While the main aim of F4 is to nurture driving talent, it's just as important for the FIA to encourage and protect the industry that provides the equipment without which there would be no racing at all and at the same time provide opportunity for the serious participants in a number of vital roles.

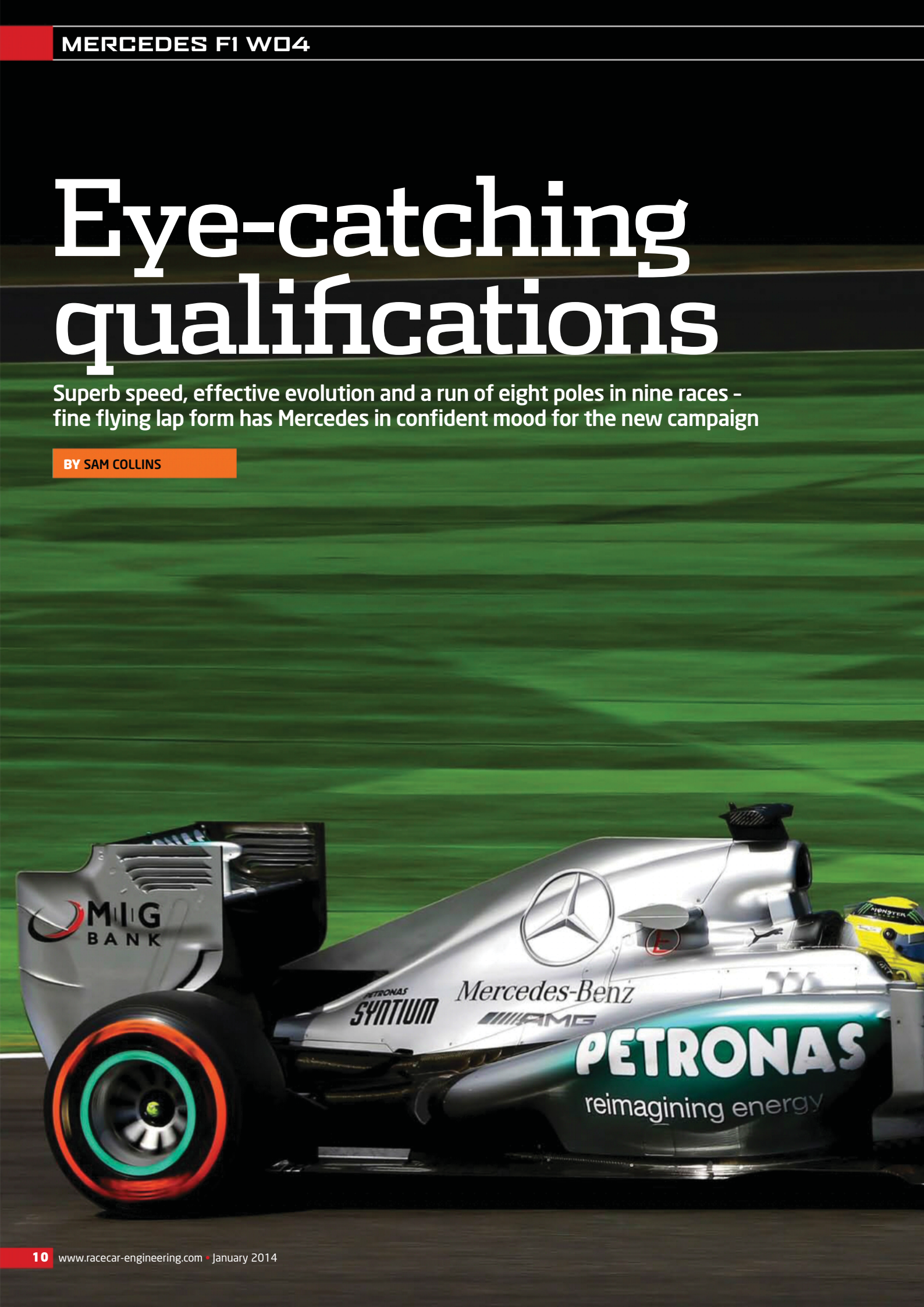
So could this be a great opportunity for F4 to bring back innovation and enervation of the junior racing car industry, as well as its other objectives, to the designated cornerstone of a professional single-seater motor racing career? Let's hope so.

A choice of chassis promotes ingenuity of the Ben Bowlby kind, not seen at the junior end of the sport for many years

Eye-catching qualifications

Superb speed, effective evolution and a run of eight poles in nine races – fine flying lap form has Mercedes in confident mood for the new campaign

BY SAM COLLINS



The Mercedes W04 was not the best car in the 2013 Formula 1 World Championship, but for a substantial portion of the season, it was definitely the fastest. From the Chinese Grand Prix in April to the Belgian Grand Prix in late August, there was a 'Silver Arrow' on pole position at eight out of the nine races. With three victories to their name at the time of writing, the signs are there that they have a very capable design that could – with more consistency – be capable of converting that flying lap form to get closer to Red Bull on a more regular basis.

It was first revealed to the media just ahead of pre-season testing in Jerez, Spain. The car featured most of the major mechanical details of the W03 with a visually similar aerodynamic design. The suspension retained pushrod-actuated dampers at the front and pullrod actuation at the rear. Propulsion again came from the Mercedes-Benz 2.4-litre V8 built by the team's sister company based in Brixworth, England.

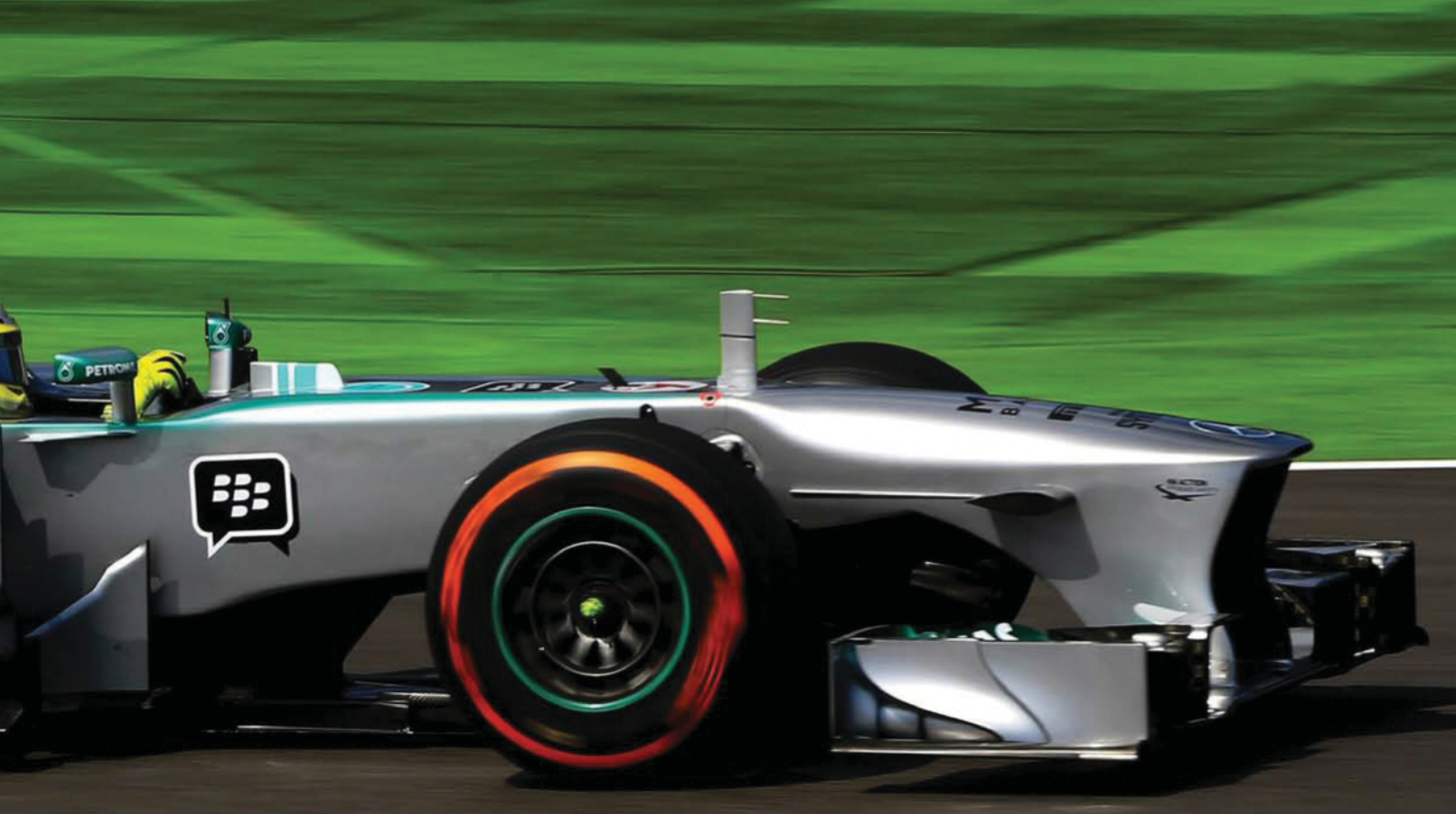
'The W04 was an evolution of the W03 in that it did not incorporate any groundbreaking technology,' explains Bob Bell, technical director at Mercedes AMG F1. 'It was very much a case of catching up with the other teams that had done a better job. So the concept was really a refinement of all of the areas of the car. We had a fair amount of catching up to do as the performance of the W03 was pretty abysmal at the end of the 2012 season. We had to make up a gap to the rest of the field, in terms of aerodynamics, systems, weight, stiffness, tyre thermal management – all of those areas.

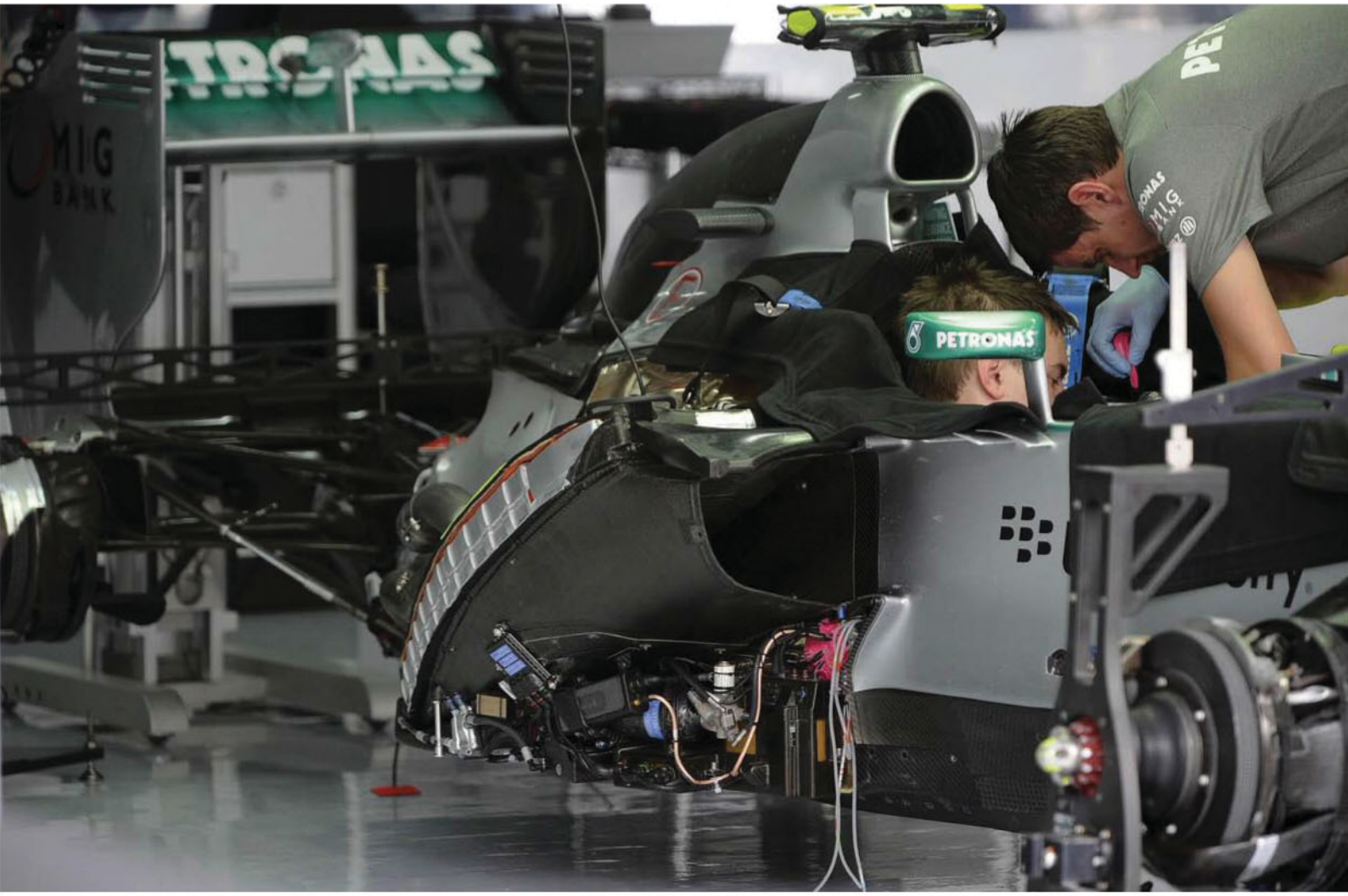
'When we started the development of the car, we felt that there was an eye-wateringly high mountain to climb. But we were realistic and looked at the areas of the car where we thought the gap was coming from. We went off and chased those – and on the whole the team did a pretty good job. We got on top of, and understood and developed, the key areas of the car for 2013, which were tyre thermal management and tyre kinematic management through the suspension systems. The Coanda exhaust also brought a lot.'

The pace of the W04 came as a surprise to some in the paddock, especially following very mixed form in pre-season testing where a fire and a crash grabbed the headlines at the car's maiden test. It was clearly a development of the W03 in 2012, which was a race winner but had inconsistent form. The first two races showed that the car offered good pace – better than many expected – but then in China the spectacular run of qualifying results began.

'I think the car was always pretty quick when it first ran, certainly over a single lap,' adds Bell. 'That's indicative of the car's weight, its aero performance, its stiffness – all of those characteristics. It was definitely a quick car and it took a lot of the early pole positions. Our Achilles heel in the race was where you had to manage the tyres over a stint, and that's really where the car's performance was lacking.' The reason for this was the over-riding centre of attention for everyone in the first half of the season, and indeed much of the focus of 2012 as well: the performance characteristics of the spec Pirelli tyres.

The first two races showed that the car had reasonably good pace, but then in China a spectacular run of qualifying results began





The car's sidepods have become increasingly compact and increasingly crowded with components, as can be seen here – a result of improvements in both design software and computer hardware. Note also the curved radiator

'The reason for the drop-off in the races was due to a number of things, like our understanding of what you needed to do to the tyres to make them last, as well as the physical things you need to do to the car to make them do that. It's a complex thing – not just about the design of the car, it's knowing what the tyres are doing, and making sure that the drivers understand what they need to do.

'There were voices raised in various quarters that if we managed to make the car quick in the race, we would not be able to make the car quick on a single lap. People claimed that we were setting our car up just to be quick on one lap, and not so good over a stint. That was not the case – we set our car up to be as good as it could be over a stint, because you get the points for the race. It just happened that it made the car quick over one lap as well.'

Mercedes clearly did manage to make the tyres work, as the W04 had won three races by the time Formula 1 took its annual holiday in August. Towards the end of the season, Mercedes was generally vying for best of the rest with Lotus, after the rival Red Bull team found an as-yet-unknown way to make its car substantially faster by the time the teams returned after the break.

'We have a strong group here with the vehicle dynamics guys, and they worked well to get on top of the tyres, which ultimately they did,' enthuses Bell. 'We don't go backwards after the first lap – we are the quickest car out there apart from the Red Bull. We know what we need to do to look after the tyres. We have been able to do that without really compromising our qualifying performance.'

The 2013 Pirelli tyres had some innovative features in their construction which, with more testing, could have proven very interesting, but a spate of high-profile tyre failures saw the Italian company revert to the 2012 tyres shortly before the August break. This, unfortunately, came just as the Mercedes engineers felt that they had got a good understanding of the 2013 versions.

'Before the tyre roll-back we did not understand how to setup the car to get the best out of the tyres, and once we got a handle on it, the tyres were rolled back to 2012 specification,' says Bell. 'That reset it all, so we had to go back and start again. But by that point the lightbulb had come on and we had started to understand what we needed to do. We were able to get the best out of both types of tyre, largely with the capability we already had in terms of its suspension response, and how it behaves. We did not have to go and redesign anything, there was no magic new bit – we just did a better job with what we had. The key to it was understanding what was needed for both a single lap and a longer run.'

'Once we managed to set-up the car to get the best out of the tyres, they were rolled back to 2012 spec'

After the string of tyre failures which dogged the British Grand Prix, the FIA banned the practice of tyre swapping, where teams would mount the right-hand side tyres on the left wheels and vice-versa, meaning that a single tyre would get used on both sides of the car during its working life.

'It was to do with tyre longevity, but also performance even over a single lap – so it was a complex thing,' adds Bell. 'It gave you more opportunity for

Top: the use of Coanda exhausts in F1 was something that Mercedes initially resisted, but eventually had to accept to keep up with their rivals. Various iterations were run on the W04 Above: the bulkhead of the Mercedes W04 reveals no obvious torsion bars. It is rumoured that the car has dropped the springs as part of its hydraulic suspension system

choice in how you wanted to use the tyres and get the most from them. It was just another tuning parameter that you could apply to the tyres that was taken away.'

One of the key elements to getting the best out of the tyres was the suspension which, famously on the Mercedes W03 and W04, is hydraulically interconnected, though this is now widespread in Formula 1.

'Although it is interlinked, it does not do away with the concepts of springing, damping and roll stiffness,' says Bell. 'Those characteristics and how you adjust them to change the performance of the car still exist, but how you achieve the changes physically on the car can be different, and that can enable you to have a system that is more subtle and more adjustable.

'However, in reality it's only an enhancement of the old springs, corner dampers and roll bars – it's just that now you can extend the ability of those systems to affect all of the car. It's an enhanced tuning aid. The regulations are very stringent on what inputs a connection between the front and the rear of the car can work to, and, in essence, that's limited to the vertical inputs through the tyres, which really restricts what you can do with them. They are complex and expensive, but because of those restrictions they only have limited use. You still need a basically good car – using it will not get you out of a hole.'

'The W04's gearbox has some novel features which allow us to make it a little lighter and a little bit stiffer'

FURTIVE FEATURES

The suspension was not the only innovative feature of the W04. Bell is enthusiastic about the gearbox of the car – something which was all-new for 2013 – and he believes it gives the team an advantage, so much so that he is reluctant to reveal exactly why.

'It has some novel features on it, which are unique,' he says. 'I can't go into too much detail for obvious reasons, but it allows us to make it a little bit lighter and a little bit stiffer. It allows us to change aspects of what it does. As these boxes are getting so complicated with so much packed in and around them, changing them is becoming very difficult. So it has some advantage there. It's not an evolution, it is a step change in technology for us. Others may be doing the same, but we are not aware of it. It is also a little bit more robust – drivers are putting a lot more demand on the gearboxes these days – but the fundamental function of the box has not changed. The casing is not all that unique – it's just carbon fibre.'

One of the notable trends of the period between the arrival of a new rulebook in 2009 to 2013 has been the increasingly compact sidepods evident on F1 cars. A range of components, such as heat exchangers, KERS control boxes and – in some cases – the car's ECU, are contained under the cooling duct. The W04 is not an exception to this trend, as Bell reveals. 'There has not been a step change in technology to make the sidepods more compact, but the engineers have just focused on taking volume out of the pieces they are packaging,' he says. 'Can they make one piece do the job of two? That sort of thing. It's generally just a case of compacting things, and all of

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that allows you to take volume out of the sidepod to give the aerodynamicists more room to work with.'

The seemingly constantly improving range of digital tools is a major part of the reason that sidepods are becoming more compact, and improvements both in processing speed and software capabilities have seen engineers able to push the physical technology incredibly hard.

'We are constantly improving that area with FEA to stress things closer to the limit and make them smaller,' says Bell. 'We use CFD through and around the sidepod and studied the cooling of the radiators and electronics boxes. The tools we are using are getting much better and that's allowing us to squeeze things in a lot more. The CAD systems allow us to increase productivity, with all of the fine details, the wiring routings etc – and that all allows us to find more space and squeeze things closer together.'

BALANCING ACT

With all of these components mounted on the outer edge of the car, it seems that it would be impossible to get the car evenly balanced side to side, but Bell does not believe that it matters. 'Teams do not worry too much about lateral weight distribution,' he says. 'It would be very difficult to get the centre of gravity exactly on the centreline of the car – it's always off to one side – but the effect is small enough that we do not worry about it. We only tend to think about ballasting fore and aft, not side to side. I think most teams have looked at the lateral inertia of the car, but it's simply not enough of an effect to be an issue.'

Another reason that the sidepods are crucial, especially with the 2012 and 2013 cars, is the exhaust layout. Despite the largely discussed ban on blown diffusers, reports of the technology's demise has been premature. Every car on the 2013 grid uses exhaust gases to seal the diffuser from turbulent flow from the base of the rotating rear wheel – the so-called blown diffuser. This is achieved using the Coanda effect which helps to route the gases to the right part of the rear floor.

'We were quite vocal in our opposition of allowing the so-called Coanda systems,' says Bell. 'We could see the arms race it would entail, and that's ultimately money. That said, we are quite well-placed here with a dyno facility on site and our engine partner at Brixworth has a lot of technologies to allow us to fully develop the Coanda systems.

'But for the smaller teams it has to be a lot harder – they either spend a lot of money to little or no effect, or they don't invest in the technology and they go backwards. I think it was a very costly arms race and probably unnecessary, but we had to do it, and I think we did a good job of developing it. But everything is critical on these cars – if your system is not working then you are nowhere.'

Right up to the end of the season, teams were developing their Coanda exhaust systems with seemingly endless iterations of the designs, and not only with the exhaust exit and bodywork.

'It's hard to say how many versions of exhaust we have had as there is a whole chain of things that effect the system,' says Bell. 'Things that influence its performance – like the little strakes down on the floor of the car used to tune the flow – and it's not just the bits that you see. There are other aspects that you don't. A lot of the teams run resonators on the exhaust system – these are additional pipes and they have an impact on how well the Coanda system works.'

These resonators work a bit like a beer bottle with someone blowing across the rim. The air pressure inside the bottle increases, but when blowing stops, the high pressure air inside flows out. This goes some way to giving the effect of off-throttle blowing.

'The technology is irrelevant in direct terms for 2014, and it has no benefit to the outside world,' argues Bell. 'Road cars certainly don't use Coanda systems like this – the only other things that do are a few aeroplanes and most of them are

BRAKE SYSTEM DESIGN

The design of the brake system has been critical on all F1 cars in recent years, and Mercedes has been working hard in this area to get the best out of them.

'The brakes are very important,' explains technical director Bob Bell. 'There's a lot of performance there but it's a challenge as there are also a lot of compromises, always between stiffness and weight. We want to take weight out because it is unsprung and at the outboard end of the car.

'You need a lot of stiffness in the suspension system outboard with the upright, the wishbones and so on, and as a result the whole area is an intense trade-off. Then you have the thermal dimension – traditionally that's a case of getting the brakes up to temperature and then having the ability to cool them. But now there is the new dimension of using brake thermal flows to influence tyre temperature, so you look at all the vents in the discs and the drums and that's all part of it.

'Some teams use adjusters to change the thermal flows. We had a look at it, but it was something we moved away from. It's just another piece of kit that can go wrong. If you can do it without having something extra which will go wrong then it's better to do so.

'And then there is the other dimension of the uprights which have to provide the structural connectivity between the wheel and the car. The aerodynamicists want the air to pass through them, while the suspension people want them to be stiffer. There is nothing revolutionary there, but it's an area of intense development, and it requires a lot or effort, complex machining and very elegant components.

'The brake materials, pads and things are just gradually evolving from the manufacturers, we have used both Carbon Industrie and Brembo this year. But a lot of it is down to driver preference for the feel. Lewis has used Carbon Industrie for many years, while Nico is more wedded to Brembo, but they have used both this year.'

'We were quite vocal in our opposition of allowing Coanda systems. We could see the arms race it would entail – and that's ultimately money'

'A lot of effort is being put in to find out if there is a completely passive way of stalling the wing to achieve a DRS-like effect'

in museums. The thing that will carry over, regardless of what the rules say, is the knowledge and understanding. There is a source of high energy gas, so there must be something that you can do with it to improve the aerodynamic performance of the car. Maybe it won't happen at the start of 2014, but people will eventually find a way of using that flow to get a benefit.'

One other area that will certainly carry over into the 2014 and 2015 Mercedes cars can be traced back to the 'double DRS' rear wing stalling device. The pure double DRS was banned at the end of 2012, but Mercedes is one of a number of teams to have experimented with a passive version still legal within the rules. It has tested the device a number of times in practice sessions, but it is unlikely to ever be raced on the W04.

'There is no doubt that there is a lot of effort being put in to find out if there is a completely passive way of stalling the wing to achieve a DRS-like effect,' Bell reveals. 'It's far from a trivial problem. Nobody as far as we can tell has a working system yet – including us. There is a physical principle out there that says that you should be able to do it, but nobody has been able to do it in practice. It's a very, very challenging problem. Next year's rules however pay a premium for efficient cars so anything you can do to shed drag is a benefit.'

Indeed, the new rules are the focus for Mercedes and have been for some time. The last time the team faced a major rule change (under the Brawn GP banner), they dominated half the races in the season and took both world titles.

Rumours in the paddock suggest that the HPP power unit is running well and serious work on the W05 has been under way for many months. If it proves to be stronger than the W04 relative to the rest of the field, and manages to maintain that qualifying muscle over whole races, then it may prove hard to beat.

HAMILTON'S LACK OF COMFORT

Sometimes whatever you do, a driver is not happy with a car or its setup. And that was certainly the case at some points of the 2013 season with Lewis Hamilton, who joined Mercedes at the start of the year. The English former world champion was open about his stuggle to get used to the W04 early in the season.

'I'm not quick enough, and not on it enough, so I need to get on it,' he admitted. 'Actually, even in winter testing I was struggling. The setup they have on the car in terms of brake cylinders and the steering wheel, it's obviously very different to what I experienced before, and where I was very comfortable. I'd been at McLaren for years so I was used to it, it was always the same.

'At McLaren I had 100 per cent confidence in the car. Here, I've been struggling with getting that confidence. It means you can't brake late enough. When you're braking it's all about feel through your foot, through your boot. It's all about the stiffness of the pedals, the modulation and the retardation of the brakes. It's the reaction of the car when you hit the brakes. There are so many different things that give you confidence. What I had before, we worked on for a long time. We got it right, and it was the same for six years.

'I've always been strong in a car I've felt confident in. I now have a car I don't particularly feel comfortable in. While it's a great car, I can't say I've just clicked with it like that. I still don't feel right in the car for some reason.'

Some in the motor racing industry suggested that the issue may be down to Hamilton being sensitive to the stability of the car, and lacking confidence in the tyres. Indeed Hamilton himself raised his own theory on what the issue was at the Canadian Grand Prix. 'Maybe it's my seat,' he said. 'Today I was doing my belts up really, really tight which I never do. Maybe I'm moving around in the car too much.'

Technical director Bob Bell, however, believes that the situation is more simple. 'It's always important to make sure that the car reacts and behaves the way the driver would like it to,' he says. 'It varies from driver to driver. They never set the car up identically, never ask for the same things. Nico [Rosberg], Michael [Schumacher] and now Lewis are generally not too far apart – they are never diametrically opposed. Nico does seem to be more comfortable with the car, but that is partly because he has been here longer and knows the DNA of the car, and knows what to expect.

'For Lewis it has been a big transition. It ebbs and flows and I think it's got to do with why on a particular track one driver is able to get more out of the tyres than another. It's a hallmark of the tyre situation we are in – you get this disparity between team-mates, Look at Vettel and Webber, for example. Webber is no slouch, but he is not on Vettel's pace on these tyres. It makes it hard for us to do much with the car to help them beyond the classic work of more downforce, less drag and trying to keep the aero balance in one place and never let it move. All of that will make a driver a lot happier.'

WRI2

Lewis Hamilton has struggled to get to grips with the W04, and his engineers have worked hard to adapt the pedal feel and bite. At the penultimate race of the year they found that there was a fracture in the chassis, but this was not the cause of his early season discomfort

TECH SPEC

Mercedes F1 W04

Chassis: Carbon fibre

Engine: Mercedes-Benz FO108F, 2.4-litre V8 N/A, NGK sparking plugs, Mobil 1 lubricants.

KERS: Mercedes HPP battery electric

Suspension: Double wishbone with pushrod-actuated hydraulically interconnected Penske dampers (front) and pullrod actuated (rear)

Wheels: Advanti forged magnesium

Brakes: Brembo calipers, Carbon Industrie or Brembo carbon/carbon friction material

Steering: Electronic power assisted rack and pinion

Electronics: McLaren Electronics TAG 320 ECU

Transmission: Seven speed sequential, hydraulic actuation, carbon fibre case, carbon clutch

Dimensions:
Length: 5094mm
Height: 950mm
Width: 1800mm

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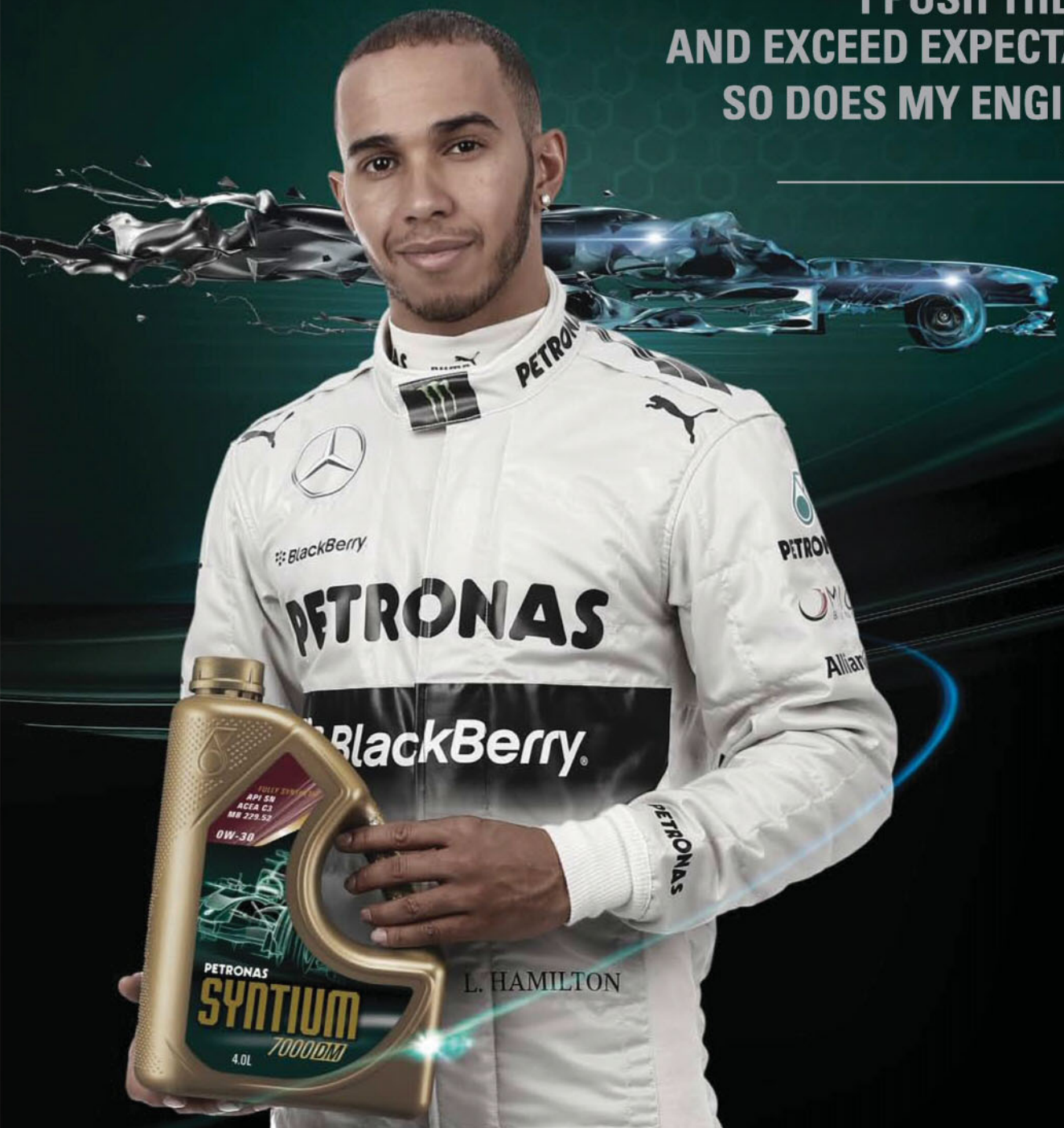

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Baptism of fire

Global debutants have had an eventful introduction to Australian Supercars

BY STEFAN BARTHOLOMAEUS

It may not be racing outside of Australasia for the first time in a decade, but the V8 Supercars Championship will be more global than ever in 2014.

While visits to the likes of Shanghai, Bahrain, Yas Marina and Austin failed to garner the attention of local fans, the introduction of new manufacturers has captured a new international audience.

Engineering resources in Japan, the United States of America, Germany and Sweden are now being directed at the championship following the arrival of Nissan, Mercedes-AMG and Volvo Polestar into the long-time Ford and Holden battleground.

Erebus' customer Mercedes-AMG programme and Volvo's new-for-2014 Polestar effort have involved their offshore counterparts from the start, while Nissan's initially domestic operation is being ramped up in a major way ahead of its second season.

V8 Supercars created its Car of the Future regulations to entice new players into the mix, but the challenge of developing competitive four-valve engines within the existing 5-litre rule package has proven significant. The Holden and Ford runners have won 30 of the first 31 races between them, while the top four-valve car – the Nissan Altima of Rick Kelly – is just 13th in points heading into the final two events.

With much of the bottom-end of the engines set, the bulk of the work for four-valve contenders has been focused on their respective cylinder heads, camshafts and inlet manifolds. For Nissan Motorsport, working with the production-based VK56DE head has proven the biggest limiting factor in trying to match the power and economy of the race-bred incumbents.

Although Nismo sent existing stocks of racing parts from its previous GT1 development programme to Australia in April, there would be no bolt-on fixes among them. The 5.6-litre VK56DE GT1 engines had, after all, needed only to be tuned to a certain point, with the SRO's balance of performance air restrictors doing the rest.

Nissan's Australian engine team have aggressively developed the head over the season, introducing several different iterations until finding a proverbial dead-end. 'We're really skating on thin ice at the moment with the amount of material we've removed from it,' admitted team owner and driver Todd Kelly after suffering two failures during October's Gold Coast 600. 'It's well and truly put a handbrake on our development programme.'

CASTING CALL

The team is now in the final stages of discussions with Nissan's Tennessee, USA, casting plant to produce a batch of heads modified to a more racing friendly specification. Although a costly exercise, Kelly says that the team has no choice.

'When we get the new castings done we can basically start from where we are now and put bigger valves in the head and bigger ports,' he continued. 'There'll be a lot more scope to change the shape of the ports and the combustion chamber. That'll be a good power gain once we start playing with that. Until then, there's not really a lot more we can do with the package we've got. We may be proven wrong by Nismo, but I doubt that they'd come back with another 15bhp or anything like that.'

Here Kelly refers to one of the team's engines being despatched to Nismo's global HQ in Japan, where a technician will be dedicated to the programme for two months. The move reflects an internal change of attitude at the Tokyo-based firm, which had initially classified V8 Supercars as a domestic programme where only access to existing parts and information needed to be delivered.

The Nismo work is expected to focus on analysis of areas such as combustion and friction profiles, utilising test equipment and software not available to the Australian team. 'Each race series has its own unique kind of character and honestly, Nismo doesn't have enough local knowledge of V8 Supercars to be able to win,' notes Nismo president Shoichi Miyatani. 'But we are trying to help the areas we can, particularly on the engine side, because it's our engine.'

Nissan is also using its global resources to re-homologate the Altima's aerodynamic package for 2014. Its US-based 'director of motorsport innovation', Ben Bowlby, is overseeing high-level Computational Fluid Dynamics analysis of the car's surfaces while they are being redesigned in Australia.

After the engine had been the major focus of both internal development and media discussion over the first half of the season, the long straights of Sandown and Bathurst had the team convinced that its straight-line performance deficit wasn't all about the powerplant. The Altimas had taken a one-two finish on the tight Winton Motor Raceway layout in August, and yet were struggling to see the top 20 on pace three weeks later at Sandown, where its speed trap figures were some 10km/h off the fastest runners.

'We could see on the speed traces that we were competitive until we got above 200km/h,' says Nissan's global motorsport manager Darren Cox, who visited October's Bathurst 1000. 'We're not getting the right airflow from the boot on to the rear wing, or it's detaching and the two are competing with each other.'

While Kelly admits that the problem will not be completely understood until offshore CFD work is complete, part of the revised kit – set to be benchmarked against the existing players and new Volvo S60 in January – will be an end-plate mounted rear wing.

Nissan is the only manufacturer to run a centre-mount design following Holden's move to the end-plate fixings for this season. Although Holden had been running with various iterations of centre-mounts for nearly 20 years, the new Commodore V8 Supercar designer Ludo Lacroix – who had previously been in charge of the Ford – is adamant that the end-plate method is superior.

'It (the end-plate design) gives a little more efficiency in drag which means the car can actually slide a little bit more

'Each race series has its own unique kind of character and Nismo doesn't have enough local knowledge to be able to win'


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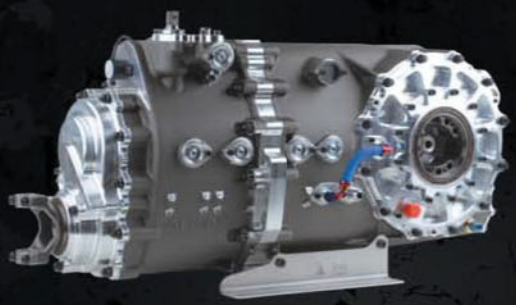

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without losing too much rear downforce,' says the Triple Eight technical director. Such qualities are not scrutinised in V8 Supercars' straightline, open-air, homologation testing.

Nissan's Cox has been scathing of the homologation process since the Altima's troubles became apparent, describing open-air testing as 'archaic' and demanding a CFD-focused approach in future. While the category has not ruled out including CFD, it has heavily defended its 200km/h airfield coast downs.

Understanding how to work the system, it seems, is vitally important for each manufacturer. The first iteration of the Altima – needing to minimise last-minute redesigns in order to simply make the first round of the 2013 season – ended up as a somewhat conservative design. Ensuring that the naturally slippery bodyshape produced enough drag had – in hindsight – been too great a focus from both the team and the category.

This time, the Nissan will do its own 270km/h coast down analysis on an airfield prior to attending the official tests. Last year, its pre-homologation testing had simply sought to mimic the 200km/h runs used in the official V8 Supercars tests and were completed within the relatively tight confines of Melbourne's Calder Park Raceway.

'The biggest difference (compared to the last aero tests) is that we'll have high-level CFD of all of the components we're testing,' says Kelly. 'Secondly, we'll be doing our testing and baselines at a lot higher speeds. I think those two things will make a huge different to the result we'll get and how that translates to our speed on the racetrack.'

Nissan's four drivers combined to score 22 top 10 finishes from the first 31 races of the 36 race season. The one-two for the Altimas of James Moffat and Michael Caruso at Winton had been the single true highlight, although that result was somewhat tarnished as it came amid a one-off trial of a new fuel blend for the four-valve cars ahead of the endurance races.

The task of turning the 6.2-litre M159 Mercedes V8 into a 5-litre V8 Supercars engine was given to HWA in Germany

Initially it was thought that economy would be a strength of the four-valve units against the existing two-valve motors. Such predictions, however, failed to take into account the difficulty of finding power and economy within the limits of a 5000cc displacement, 10:1 compression ratio and 7500rpm rev limit.

V8 Supercars did its best to mitigate the problem pre-season by introducing sprint race formats that removed fuel stops from the bulk of the championship. Economy disparity was still an issue, however, ahead of the Sandown 500, Bathurst 1000 and Gold Coast 600 enduros, with a number of different solutions tabled for the marquee races.

Trialing a 70 per cent ethanol fuel blend (in place of the regular E85) in three of the four-valve cars at Winton in August set off a storm of controversy. Although all teams had signed off on the process, the sudden appearance of the two E70-propelled Altimas at the front of the pack proved a major bone of contention. V8 Supercars stood by its claim that there had been no performance gain, while key Holden representatives very publicly disagreed.

The situation saw the alternative fuel abandoned, with a set number of compulsory pitstops instead put in place for the Sandown and Bathurst. The Nissan and Mercedes teams argued bitterly that they were still being disadvantaged due to enduring longer fuel-fill time at those compulsory stops.

A minimum fuel drop requirement was subsequently stipulated for the final endurance event – the Armor All Gold Coast 600. With that rule having now been mandated for all fuel races in 2014, the engine development focus for Nissan, Mercedes and Volvo Polestar can now be strongly focused on performance.

Alongside the Nissan, the progress of the Mercedes has been one of the key points of interest in the inaugural Car of the Future season. Funded by eccentric Sydney-based global property magnate Betty Klimenko, the team's deal with the German AMG Customer Sports/HWA outfit was only concluded five months before the start of the new season.

RACE WRANGLINGS

The sign-off – and therefore the start of proper development work – had been delayed by six weeks while internal politics were sorted. Having initially knocked back the plan on the grounds that the 'working-class' category didn't fit its brand image, Mercedes-Benz Australia was ultimately coerced by its German counterparts into letting the programme run.

Klimenko has subsequently spent an unprecedented amount of money on the championship. While Nissan is thought to be financing the previously Kelly Racing-branded team to the tune of $2m to $3m per season, Erebus' spend is said to have quickly stretched into eight figures.

The job of turning the 6.2-litre M159 Mercedes V8 into a 5-litre V8 Supercars engine was solely left to HWA, with the German factory also responsible for development and servicing. A decision to move servicing in-house at Erebus' Queensland shop was taken mid-year, while performance also soon became a more collaborative effort. Discussions over how the programme will work in its second season remain ongoing.

Much of the E63 V8 Supercar's early struggles were a direct function of the tight timeframes involved in getting the project up-and-running. Despite having only undertaken preliminary work prior to the September sign-off, the team had its first car on track in Australia less than four months later.

Its initial race outings were plagued by driveability issues stemming from the engine's twin-butterfly intake manifold, which had been adapted from the SLS GT3 version of the M159. Particularly sensitive to high ambient temperatures, the system saw its drivers reporting significant throttle-over-run on corner entry.

Trials of a new fuel blend in three of the four-valve cars set off a storm of controversy, as two Altimas were propelled to the front of the pack

With V8 Supercars rejecting an application to move from AMG's 2D to 3D throttle mapping, the problems were eventually solved with a switch to an eight-butterfly manifold in May. At the request of the category, the E63s also joined the rest of the field on a cable throttle as part of the revised package, having been earlier given a waiver to run AMG's fly-by-wire system.

'It made absolute sense in terms of cost containment,' explained V8 Supercars' Mark Skaife. 'But it proved too difficult to make that throttle body system work for them with the level of competition in the pit lane.'

The fly-by-wire was one of several freedoms given to the Mercedes that went unknown to rival teams until the eve of the official pre-season test in mid-February. The allowance for a flat-plane crankshaft, which has given the German vehicles a significantly higher note than their rivals, and electric-assisted steering were among other notables.

Like the fly-by-wire, the electric steering was also soon abandoned. The tight packaging of the electric unit had too made it sensitive to temperature, with the team's visit to the scorching Austin, Texas, in late May almost single-handedly crippled by the system overheating and shutting down. Able to rig up temporary extra ducting for the Sunday at the Circuit of the Americas, the cars were switched to a more traditional mechanical setup from the following event.

According to Erebus' CEO Ryan Maddison, the team hopes that it will eventually be able to re-introduce the higher tech fly-by-wire and electric steering systems. 'We didn't want to lose the Car of the Future aspect and technology out of the vehicle,' he says. 'They are effectively AMG components that are successfully used on AMG race and passenger cars and we would like to utilise them, but right now we need to make sure we are not compromising our programme.'

With further engine refinements and consolidated chassis work being undertaken through the mid-season, Erebus scored a breakthrough top five result at September's Sandown 500. Just four top 10s had been scored by its three drivers across the first 31 races, however, with its top driver, Lee Holdsworth, sitting 20th in points ahead of the final two events.

Erebus' development budget has reputedly stretched to eight figure sums to compete in the V8 series

The initial homologation and controlled development of the new technical packages has proven a learning process for V8 Supercars as well as the individual teams. Having spent nearly two decades making the Fords and Holdens as technically similar as possible, balancing the competitive desires of the new players with the reality of the strength of the existing opposition has not been easy. AMG has made significant noises about pushing for an increase to the compression ratio, but it appears that such a fundamental change will not be forthcoming.

Standing to benefit from missing the first Car of the Future season is Volvo, which announced in June that it will finance a manufacturer switch for existing non-factory backed Holden team Garry Rogers Motorsport for 2014. Although GRM's Melbourne base is in charge of fitting the S60 bodywork around the control chassis, the engine development is being undertaken at Polestar's Gothenberg, Sweden, HQ.

The Christian Dahl-owned official performance arm of Volvo currently runs a five-car Scandinavian Touring Car team while also producing limited-build road cars. Although not on the scale of its previous C30 World Touring Car project, competing with Nismo, HWA and traditional powerhouses such as Triple Eight, Walkinshaw Racing and Ford Performance Racing is a big ask.

Polestar's starting point is the 4.4-litre Volvo B8444S V8 that has been out of production since being dropped from the S80 sedan and XC90 SUV ranges. As usual when an engine is removed from the production line-up, Volvo has significant stocks of the block and head in its global inventory, and is confident that its package will be strong enough by the start of next season. Unlike Nissan, of course, there can be no casting changes if the head isn't up to scratch.

'All of the simulations we've done show that the power is going to come from it,' insists Volvo's director of motorsport and powertrain specialist, Derek Crabb. 'A lot of that is in the formation of the head – not just the air in and out but the temperatures and everything around that. Getting the right driveability, power and reliability in the timeframe will be tight, but engines are always critical for a start-up.'

A key distinction of the Volvo engine is its acute 60-degree bank layout, which the category effectively had no choice but to nod through if it wanted Volvo's presence. 'We thought it would be a massive issue to be honest, but we sat down with V8 Supercars and it was far easier than we thought,' says Crabb. 'It won't have any impact on pure power – it just changes the airflow and packaging.'

Polestar has spent recent months quietly putting its package together, with dyno testing not expected to take place until December. If all runs smoothly, the first motor will be sent to Australia and put in one of GRM's already completed new chassis before the end of the month. If not, the team could be forced to complete January's aero testing with its existing Holden engine sitting beneath the S60 panels.

Although there is much work to do, Dahl insists that he's not worried. 'Everyone looking from the outside is scared when they see the first round looming, but you do the hard work and it all comes together in the last weeks. It was the same thing when we did the C30 from scratch – we didn't have a component with a month to go, but then everything came together and we went racing.

'As long as you have control of your time schedules and supplies you will be fine. If you're done developing a new package two months before the first race then you didn't push hard enough to maximise everything you could.'

As Nissan and Erebus will attest, making the first race is only the beginning.

Balancing the competitive desires of the new players with the strength of the existing opposition has not been easy

Carlsson's all-new continental climber

The German firm plans to take its new hillclimber to Europe's peaks – and is looking at taking a revised version to Pikes Peak in Colorado

BY SAM COLLINS

Mercedes-Benz has a long history of hillclimbing, famously entering the works W125s on various major events around Europe complete with twin rear wheels. Today, while the works team is focused on Formula 1, others keep the tradition alive.

German firm Carlsson is well known for its range of tuning parts for the Mercedes-Benz range, but its Swiss importer is about to increase the brand's motorsport presence significantly by tackling the world's most famous hillclimb.

Reto Meisel has been a regular hillclimb competitor for more than a decade, winning the Swiss Championship in 1998 at the wheel of an Opel Kadett. It was not to be his last victory.

'After winning the championship I bought an old DTM Mercedes 190E and won the championship again in 2002,' he enthuses. Meisel then crossed the border and contested the tougher German championship and in 2007, 2009 and 2011, won the German hillclimb championship with the car.

But Meisel has his sights set higher, and at the Geneva Motorshow in 2013 he took the covers off his new machine for the first time – the purpose-built Carlsson SLK340. Built around the standard metal monocoque of the Mercedes SLK (R171), the car shares very few parts with the production version.

'We ordered two cars from Mercedes, and one of the engineers there gave us a disc with all of the CAD data on it,' says Meisel. 'It's a front engined car, but now has a transaxle layout. We will fit the Judd DB engine. It's a Le Mans engine so has a long life, it's lighter, has more power than the older Judd engine we ran in the 190E – it's the perfect engine. We do not run a restrictor and get 610bhp.' In this unrestricted form, the DB engine also produces around 440Nm of torque and weighs roughly 115kg.

'I changed to a new car partially for safety reasons,' Meisel adds. 'The old car's seat, pedal box and the rollcage were all about 10 years old. On this new car I have a specially-made composite seat from Fibreworks – they also provide the Audi R18 seat. Mine is similar in concept, a bit like a nest and meeting the latest WRC standards.

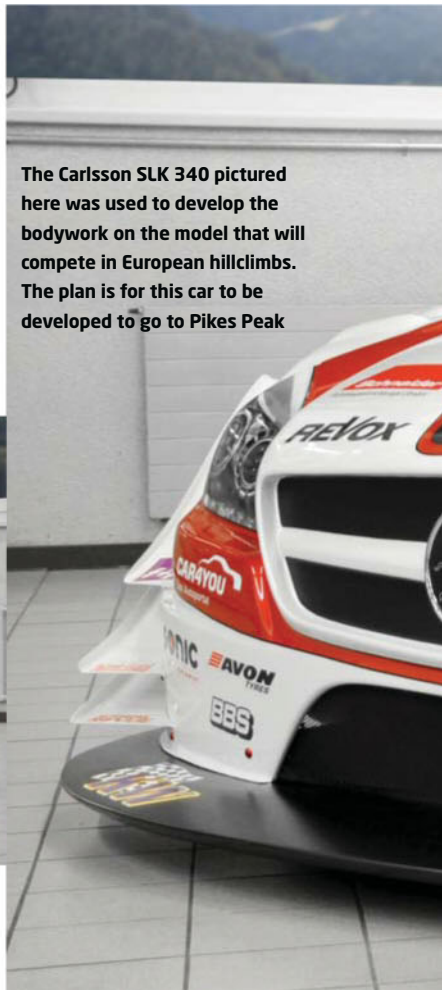
'The rollcage is probably one of the most sophisticated of its kind – it's fully integrated with the car's base chassis and all the suspension pick-up points are on it. So it's kind of a hybrid chassis.'

One of the reasons for Meisel's extra focus on safety was the death of Georg Plasa in 2011 while at the wheel of his BMW 134 Judd. 'Plasa was a good friend of mine, and in fact the gearbox in this car is a bit scary, it is the old one from Georg's car he was using when he crashed,' he says. 'We shipped it to Hewland who checked it, we changed the crown wheel as we have a bigger rear wheel. Then we fitted it with a Megaline paddle gearshift – it will be the first hillclimber fitted with an electronic shift.'

The Hewland TMT transaxle is mated as usual to the same firm's TPT Powerflow, but as the expected performance of the engine slightly exceeds the maximum recommended torque for the layout, the result will be interesting. 'The torque is controlled by what I think is a masterpiece of engineering – the Sachs anti-stall clutch. It is a centrifugal force-based working system which allows very smooth starts and all controlled by my right foot.'

The car's suspension is pure racecar. Designed in-house by Meisel's engineers, the double wishbone layout features

'The Judd DB is a long life Le Mans engine, lighter and with more power than the older Judd we used'



The Carlsson SLK 340 pictured here was used to develop the bodywork on the model that will compete in European hillclimbs. The plan is for this car to be developed to go to Pikes Peak

upside-down coil-over shocks from KW. 'The suspension is not finalised, but we have been using the data logger to record tyre temperatures and the suspension movement,' says Meisel. 'It's the best way to get the setup right. We will also fine-tune it on a F1 team's seven post rig.

'Uprights and a number of other components are made here, so we can build up a second car without any great problem. The brakes are low weight carbon fibre-reinforced ceramic monobloc brake discs from Sicom, resulting in extremely low unsprung mass which is a focus.' The car is also fitted with Teves ABS.

The aerodynamic package of the car is fairly extreme, with a substantial diffuser, front splitter, diveplanes and a full-width twin element rear wing. 'The recent E1 regulations allow us, uniquely in the touring car scene, to make big changes in chassis and aerodynamics,' says Meiser. 'A completely removable front, a closed under-floor, an extensive front splitter and the front and rear diffuser complete the aerodynamic package. The design is tending towards the Mercedes-Benz SLS GT3 of the FIA GT3 Series. In terms of style, our car will not rank at all behind the factory made cars. The wings on the final race car have been revised with new endplates compared to the pictures here. We had no wind tunnel time, but one of my friends has a Faro arm, and a laser system to measure the car and make a digital model of it. So we have done some basic CFD that way. Maybe next year when the car is complete we can go to a small aircraft manufacturer in Switzerland to test it.'

Instead of just preparing a single car, Meisel is actually building a pair of the SLK340s. The first car will be used in European hillclimbs, and is likely to be rolled out, while the second – pictured here – was used to develop the bodywork, but that car will be built into something even more extreme.

'My goal is to go to Pikes Peak with this car, but perhaps not with this engine,' says Meisel. '600bhp is enough, but the altitude is an issue, so you really need a turbocharged engine. When we build the car for that, I need either a turbo four, or a turbo V6. When the racecar is completed we will start to build up the second chassis, the one you see here, up into a car specifically for Pikes Peak. The reason to build a second car is that I can ship it on a boat which is far cheaper than flying it there. I think it will be ready for 2015 or 2016.'

The European specification SLK340 is expected to run for the first time this spring.

TECH SPEC

Carlsson SLK340

Class: E1

Chassis: modified Mercedes-Benz sheet metal, integral TIG-welded rollcage, front and rear frames

Suspension: double wishbone, inverted three-way KW coilover dampers, fabricated steel uprights

Engine: Judd DB 3.4-litre V8 N/A

Exhaust: Inconel 8 into 1

Gearbox: used Hewland TMT transaxle
Max torque: 44g/m
Differential: Hewland TPT Powerflow
Gearshift: Semi-auto or full manual Megaline pneumatic closed loop

Digital interface: CAN Bus

Paddles: Hall effect contactless

Clutch: Sachs automatic RPM-controlled centrifugal twin-plate clutch

Electronics: Cosworth. Display, logger, PCM and video system

Brakes: Sicom carbon fibre reinforced ceramic monobloc disc, Teves ABS

Wheels: BBS 10x18 (F) 12x18 (r)

Bodywork: Flossman. Carbon fibre, with front splitter, full underbody, rear diffuser, rear wing.

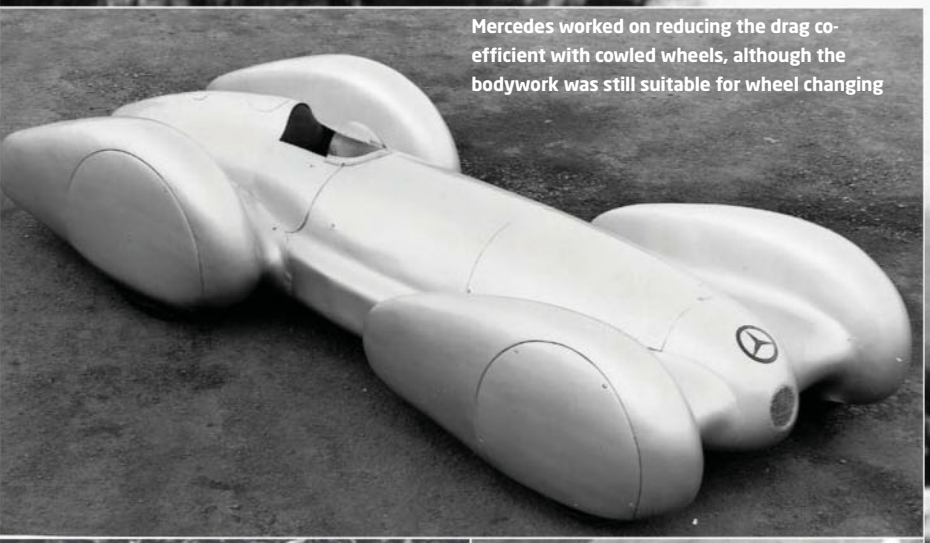
Weight: 780kg inc 5 litres of fuel

The rise of the Silver Arrows

The quest for German excellence meant huge investment in racecar engineering

The Mercedes W154 was the last of the dominant Mercedes pre-war Grand Prix cars and took Rudolf Caracciola to the 1938 European title.

Prior to this, a new Grand Prix formula was agreed in October, 1932, limiting weight to 750kg and the frontal width to 34in, with the rules to be stable between 1934 and 1937. The German Government of the time realised the potential to demonstrate the country's engineering excellence, deemed a necessary attribute of the



Mercedes worked on reducing the drag co-efficient with cowled wheels, although the bodywork was still suitable for wheel changing

Main pic: Hermann Lang in a W154 at Donington, England in October 1938. Clockwise from top left: Rudolf Caracciola leading in Monaco in the W25, April 1936; Caracciola in the W154 at Pescara, Italy, August 1938; leading in Reims-Gueux, France in July 1938

LAT

time given the sanctions and hardships post-World War 1.

The Government agreed to award 500,000 Reichsmarks (approx $250,000) to companies producing successful Grand Prix machines. Auto Union and Mercedes both produced cars – although Mercedes' budget was four times the size of the grant.

The design team led by Dr Hans Nibel, alongside Max Wagner – who produced the Mercedes Type M25 – created a car with a supercharged 3.36-litre engine developing 354bhp. Before the end of 1934, the unit was replaced by another, of 3.99 litres developing 430bhp at 5300rpm.

The engine, however, highlighted shortcomings in the chassis department. Nibel died in 1934 and was replaced by Hans Gustave Rohr, and under his guidance, the car dominated the 1935 season.

But after a disappointing 1936 season, a new design was commissioned for the 1937 season, featuring a 5.66-litre, 645bhp engine in the W125 chassis, which was a tubeframe design with a wishbone front suspension. The car, designed by the 30-year-old Rudolf Uhlenhaut who could drive almost as fast as Mercedes' regular drivers, was clocked at 193mph at Spa in 1937.

Uhlenhaut's W125 carried a supercharger fitted downstream of the carburettors, with the effect that the turbocharger was actually compressing the final mixture. Such was the superiority of the Mercedes Grand Prix cars that a new set of regulations was thought up for 1938. This replaced the formula limited by weight with one limited by engine capacity, which meant that the W125 was no longer eligible. And so Mercedes engineers got to work on a new car, the W154.

TYPE M154

Uhlenhaut and Wagner started work on a 3-litre car that was largely based on the W125 chassis, but coupled reliability with a low frontal area, powered by a short-stroke V12 engine that developed 485bhp at 8000rpm. This was developed in-house by Daimler-Benz specialist Albert Heess.

Powerful pumps propelled 100 litres of oil per minute through the engine, which weighed around 260kg. Compression was provided by two single-stage superchargers, replaced in 1939 with a single two-stage unit.

The M125 was clocked at 193mph at Spa in 1937, and such was the superiority of the Mercedes Grand Prix cars that a new set of regulations was thought up for 1938

First track test of the Mercedes 154, featuring a 60-degree V12 3-litre supercharged engine

INTELLIGENCE GATHERING

There was considerable difference between the racing organisations of Mercedes-Benz and Auto Union, says a British Intelligence document produced in 1947 which looked at the development of Germany's Grand Prix racing cars between 1934 and 1939.

The gross outlay was roughly the same between the two – around RM2.5m ($1.25m) in each case – although the state funded roughly one fifth of this total spend for each. In 1937, Mercedes-Benz had a large experimental workshop devoted entirely to the development of Grand Prix machines. In the summer of that year there were three engineers working on the development of the Type M154, and one engineer on chassis modification during the previous year for the Type W125.

No draughtsmen were carried by the experimental workshop – components were detailed by the main drawing office when required.

The workshop did not manufacture any of the components for the cars, being engaged solely on assembly and experimental work. Absolute priority was given to racing requirements by the main machine shop of Mercedes-Benz however, with the result that in an emergency a new component could be manufactured far more quickly than in the case of Auto Union, where all components were actually manufactured in the racing workshop.

The design of the Mercedes 1.5-litre M165 was carried out by the Mercedes-Benz main design staff, to principals already proved on the Type M163.

CAR TRANSPORT

Eight large diesel lorries were permanently attached to the workshop for transporting cars and equipment to the circuits. One of these was equipped as a mobile workshop complete with lathe, borer, welding plant and a shock absorber test jig. A second lorry was supercharged for use in transporting urgently required spares when necessary.

One car for each driver – plus one reserve machine and several spare engines – were taken to each event. In addition, there was a practice machine available. This was generally used as a mobile testbed for any new design features. Auto Union methods contrasted sharply here.

A doctor's services were retained jointly by Mercedes-Benz and by Auto Union, and he always accompanied the teams to any event. Also present were representatives of Shell and Continental, which provided the tyres for the cars.

Auto Union's view was that the RM500,000 per annum would fully cover the expense of racing. A racing workshop was formed at Chemnitz under Oskar Siebler, and an engine research lab at Zwickau, Saxonia, under Robert Eberan von Eberhorst. The upkeep of the two amounted to RM2.5m per annum. This figure was much the same as that for the Mercedes-Benz racing workshop.

There was the fundamental difference, however, in that the directors of Auto Union regarded their racing workshop and laboratory as a self-contained unit, responsible for the actual manufacture as well as the design and development of the Grand Prix machines. The racing programme was not, according to the report, allowed to interfere with the normal work of the main Auto Union workshops.

Fuel was carried in a single fuel tank in the rear of the car between 1934 and 1939, when an additional tank was fitted. The Mercedes engineers sought to increase power through increasing the revolutions, piston area and volumetric efficiency. It was undesirable to increase the piston speed above 4000ft/min to help with reliability, and so the company switched from the V8 – that had powered the cars since 1934 – to the V12.

The 3-litre Mercedes produced 485bhp at 8000rpm at its peak in the French Grand Prix at Reims in 1938, where the W154 for the first time used a five-speed gearbox.

SHOCK DEVELOPMENTS

One of Uhlenhaut's first major decisions was to abolish the use of all friction-type shock absorbers, on the grounds that their damping characteristics were always unstable, being immediately varied by the presence of oil or water.

After the 1936 season, therefore, all cars were fitted with double-acting piston-type shock absorbers, which resulted in heavy damping to the downward movement of the wheel.

The effective spring rates of the front and rear suspension systems were identical when in their normal position. The result of this was that when the fuel tanks were practically empty, the natural periods of the front and rear suspension system were the same, and they could be damped accordingly. When the fuel tanks were full, however, the natural period of the rear suspension became considerably longer than the front. This would theoretically cause an increase in the resultant pitching of the car as a whole, if the same amount of damping was employed as in the previous case.

For this reason, the Type W154 (and W165s) sported two-position shock absorber controls, enabling the driver to slightly modify their characteristic as the fuel tanks became empty.

Superchargers were investigated for the M163, and Mercedes switched to a two-stage Roots type mounted horizontally at the front of the engine

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The works Mercedes-Benz W154 team in the pits at Bremgarten, Switzerland in August 1938

TECH SPEC

Mercedes W154

Engine: 60 degree V12, 2.96-litre 485bhp @8000rpm
Cylinder block: chrome-steel barrel with integral head of inverted V-form
Valves: four poppet valves per cylinder of Krupp steel, 15 per cent chrome. Four overhead camshafts, gear-driven from the rear end of the crankshaft
Con rod: one-piece nickel-chrome-steel with split big-end
Lubrication: dry sup of 15 to 20-litre capacity
Cooling: 100 per cent EG maintained at 1.5 ATA pressure. Normally run at 100degC

Supercharger
Type: Roots two-stage, horizontally mounted front end of crankshaft, gear-driven through flexible coupling at 1.25 x engine speed
Pressure: 2.3 ATA
Materials: rotors of nickel-steel, casing of Elektron alloy
Carburation: multiple-choke MB carburettor on suction side of turbocharger
Ignition: Bosch Magneto

Transmission
Clutch: single plate dry 287mm

Suspension
Front: parallel wishbone links with open vertical coil spring and double acting hydraulic shock absorbers
Rear: De Dion with torsion bar progressive action springing and double acting hydraulic shock absorbers

Steering
Type: screw and nut with turning circle of 12.5m (41ft 6in)

Brakes: hydraulic two-leading show with twin master cylinders
Lining: lurid BA

Dimensions
Wheelbase: 2730mm
Track: 1475mm front, 1310mm rear
Weight distribution: 40.8 per cent front, 59.2 per cent rear
Total: 1316kg (with fuel and driver)
Fuel tank size: 400 litres

RACE DEBUT

The W154 debuted at a non-championship race in Pau, France in 1938. Two cars were entered, for Rudolf Caracciola and Hermann Lang. Lang crashed in practice, leaving Caracciola – second on the grid – to start the race. He handed the car to Lang mid-race, but the car developed a sparkplug problem and finished two minutes behind.

The race record of the W154 in the hands of Caracciola, Manfred von Brauchitsch and Lang was enviable, as they qualified and raced at the front of the grid just about everywhere, although it was Englishman Richard Seaman who won the German Grand Prix for Mercedes-Benz that year when Von Brauchitsch's car caught fire.

Post-war, Mercedes attempted to turn the W154s into oval racers with a view to competing at Indianapolis in 1951. The cars were entered for two races in Argentina that year, and attained two second-placed finishes before Mercedes discontinued the programme.

CHARGING FORWARD

In addition to development of the carburettors of the V8 engine family used between 1934 and 1937, superchargers were investigated for the next generation engine, called the M163. Tests carried out with a Zoller, vane-type supercharger were considered to give unsatisfactory results, trouble being experienced with the vanes seizing in their guides at 5000rpm. Instead, Mercedes engineers switched to a two-stage Roots type supercharger, mounted horizontally in the front of the Type M163 engine. The rotor housing of the first stage was longer than that of the second stage, and the rotors revolved at the same speed – 1.25 times that of the engine speed. Fuel was supplied by means of a multiple choke DB carburettor to the inlet side of the first stage. Before reaching the carburettor, however, fuel passed through a small radiator mounted in front of the normal coolant radiator in order to still further increase the ultimate charge density.

The 1938 Mercedes Type M163 engine was fitted to the W154 chassis with twin hydraulic master cylinders in place of the single one normally used. The cylinders were mounted side by side, one cylinder feeding the front pair of brakes, and one the rear pair. Balance between the two was obtained by a short lever which was pivoted at its centre to the brake pedal thrust rod, and this lever also ensured that – should there be a failure to either the front or the rear system – it would not lead to a total failure.

The second issue around the brakes concerned fading, and the W154 was designed to lower the temperature of the brake drums. The orthodox peripheral finning to the brake drum was replaced at the end of 1938 by a type of centrifugal fan.

The fan not only promoted the flow of air over the outer circumference surface of the drum, but also extracted the air from the actual internal braking surface of the drum by means of the vent. This prevented the alloy drums from melting.

The 3-litre cars were pretty uniform in terms of drag coefficient – around 0.65 – although Mercedes established that just 0.05 of that was due to the body alone. The company therefore started work on cowling the wheels for the high-speed circuits, although these had to be quick to remove to facilitate wheel changes during pit stops. With the cowling of the wheels, the cooled brakes were key to the success of the system. It was with the cowling that Caracciola established a speed record of over 127mph (204km/h) for the standing mile on the Dessau autobahn in February 1939. The drag co-efficient of this car was 0.21. The outbreak of war prevented further records being achieved with the W154, although technical development, particularly around the brake material, gathered pace.

Post-war, Mercedes attempted to turn the W154s into oval racers with a view to competing at Indianapolis in 1951

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The rally team on the right track

Designed and developed under tight time constraints, the Hyundai i20 WRC isn't expecting much at Monte Carlo 2014. But some eyecatching investments in technology and driver recruitment could make next year's event a different story

BY MARTIN SHARP

In 2013 two brand-new top-level World Rally Cars contested their first WRC event: Sébastien Ogier set off from Valence in his all-new Volkswagen Polo R WRC for the first special stage of the Monte Carlo Rally – and was fastest on that stage. The presence of another Sebastien; nine-time World Rally Champion Loeb in a Citroën DS3 WRC, was the only barrier to Ogier claiming victory on the Polo's debut event. Volkswagen Motorsport expressed surprise at the evident pace of their car and driver, and then the Polo won in Sweden – the first of 10 victories which landed them both the Manufacturers' and Drivers' titles in the car's first year.

Such a promising start to the season saw VW change tactics early season from a 'development' 2013 while preparing a new homologation for 2014 to an all-out blast to the 2013 titles. Then, mid-season, the rules changed to put back new 2014 World Rally Car homologations to 2015. Teams would not re-homologate complete cars for 2014, Jokers were limited – and VW Motorsport had free rein to attack the titles without complicating matters by developing another car for 2014. The new car will now appear in 2015.

In 2014, again two brand-new World Rally Cars will be setting off from Monte Carlo, arriving at the first stage after a halt in Gap. But nobody is expecting a fairytale debut in the Volkswagen mould from the Hyundai i20 WRC. As a comparison, VW Motorsport's Hanover premises were well-established many years before its 2000s WRC campaign began. And that started two years before the Monte Carlo Rally.

Meanwhile, Hyundai Motorport's Alzenau, Germany, premises were empty shells when chassis chief Bertrand Vallet became its first European employee on 1 December 2012. Hyundai team boss Michel Nandan joined one month later, on 1 January 2013.

VW Motorsport had existing cohesive teams of time-served technicians when it started on the WRC programme and just needed to hire WRC engineering specialists. A year before it entered the WRC, the team tested the Polo R in nine of the 13 countries which host the WRC. At the same time running Ogier and Andreas Mikkelsen in Skoda Fabia Super 2000s – which have identical floorplans to the Polo – in several 2012 rallies.

Meanwhile, Hyundai Motorsport has had just 12 months to build up its personnel from scratch, equip its bare facilities, develop a car for debut at the 2014 Monte Carlo and develop another car for a new homologation for 2015 while campaigning a full 2014 WRC season with its first homologated car.

Nandan has extensive previous experience of getting new Group A and World Rally Car projects up and running from his days as chief engineer for Toyota Team Europe, Peugeot

Sport and Suzuki Motorsport. When asked whether he considers his current project to be tight in timing his understandable reply is: 'This is the tightest I have ever seen in my life in motorsport!'

When Nandan joined the team, ex-Peugeot Sport chassis engineer Vallat had spent one month at the team's Alzenau base working with Korean engineers on a prototype concept car which had been prepared at Hyundai's Namyang R&D facility in South Korea. The engineers investigated the entire car, developing parts to make them more reliable and more easily serviced.

On first seeing this original car, the experienced Nandan recalls being pleasantly surprised that his team's task did not seem as massive as it could have been: 'They really didn't do a bad job. It helped us to be developing the car this year – we didn't have to restart everything again.'

That first R&D car was two steps back from the i20 WRC which went for homologation. After liaison with the R&D centre and its wind tunnel on body evolutions and cooling system design, a second revised car was built in April. A bare bodyshell arrived at Alzenau in February which went to Matter, France for preparation and after design and build in May that was the car that began testing in representative WRC conditions in July.

The chassis of this car is slightly different to that of the earlier R&D cars, with evolutions of some aspects. 'I would not say it's 100 per cent different, but I would say not a lot of parts are the same,' says Vallet. 'A very small number of parts are the same, but everything is an evolution from the other and not a complete new car. One big difference between the R&D cars and the actual rally car was that the R&D car was more concept-based – to validate some concepts and the actual rally car is defined in order to be reliable, serviceable, and to be light and efficient.

'So the R&D cars were more focused on concepts but with the rally car we try to improve the efficiency – the global efficiencies like serviceability and weight and reliability.'

Of course, while this process was under way the facilities had to be equipped and the right people hired, as Vallat recalls. 'In December the workshop was completely empty,' he says. 'There were not a lot of people on the design side, only some people from Korea, but they went back to Korea and we had to hire some engineers. We still have a very good relationship with the R&D centre in Korea – the design is one thing, but on the facilities and the calculation side we had very big support from Namyang.'

KOREAN COLLABORATION

'The Koreans are really very much involved in our facility,' continues Vallet. 'And liaison and communication is easy. We have some Koreans here, and we have all the connections to the R&D centre. This is not only to have good support, but also to have a good connection. And also where the language issue is concerned it's better to have Korean speakers here. Sometimes, because of the time difference we ask the questions before leaving the office and we have the answer when coming back to the office. At times they work on the subject throughout the day – and then you have the answer overnight.'

This liaison had resulted in a stiffness figure for the caged body assembly which Vallat admits he would not have expected. 'It's good enough – we are quite happy,' he understates. And side impact crash calculations, using massive computer power have resulted in positive deceleration and deformation figures on which the team can rely.

Inevitably, there were delays to the schedule, but interestingly, not because suppliers were experiencing similarly tight lead times to Hyundai. 'Even if they had some small delays they always managed to find a solution to let us drive,' says Vallat. 'Sometimes we were really on the edge. Sometimes we had no spare parts or not enough. We were not so comfortable with spares, but at the end it is still working, so we have been quite lucky.'

The car's test drivers in 2013 were Chris Atkinson, Bryan Bouffier and Juho Hänninen. 'The first thing of testing is to better understand the car, and to have all things working together,' says Vallet. 'We had no big surprises because many components are coming from well-known suppliers who have good experience in the WRC. We had to improve some points on reliability and quality of manufacturing because we have to improve our internal process. It's like this because on the first of December it was a completely empty building with no engineers – now we have more

Hyundai had just 12 months to build up its personnel from scratch, equip its bare facilities, and develop a car for Monte Carlo 2014

than 70 people and we have a complete workshop and machining facility, body shop and some prototype cars running, a purchase department, an accounting department, marketing department and many things we have to make work together. It's the setup of all these processes all together with the building of the car, which makes things a little bit more complicated than they should be.

'Because we've started from scratch, we are exactly where we want to be. We haven't had to change some established way of thinking, unlike a company which had adapted to some kinds of theories and then has to change the theories. Now we go all together to something which is completely new. Some things are more difficult because we have to establish a way to work together, but some things are more easy because it's completely new, so we go directly to the point, and we use a straight line all the time.'

Nandan describes the current i20 WRC as an acceptable compromise. Vallet emphasises that this doesn't just mean that the team know where the weak points are, but that it is also well aware of its strong points. Although the 2014 Joker restriction does not apply to Hyundai as the i20 WRC is a new car from a manufacturer new to the championship, the plan is to focus on car areas that can be improved firstly by VO, or freedom of the regulations, and then through Jokers. 'It's not important to know that we go faster because we have a better engine or better suspension,' says Vallat. 'The important point is simply to go faster!'

Design work on the 2015 car began in 2013 in collaboration with the R&D centre. Testing with the current car indicates reliability requirements are close to achieved, so the compromise has shifted with the 2015 car to target overall performance improvements while retaining reliability.

The current car runs Reiger dampers and an Xtrac transmission with GKN shafts and electric motor-pressurised hydraulics powering the handbrake-activated rear drive disengagement, similar to the later Polo R Xtrac mechanism.

The i20 WRC features a 1.6 GDI Turbo, Brembo brakes and Reiger dampers

Development is split between Alzenau, Namyang and France's Pipo Moteurs

Currently there have been four power unit iterations. An 'Appendix' – or global – engine, the first Korean-designed unit is described as 'probationary'. Engine chief Stephane Girard joined Alzenau from Peugeot Sport in April 2013, by which time the Namyang centre's second iteration was in place. While there are plans to have a complete engine department and dyno facilities in place at Alzenau by next year, Girard immediately began work on the third iteration, splitting development tasks one-third in Alzenau and one-third in Namyang. The final third is at French specialist competition engine operation Pipo Moteurs, which will continue development and rebuilds in 2014 until Hyundai's in-house engine facility is up-and-running.

The homologated engine is the fourth iteration, known as Step Four – a reliability optimised version of Step Three, which was the first unit to go testing in the car. Problems discovered here were ironed-out into the Step Four – which includes a revised cylinder block and head, many small improvements including piston shape, and fuel injector type.

Until the Hyundai arrived, all World Rally Cars used Bosch injectors. And until Girard arrived in Alzenau, the Hyundai engine was also using Bosch injectors. However, he changed them to Magneti Marelli. Was this change for reliability or performance? 'We had no problem with Bosch for reliability – but the future sits better for me with the Marelli injectors.'

'It's not important to know why we go faster, the important point is simply to go faster!'

INJECTING PERFORMANCE

Having worked for five years on Peugeot's direct injection LMP1 engine, Girard has full understanding of the relationship between the injector and the combustion chamber in a competition direct injection engine: 'I've got some good past experience with diesel ones which are higher pressure, and Magneti Marelli is one of our main technical partners – they have been developing a hell of a lot of injectors for the Formula 1 regulations.'

In the Hyundai Appendix engine, the new injectors showed a marginal performance improvement on the dyno. 'With Step Four, 90 per cent of the differences are reliability related,' says Girard. 'The injectors change is probably the only one which is not necessarily related directly to reliability.'

While not looking to develop an engine lubricant heat exchanger similar to that on the Polo R WRC ('It's too complex'), when asked about the location of the i20's oil cooler, Girard offered: 'We've tested the Laminova type. It's not the best for cooling, but it's a really good one for packaging and quickly sorting a reasonable solution.

'Engineering-wise, in many aspects the 2014 car – including the engine and the engine installation – is not as nice as we all would have liked it to be. We were working with urgency and the famous KISS [Keep It Simple, Stupid] philosophy! And that's the process I have been following on the engine side – I am open to criticism, and there will probably be a hell of a lot of people,

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The Hyundai i20 put through its paces during gravel testing in Seville, Spain in October 2013

TECH SPEC

Hyundai i20 WRC

Base: 3-door Hyundai i20

Engine: 1.6 GDI Turbo

Performance: >300hp

Transmission: 6 speed sequential

Drivetrain: four-wheel drive

Steering: hydraulic power-assisted steering

Tyres: Michelin

Brakes: Brembo

Seats, seatbelts and steering wheel: Sabelt

Suspension: Reiger

ECU: Magneti Marelli

Driveshaft/propshaft: GKN

Dimensions:
Length: 4000mm
Width: 1820mm

Fuel tank: 70-litre

Weight: 1200kg minimum/ 1350kg with driver and co-driver (as per FIA regulations)

including former colleagues, coming to ask me "Why did you do that thing like that?"

'Developing the engine has all been really simple and basic to focus quickly and bring us to a solution that will allow us to run and bring the team together and improve our performance slowly. So, with the oil cooler, we put it where we can! It goes where it's convenient and where there's not so much problem with it.'

The final decision was not made at press time, but it is entirely likely that Girard's engine team will be homologating a new engine for 2015 with the new car. 'That's why we didn't spend too much time working on this current engine because we know it's going to be for one year, although the idea is to have something reasonable.

'We're trying to learn, and trying to find where are the key points to work on – we've got some ideas about that already. And we're trying to see where are our limits and where we've got to improve.'

So, the first level of that improvement is the switch to Marelli injectors for 2014? 'That's part of the idea, but there are many many more – I would say the FIA always tries to make the regulation as strict as possible, but that doesn't stop you having some imagination and trying to extract the best out of what the regulation is saying. We've already started on the 2015 engine – we've got to basic principles, ideas and development – now we've got to start to actually design things and think about packaging targets and on what areas we are going to work.

'And it is a short time still for this 2015 engine. Engine-wise, we've got to give the direction of things we will do and things which we cannot afford to do in a short amount of time. We know already the main strengths and assets of our package, and with discussions with our partners, we also know what is possible and what isn't. With all that, we will try to do a mix to achieve something. For 2014, the engine will be 50 per cent Global and 50 per cent optimised; the 2015 engine will 80 per cent to 90 per cent optimised and Global – using all the possibilities of the regulations. We'll be looking to use all the ideas that can come out of our brains.'

This all meant releasing drawings of certain components to suppliers for the 2015 engine in late 2013.

So, basically a simple engine for 2014 and something magic for 2015, then? 'Magic – no! There's no magic in that. It will be cleaner, nicer, clearer and better for sure. And there will also be better collaboration between the engine and chassis engineers to make everything work together. Better packaging too, because as you've seen on the short-scale development we had to put together the parts in a limited amount of time and without too much detailing, and as we are going to be a global activity here at Alzenau we are hopefully about to do something much nicer.'

When pressed on what constitute acceptable aims, Girard is pragmatic. 'If acceptable means being able to win Monte Carlo Rally, we are not at this level now,' he says. 'We have to be conscious that if within six months we manage to run a complete factory team, a complete car, a complete engine and beat the others, then the others are just wasting their time.

'I'm not expecting us to win. I hope that we're not ridiculous; I'm sure we won't be, but I just hope we will be playing with the others but a little bit at the back, just enjoying and learning. And for sure it will be a steep learning curve.'

Do not be distracted; this is actually fighting talk. The well-funded Volkswagen Motorsport's two-year lead-in to its 'surprise' double victory in the 2013 WRC is ball-park timing for a manufacturer team with a new rally car these days.

Sure, there was previous acrimony and few good results with the UK MSD-run Hyundai Coupé Kit Car and Accent WRC of yore, but Hyundai Motorsport in its current incarnation is a proper works team, strapped by arguably the most tight development time schedule ever for a works team, yet already staffed by many experienced and talented engineers, with more to come.

Which is proof of a proper works budget in place.

And this was further proven by the November 2013 appointment of the sought-after rally driving talent, Thierry Neuville. For three years, with a six-figure salary.

Rumours abound that Hyundai's initial setup budget is €55m. This WRC team is not to be discounted.

'We've already started work on the 2015 engine. We already know the main strengths and assets of our package'

Out of the frying pan

The balancing of Grand-Am's Daytona prototypes and the P2 cars is well under way with the first race – the Rolex 24 at Daytona – fast approaching

BY ANDREW COTTON

The merger between the Grand-Am and American Le Mans Series, under the IMSA banner as Tudor United SportsCar Championship (TUSCC), has provided the rule-makers with something of a challenge as they try to balance the performance of the top class of Grand-Am, the tube-frame Daytona prototypes, and the carbon chassis P2 cars from the American Le Mans Series.

At the time of going to press, final regulations hadn't been released after an eventful testing period at Daytona and Sebring in mid-November, while full-scale wind-tunnel testing has been delayed due to a servicing issue with the preferred tunnel. However, initial findings in the 40 per cent wind tunnel have been encouraging as the simulation work has so far been validated.

Broadly speaking, the P2 cars provide the benchmark in performance, and the Daytona prototypes have been balanced up to their speed on all circuits. That includes an increase in downforce of 60 per cent, and an increase in horsepower of 50bhp.

Two versions of the regulations were issued a week apart, and with significant differences. The first included freedom in areas that led teams to estimate upgrade costs to be more than $600,000, but the second clarified these areas, and the target

'We went with the most efficient way of adding downforce that we could, which was through the diffuser and the underbody aero'

update price is $200,000, which IMSA believes is a realistic target figure.

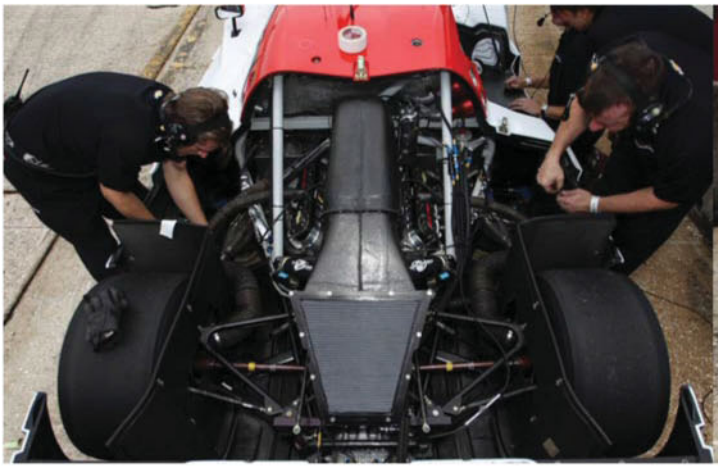
Prior to the November tests, in which two drivers crashed in similar circumstances leading to urgent investigations, *Racecar* spoke to Scot Elkins, VP competition and technical regulations. 'The options that we decided upon, adding downforce, increasing power and adding traction control were the options that we had,' he said.

'We had different ways of adding the downforce, but we went with the most efficient way that we could, which was through the diffuser and the under body aerodynamics to try to keep drag levels consistent, and try to minimise some of the front to rear balance we would have to do. Utilising underbody aero helped to push the centre of pressure forwards a little bit rather than just piling downforce on to the rear.'

The wind tunnel model demonstrated an increase of 56 per cent downforce, and while there is still much to be finalised, including the front aerodynamics, rear wing, and base weight, the team was encouraged by the test results.

'Everything was encouraging because the whole purpose of the test was to validate what we had done,' said Elkins. 'We are working with the Ford model exclusively for the test, and have the ability to keep the downforce level up, while still able to balance the car close to where it was in 2013. That was the biggest part, validating all the CFD. It has come a long way. We have one shot at doing this.'

Balancing performance is a dangerous path to tread, as European series have discovered. Quite apart from allowing all the cars equal opportunity, either through equivalence of technology as in the WEC, or pure performance balancing as in GT racing, allowance has also to be made as some cars are better suited to some circuits than others. With the cars still to run on



The Daytona prototype has been balanced up with a targeted increase in downforce of 60 per cent and an increase of 50bhp

MARSHALL PRUETT

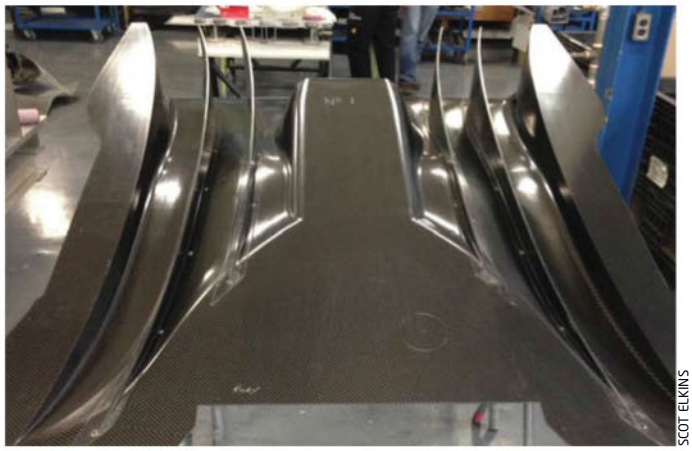
The Action Express Corvette, pictured here during testing at Sebring before moving on to Daytona in November 2013

track alongside each other, IMSA expects to have to change the performance levels, perhaps on a race-by-race basis.

'We are not going to hit this perfect first time out,' said Elkins. 'There will still need to be some tweaks, but we won't know for sure until we get to those tracks. The simulation is telling us where we may need to make some changes, but we will know better when we see the cars running.'

To help the organisation, the cars will all run on control Continental tyres, and will all carry the same data logger – likely to be the Cosworth unit that has been used in the WEC and the ALMS for years. 'We are going to have sonic restrictors on the DPs and the P2s now,' said Elkins. 'We will have the ability to make changes there, and we will always have the ability to make changes to weight, so we can do some things on the fly if we have to, we can make changes to the wickers – so we have some tools in the toolbox.'

Weight is a particular issue, and not just for the DPs with their considerable weight gain. The majority of P2 cars were built to 925kg, but may have to have up to 60kg added, which could require crash-testing the cars again. However, IMSA is trying to reduce the amount of weight in the DP cars and expects to add around 40kg to the current LMP2s. 'It is a 1-1 ratio,' said Elkins. 'Where we can reduce weight of the DP, we don't have to add as much weight to the P2. The decision to allow carbon brakes allowed us to shed weight from the DP car, and if we do that, we won't have to add as much weight to the P2.



SCOT ELKINS

The chosen method of adding downforce was through the diffuser (pictured) and underbody aerodynamics. According to Scot Elkins, utilising the underbody aero helped to push the centre of pressure forwards 'rather than just piling downforce on to the rear'

'The rear wings weigh a little bit more than before. Teams are adding six-speed gearboxes and paddle shift systems. We are trying to figure out where we can get to for the minimum weight, and that will determine how much we have to add to the P2. I think it will be close to 40kg.' None of the manufacturers have come back to IMSA with weight worries.

Following the eventful track test session (see p42), the cars will run in Windshear's full-scale wind tunnel. 'We are looking at utilising the Le Mans aero kit of the P2 cars at a number of circuits, but we haven't 100 per cent determined that yet,' said Elkins. 'We are still waiting for some validation on the DP car. There may be some instances where we increase the restrictor size on the P2 cars by up to five per cent. Not massive, but enough to give a little more horsepower to balance things out. We don't want to vary from the P2 cars too much. The spec stays the same, we are just doing balance of performance stuff, restrictor, weight – stuff like that.'

LOOKING AHEAD

With LMP2 being held as the benchmark, it seems likely that the category will evolve into the main class when new regulations are introduced in 2017. The IMSA organisation has been working with the ACO and the FIA to finalise these regulations, which will suit the WEC and the TUSCC. 'I think it is fair to say that we are working together with the FIA and ACO on what the next specification will be,' said Elkins.

'We are creating a new specification for the car will begin in 2017, and that is for both P2 and the Tudor championship. What is fair to say is the next car for us will not be a tubeframe car – it will be a monocoque car, like a P2. It is probably going to be a closed car. We are just getting started on our hopes and dreams for the next specification. By delaying it for a year, we are giving ourselves the opportunity to really work together with the ACO to create something that is a worldwide spec for the type of drivers and teams that we have here and in Europe.'

The Le Mans link is important to the organisation, and is more than just lip service to keep the ACO happy in the short term. P2 and GTLM cars, for example, that are eligible for Le Mans will be invited by the ACO next year, and the TUSCC calendar has been set to accommodate this. That means that the GTLM cars will not compete at Detroit.

IMSA already had a short time scale in which to work, but the testing accidents at Daytona, little more than two months ahead of the first race, have piled on even more pressure. Elkins and his team may have to compromise on performance in the interests of safety.

'The next car for us will not be a tubeframe car – it will be a monocoque car, like a P2. We are just getting started'

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Testing times

BY MARSHALL PRUETT

Blown tyres, rotating Daytona prototypes and skyward launches led to the premature end of testing at Daytona International Speedway for the new TUSCC on 19 November.

The two-day test, a first for the series, was fraught with unexpected issues for spec tyre supplier Continental and IMSA, sanctioning body for the championship, when Richard Westbrook suffered a blown right rear tire at 192mph entering turn 1 on the 3.56-mile circuit to close the morning test session on the 19th, and João Barbosa followed at the end of the day, experiencing the same phenomenon with a blown right rear and airborne sequence at approximately 170mph while exiting the banking off of NASCAR Turn 2.

Common denominators were easy to find: both drivers were piloting Corvette-bodied Coyote chassis, both were on the new Continental DP-1000 tyre, both had come off of the banking when their tyres exploded and both cars left the ground when turned backwards.

The latter issue can be attributed to IMSA's new, 2014-spec, high-downforce DP body package. Gone is the narrow single element rear wing in favour of a new, dual element design and – in the most significant aero development for the DP to date – a new, Multimatic-produced, four-strake diffuser and tunnel unit helped to add an additional 60 per cent to the DP's downforce totals.

Coupled with the round, elongated topside DP body profile, the diffuser, tunnels and rear wing made lifting the back of the DPs easier than at any time in more than a decade of competition. Westbrook's Spirit of Daytona car reached unexpected heights, and the crash was particularly violent.

'The tyre went, I got into a slide, thought I could catch it, then it all went quiet as the car lifted'

'The tyre went, I got into a slide and thought I could catch it,' he said. 'Then everything went quiet as the car lifted. It was the weirdest sensation. I knew something strange was going on, then realised I was airborne, and I thought it was going to really hurt because I was spinning in the air, was disorientated, and knew I was pretty high up because it went quiet for so long. My immediate concern was if I was going to end up in the grandstands, and it was not going to be good. I hit the top of the catch fencing, which is what brought me back down, and then went into a series of rolls.'

Barbosa was more fortunate as his car lifted and eventually returned to the tarmac on all fours.

The immediate blame for the tyre failures could have been assigned to the extra 1000 pounds of downforce being carried by the high-downforce DPs, but overheating right rears – especially on the inside shoulder of the DP-1000s – was experienced by a comparatively low-downforce 2013-spec DP.

'We saw the inside right rear was beginning to come apart,' said veteran team owner and crew chief Kevin Doran, who ran a Riley-BMW without the updated aero kit. 'We massaged the setup to bring the temperatures down, but the right rear was going away on us pretty quickly.'

Westbrook and Barbosa had turned approximately 20 laps on new tyres when their failures took place, and the Spirit of Daytona team experienced an earlier failure on the right rear – one that was caught before any damage was done – while at the 20-lap mark. But another wildcard came into the frame with the 2014 Michael Shank Racing Riley-Ford DP that made it even harder to draw a straight line through the issues.

'We bolted on a fresh set of Continentals at 9.30am and ran them until the lunch break,' said Shank. 'They were brand-new like the guys who lost their tyres, but we had no issues and put damn near 44 laps on ours with zero issues. Same downforce, same tyres, no issues.'

IMSA was expected to announce its findings and possible solutions to the tyre issues and its rearward aerodynamic concerns with the DPs in late November, giving teams little time to react heading into the final pre-race test during the Roar Before the 24 on 3-5 January 2014.

THE PRESSING LMP2 ISSUES

The LMP2 regulations are the subject of much debate not just for 2014, but also for 2017 when the category is due to welcome the new generation cars as the only global prototype category.

With the class targeted at customer teams, and organisers wary of manufacturer involvement, cost control has been a hot topic in recent months. Organising bodies are seeking to cut costs by extending the life of the engines, limiting the number of engines used per season, and for the 2017 regulations, to bring the LMP1 and LMP2 chassis regulations into alignment. Already in 2014, new LMP2 cockpits may be designed in accordance with 2014 LMP1 regulations to allow easy transition to the top class at a later date.

The problem is that building a new car to the cost cap is difficult – a manufacturer requires volume to reduce unit costs. So far only ORECA, with P2 and LMPC cars using the same chassis, based on the original Courage LC70, have been able to make a profit.

For many others, cars have been sold at a loss, and under the new regulations, manufacturers are going to have to take a financial hit again.

While Wirth and Pilbeam expect to build LMP2 cars to the cost cap, others have abandoned the idea, and will have to sell cars at a loss. Manufacturers such as Dome, Caterham and Lotus are likely to enter cars next year that will not meet the cost cap, although they will be required to sell the cars for the regulated price.

The LMP2 regulations already limit the price for which a car may be sold, evolutions of the package, homologation and a control on spare parts. There is a proposed limitation for any new cars that arrive in 2014 that would prevent them from having a major update or new model within a three-year limit to avoid spec creep which would disadvantage existing manufacturers.

The FIA is seeking to increase the life of the LMP2 engines, although the body has to acknowledge the potential loss of revenue for the engine manufacturers who would lose out on lease revenue, or rebuild income. With a limit on the number of engines, manufacturers have argued that the regulation excludes the possibility of running an engine from a previous year in testing – a factor that would drive up costs rather than reduce them.

One proposal from a manufacturer is to have the engines 'lifed', which would allow the organising bodies scope to extend the use of each engine without the artificial limitation of the calendar year.

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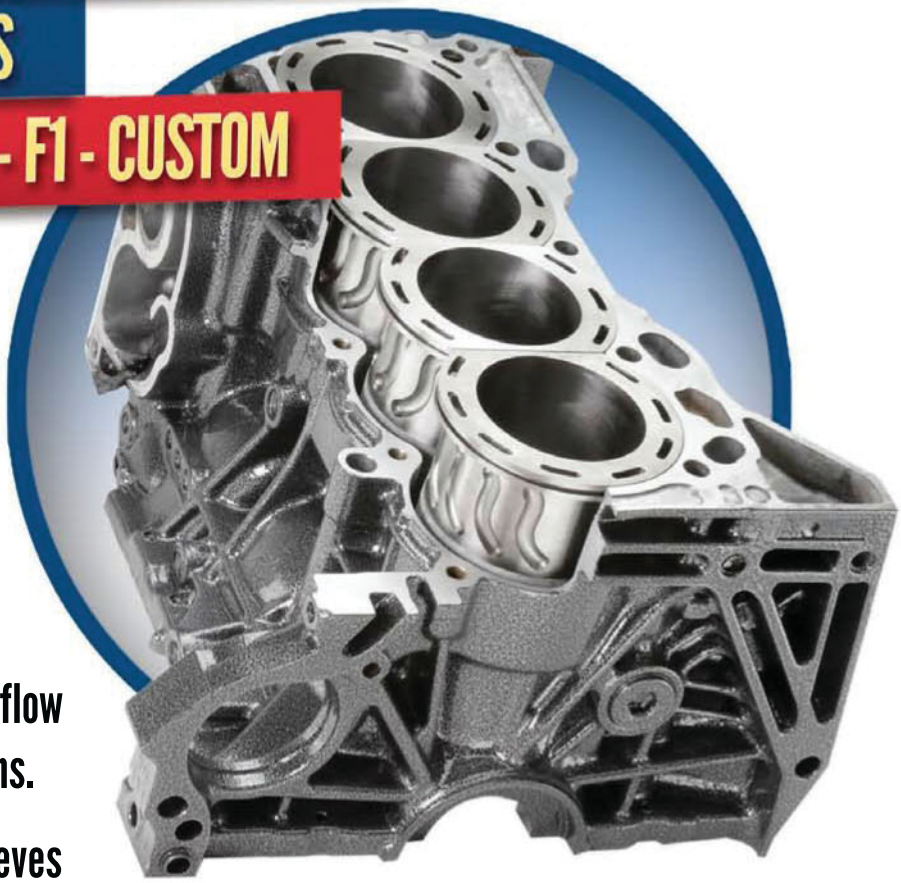

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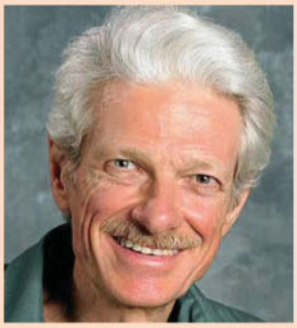

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Changing thinking on Supermodified rears

Armed with new information from a reader, our chassis expert returns to the topic of rear suspensions in this highly varied class

GRAHAM GOTT, STACKPOLE ENGINEERING, WRITES

I have a minor correction to your November 2013 issue. Supermodified rear suspensions are generally an open tube axle (like a sprint car). Some folks run splined wide 5 or six-pin adaptors, but since splined wheels have become much more commonplace, a lot of guys have switched over to them on Supers. There were a few experiments with closed tube axles back in the late-80s, but the added weight of a closed tube axle immediately ruled them out for many.

'There were experiments with closed tube axles, but the added weight ruled them out for many'

There is always a right birdcage with an open tube axle, but in a lot of cases the left birdcage is not run and the torque arm does double duty, both locating the axle longitudinally and reacting drive/brake torque. If there is no left birdcage, the left brake caliper gets bolted directly to the side bell of the rear end using lugs cast in place by the manufacturer. There are a ton of variations between cars in this area, which is one of the things that makes Supermodifieds cool.

While most Supermodifieds have beam axle fronts, there are several possible variations at the rear

JIM FEENEY PHOTO

THE CONSULTANT SAYS

Graham is correct. This response led me to update myself a bit on recent developments in the Supermodified class. My comments in the feature he's referring to were based on my recollections from helping with a Super in California in the 80s, plus some pictures I'd seen much more recently. Supers don't run in North Carolina, where I've lived since 1999.

I did find pictures online now of Supers with wide 5 hubs (not just adaptors – hubs like you'd find on a dirt Late Model), but the pictures – those I was viewing earlier and also fairly recently – were all at least a couple of years old, and all were of cars from the western US. It appears that east of the Rockies, open tube axles have been the norm for many years.

It further appears that Supermodified racing on the west coast has been in a state of collapse since 2011. On the other hand, it appears to be newly popular in the Midwest, and still popular in Ohio, Pennsylvania, and New York.

I definitely agree that having lots of variation in the cars makes the class interesting. Back in the 80s on the west coast, it was really wild. A 'best rules is no rules' philosophy prevailed. I don't remember open tube axles, but there were rear-engined cars. One of them, fielded by the Trigueiro brothers, had four-wheel drive. Another had the engine mounted backwards, in front of the left rear wheel, with the driveshaft running back along the engine's right side to a conventional (for a Super) radically offset quick-change beam axle with a torque arm.

Beam axle rears with torque arms were almost universal, but quite a few cars had independent front ends.

Engine choice varied too. Big-inch aluminum small block Chevys were the most common, but the car with the backwards rear engine had an aluminum big block. One car had an injected, unblown Keith Black hemi. Sometimes Keith Black himself showed up to help tune it. There was one car with forced induction: the Gerhardt-Offy. It had an Indianapolis-style turbocharged four-cylinder Offenhauser. Nobody else used a turbo. This was short-track racing, and turbo lag was a disadvantage. Roots blowers would have been legal, but I never saw one.

POSSIBLE VARIATIONS

Nowadays, where Supers still run, they all have aluminum big block Chevys, and for the most part they are required to have beam axle front ends. However, there are some interesting possible variations in the design of the rear suspensions.

In terms of suspension dynamics, an open tube rear – other than weight – is not much different from a closed tube with a spool, with one or more birdcages. In either case, there is no law of nature that requires us to have birdcages at both ends. With the open tube, we do have to have one at the right end.

It would theoretically be possible not to have a brake at that end of the axle, but the rules require four brakes – one for each wheel. The two rear brakes both act on both wheels, as with any locked axle, but each caliper reacts its torque through its own linkage. Therefore, we cannot get yaw moments from staggered caliper or rotor sizes, or from side-to-side hydraulic proportioning, as we might at the front. But we can have various effects on dynamic wedge in braking depending on side-to-side rear brake proportioning combined with right and left anti-lift or pro-lift properties.

I am not personally aware of anybody actually using left/right brake bias as a tuning variable on a Super, but in a car where the left wheels statically carry about twice as much weight as the rights, it would seem to be something to seriously consider.

Lateral brake bias probably offers possibilities that have not yet been explored, and not just for Supermodifieds. It might be possible to use four master cylinders, and three balance beams in series-parallel, but that sounds pretty scary.

I have seen the right front brake eliminated entirely on sprint cars – in fact, that's the norm. I have seen shut-off valves and proportioning valves used to limit right front brake apply pressure. I have seen the use of front tyre stagger, whose main effect is to provide front lateral brake bias. I have yet to see anybody use different size brakes on the two front wheels, but that would definitely be possible.

Using popular calipers, you could use a caliper with four 1.75in pistons on the left, and one with four 1.375in pistons on the right. With equal-size rotors and tyres, that would give about a 62/38 lateral brake bias. On a Super, that would probably give better straight-line braking than symmetrical front brakes. The car would have less tendency to turn right, and less tendency to prematurely lock the right front.

With enough built-in left brake bias, we might even contemplate using an adjustable proportioning valve for the left front rather than the right front.

Proportioning valves generally output a fixed proportion of the input pressure, once they reach their actuation threshold. Short of activation threshold they output the input pressure unchanged. If we plot output pressure as a function of input pressure, we get a straight line with a slope of 1 up to actuation threshold. There, the plot has a 'knee' and is linear again from there on, with a slope of less than 1. What we change with the adjuster is the actuation threshold, or the location of the knee. The slope of the plot after the knee is determined by the rate of the spring in the valve. The adjuster generally changes the spring's preload.

JIM FEENEY PHOTO

The Super's monster rear wing has to stay within the width of the rear wheels

When we use a proportioning valve to the right front, we get equal line pressure to the right and left up to actuation threshold, and then an increasing left bias from there. We have greatest left brake bias in hardest braking. If instead we had asymmetrical front brakes and a proportioning valve for the left, we'd have greatest left bias in gentle braking and decreasing left bias in harder braking. This could be desirable if the objective is to use lateral brake bias to free the car up when trail braking on entry, yet not have the car try to spin when braking hard in a straight line.

We should note that in braking, as with lateral force, ground plane force distribution influences the action of any 'anti' or 'pro' effects we have in our suspension geometry. In the case of a locked rear axle, caliper force distribution affects the linkage forces, without changing ground plane force distribution, and that with any beam axle the right side linkage acts partly on the left tyre and vice versa.

Open tube axles are always locked, as a matter of structural necessity. With a closed tube axle, we can run a locker or a limited slip. In that case, rear lateral brake bias generates yaw moments the same as it does at the front, in addition to affecting wheel loads by influencing 'anti' effects.

SAVING PARTS

It is quite possible to eliminate the drop link at the front of the torque arm and just have a single pivot attaching it to the sprung structure, and then eliminate the left birdcage and its usual two trailing links. This is possible with a closed tube axle as well. This option saves parts, and therefore weight and complexity. If a structure similar to a torque arm has no drop link, and locates the axle longitudinally, I would call that a trailing arm or radius rod assembly rather than a torque arm.

To behave similarly under power to a torque arm plus left birdcage on horizontal trailing links, the trailing arm needs to have the front pivot at axle height, at the same longitudinal location where the drop link would otherwise be. The system then appears to be equivalent, and we've simplified it.

To mount the caliper on the left bell of an open tube centre section, we just use off-the-shelf sprint car parts. However, the penalty is that we give up having separate control of left rear anti-squat (under power) and anti-lift (under braking), because we are using the same linkage to react both the torque from the left rear brake and the torque from the pinion. Is that a problem, actually?

The main reason for having so much anti-squat, so far to the left, is to counteract the tendency of a left-heavy car to turn left under power and consequently be loose on exit. The anti-squat makes the car gain a lot of wedge under power, reducing the oversteer – sometimes to the point of creating a power push.

A left-heavy car also has a tendency to turn right under braking, making it tight on entry. In addition to lateral brake bias, we can use wedge change to control this, as we do on exit. Having a lot of anti-lift on the left rear and relatively little on the right rear will make the car de-wedge on entry, reducing the understeer – but again, perhaps excessively.

There is no guarantee that the same left side geometry will give us the balance we seek for both entry and exit. However, assuming that we are setting up for minimal roll steer, the right side linkage will not generate any significant pro-squat or anti-squat under power, but it can be made to generate just about any amount of anti-lift we want under braking. That means we can optimise the left side linkage to balance exit behaviour, and balance our entry behaviour with the right side linkage. We merely have to be able to vary the geometry on both sides.

That would involve having two separate trailing links on the left, rather than a single trailing arm, and two separate links on the right, with sliders or multiple holes to mount the links.

One other possibility, when using a trailing arm or two trailing links on the left in place of a torque arm, would be to put the left caliper on a brake floater. That's like a birdcage, but with only one link. It reacts the torque from the brake, generating whatever pro-lift or anti-lift we wish, while letting something else provide longitudinal location.

Open tube axles are always locked, as a matter of structural necessity. With a closed tube axle, we can run a locker or a limited slip

Advanced Vehicle Dynamics Workshop

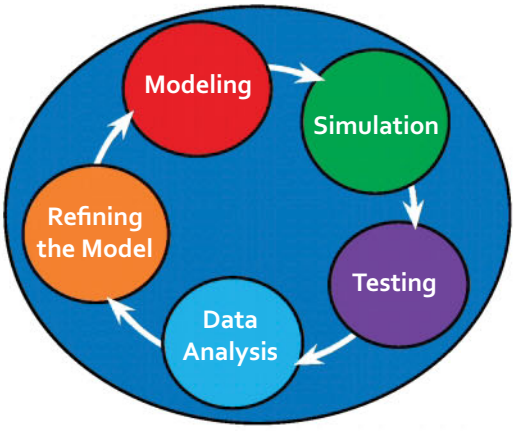
Two Locations Confirmed: Australia & Europe

Melbourne, Australia
Part One: December 17-21, 2013
Part Two: January 6-10, 2014

Europe (Munich & Oxford)
Part One: January 20-24, 2014
Part Two: February 10-14, 2014

This workshop will cover topics ranging from tires, aerodynamics, steady state and transient weight transfer, suspension design and setup, damping to data acquisition, and simulation. The advanced seminar is an intense two weeks of theory and application where you will learn practical tools that can be taken immediately to testing and on-track.

With a vehicle on a setup pad, you'll learn tips and tricks to perfect the ideal setup. As part of the workshop, participants will put methodologies into action with guided exercises that will require a laptop computer.



For more details and to register, please contact rachel.trapp@optimumg.com

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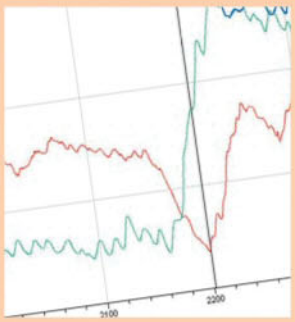


Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

To allow you to view the images at a larger size they can now be found at www.racecar-engineering.com/databytes

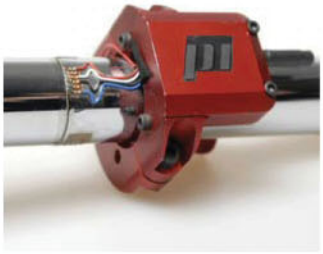
Torque talk

From strain gauges to monitoring magnetic fields, there are several solutions to help make a car's power and torque known quantities

A famous quote says that horsepower is how hard you hit the wall and torque is how far you drag it behind you, which is not far off the mark in explaining the difference and relationship between the two. It is, however, not a particularly logical approach to measurement – for that a much more subtle approach is needed.

Knowing the power output and power-delivering characteristics of an engine are among those critical elements needed in order to understand and predict a racecar's behaviour. Any race engine should be tested on an engine dyno prior to being installed in a racecar so the power and torque curves should be a known quantity to the engineers. It is, however, often very useful to be able to quantify the power output as the car is going around the track as well and going even further to measure the torque generated at the wheels as well.

In order to measure the torque transmitted through a shaft such as clutch shaft, driveshaft or half-shafts, it's best to look at how they twist. There are several ways of doing this. One solution is a strain gauge, but others include monitoring the relative position of each end of the shaft, or by measuring the change in a magnetic field introduced into the shaft.

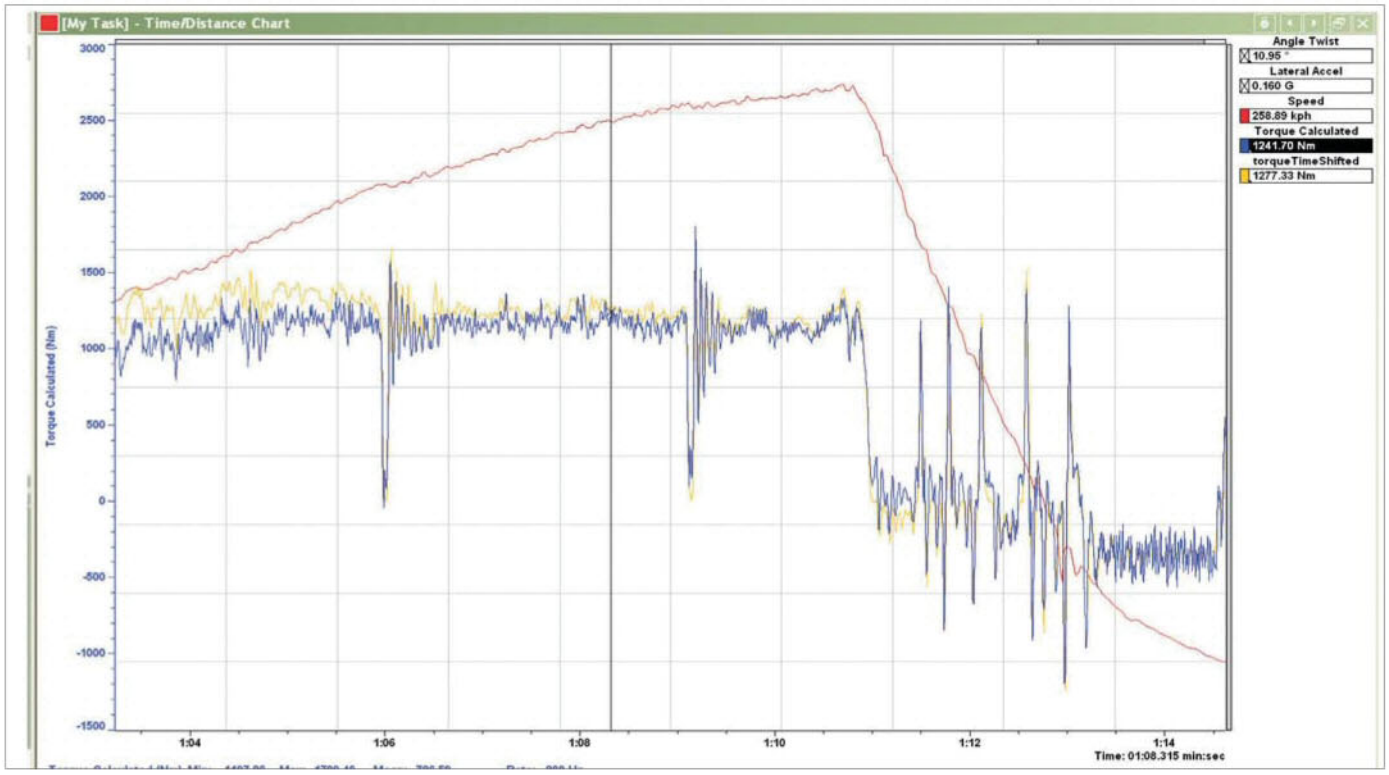


A strain gauge torque sensor with a fully balanced RF transmitter

All these methods have their own pros and cons. Looking at the case where a strain gauge is fitted to the rotating shaft, there are two immediate problems that need solving.

First of all, rotating shafts in a drivetrain can twist a lot, so a special strain gauge capable of measuring large angles is needed.

The other problem comes from how the electrical signal is transferred from the shaft to the data recorder. Using an RF transmitter is one solution which works well, but does require some extra hardware to be fitted to the driveshaft. Care must be taken to ensure that the hardware installed on the rotating component is completely balanced so that it doesn't influence the drivetrain. The big



Comparison of torque data from strain gauges and twist angle measurements

Any relative movement between speed sensors can be interpreted as a twist of the shaft, and this influences the torque movement

advantage with this solution is that the signal can be 0-5 volts, making this an easy addition to any data system.

Another method is to measure the twist of a shaft by fitting a missing tooth trigger wheel and speed sensor on each end of the shaft. By accurately measuring the position and speed of each end, the angle of twist of the shaft can be measured. This is often termed a phase shift measurement technique.

The critical thing in this measurement technique is the shape of the signal wave form generated by the sensors, and there will be an induced angle reading due to the response of the sensor at high RPM. In order to compensate, the torque system will have to allow a calibration which takes this into account.

This method also requires the material properties of the shaft to be known in order to accurately determine the torque.

First it is necessary to determine the twist angle. This can be seen in the maths channel shown below.

This calculation does not include the effect of other hardware in the system, any U-joints, or the position of the trigger discs for example, hence it is a very simplified calculation. However, it still gives a good measured value when compared with a strain gauge system.

Another thing to consider with this method is the mounting of the speed sensors. These need to be rigidly mounted and also need to maintain their relative position to one another as much as possible throughout the movement of the suspension.

This is critical, as any relative movement between the sensors can be interpreted as a twist of the shaft, and hence influences the torque measurement. If there is to be a relative angle between the two sensors, this needs to be calibrated for. During the life cycle of any shaft in a drivetrain, there is the possibility of plastic deformation. While this may not be critical to the mechanical function of the car, it will influence the torque measurement. The software used for the calculation of the torque therefore needs to allow both calibration and further zeroing if necessary to allow for any changes in the system.

An emerging technology using magnetic fields has become popular with top level motorsport teams. This system requires the measure shaft to have a specific magneto elastic material attached to the shaft or a portion of the shaft to be made of this material.

A non-contact sensor then monitors the magnetic field which changes depending on the twist angle of the shaft. This method produces extremely accurate results, but a downside is that it is expensive and also fragile. A minor disturbance to the magnetic field causes inaccurate results so anything that causes a disturbance to magnetic fields needs to be routed away from this system or carefully shielded. This includes any tools used to dismantle or service the gearbox.

It goes without saying that having a direct reading of torque throughout the drivetrain of a vehicle as it goes around a track gives great potential for optimising performance. Feeding the torque back to differential controllers, traction and launch control systems will ensure the optimum performance for any situation.

COSWORTH

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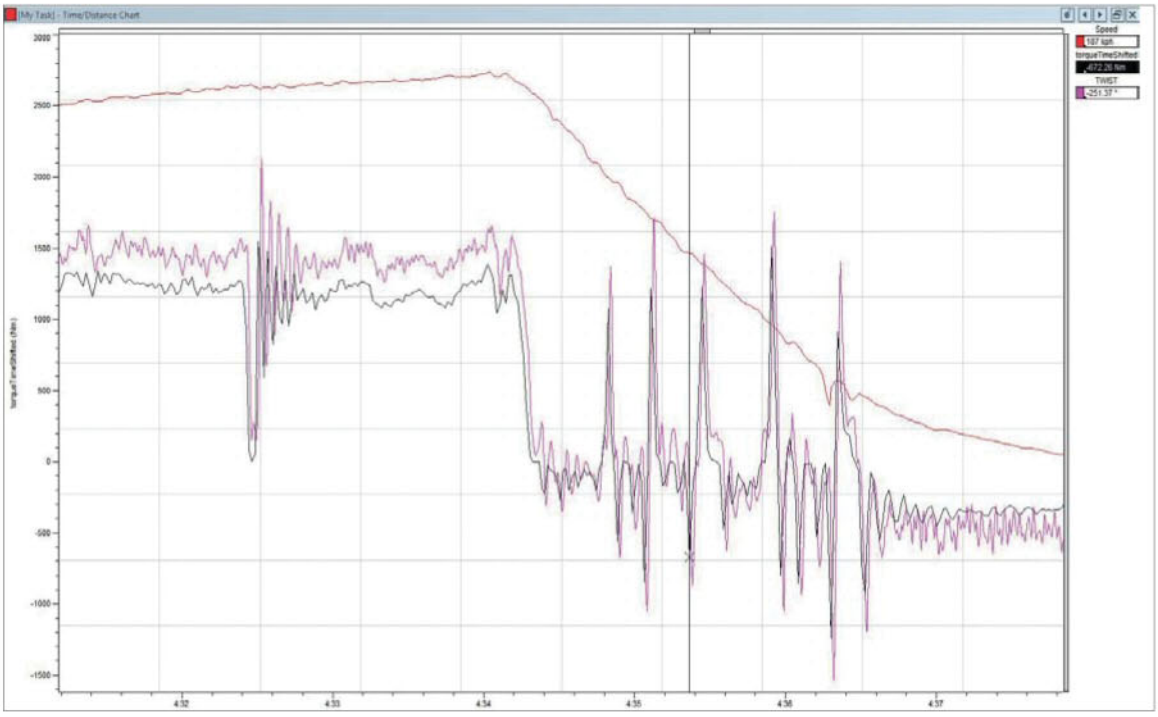
MATHS CHANNEL

Twist_Angle = choose(angle2>angle1, angle2 - angle 1, (360 - angle1) + angle2) //equation checks for the difference in angle and as appropriate calculates the angle of twist.

Torque Moment = Twist_Angle x Polar Planar Moment of Inertia x (Modulus of Rigidity/Length between trigger disks)



Torque and twist measurement shows the behaviour of the drivetrain during upshifts and downshifts. Note the large torque reversal during downshifts

Further education

More analysis of a prize-winning Formula Student entry, including a look at responses to flap adjustments

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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We continue this month with our investigations into the aerodynamics of the University of Hertfordshire Formula Student Racing Team's 'UH16' 2013 car. The University of Hertfordshire had won the half-day session in the MIRA full-scale wind tunnel as a special award provided by *Racecar Engineering* to the team that the Institution of Mechanical Engineers adjudged had the best publicity and on-event presence in the 2013 Formula Student competition.

UH16 was the team's first car to feature a full aero kit, which comprised large front and rear dual-element wings with main elements and flaps all based on the same 'high lift Selig 1223' aeronautical wing profile. The rationale for selecting this profile and these configurations for this first iteration full aero package was explained in last month's Aerobytes, but can be summarised as a pragmatic approach that shortened the required development time.

As a reminder of the baseline configuration, **Table 1** gives the coefficients at 40mph. This low test speed was selected for most of the runs, because it was close to the average speeds encountered in events, although some tests were also done at 60mph to examine how the data varied.

In summary, then, the car had quite high drag but also produced good levels of downforce – especially in relation to its low overall weight. In this latter respect, as noted last month, it was considerably better than the 2012 Formula 3 Dallara and even the 2007 Formula 1 Honda we have tested for this column, generating roughly double the downforce of the two Formula cars as a proportion of its own weight at these low speeds.

The team then set about adjusting wing flaps in the various configurations that are used in different phases of the dynamic tests of the Formula Student competitions, so that the data responses could be observed.

With the front flaps both at maximum angle, the rear flap angle was reduced by one adjustment hole in order to gauge the level of response. The results compared to the baseline at maximum rear flap angle are shown in **Table 2**.

As expected then, drag, total downforce and rear downforce all decreased. And while front downforce measured at the front tyre contact patches increased slightly, this was presumably because of the reduced leverage behind the rear wheels arising from the rear wing's overhang.

Looking at these numbers the other way around, the final increment of increased flap angle adjustment from '1 hole from maximum' up to 'maximum' was not particularly efficient, with 101 counts of rear downforce for 62 counts of drag (-L/D = 1.63), overall -L/D actually dropping by

Table 1: coefficients at 40mph on UH16 with maximum flap angles front and rear

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	1.158	1.758	0.980	0.778	55.7	1.518

Table 2: the effects of reducing rear flap angle at 40mph, with the differences in 'counts', where 1 count = a coefficient change of 0.001

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	1.158	1.758	0.980	0.778	55.7	1.518
R/flap down	1.096	1.694	1.018	0.677	60.0	1.546
Difference	-62	-64	+38	-101	+4.3	+28

Baseline configuration on UH16 with all flaps on maximum

Reducing rear flap angle produced the expected responses

The rear flap in 'DRS' position significantly reduced drag – and downforce

Then the outer front flaps were also reduced to minimum

Initially just the front inner flaps were set to minimum

Table 3: the effects of reducing flap angle at 60mph

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	1.146	1.797	1.055	0.742	58.7	1.568
R/flap down	1.096	1.746	1.092	0.654	62.5	1.594
Difference	-50	-51	+37	-88	+3.8	+26

Table 4: the effect of the DRS configurations at 40mph, differences in counts

Fr. Inner flap	Fr. Outer flap	Rear flap	CD	-CL	%front	-L/D
Min	Max	Max	1.102	1.452	28.7	1.318
Min	Max	DRS	0.723	0.791	77.5	1.095
Min	Min	DRS	0.674	0.568	46.0	0.843
Overall difference			-428	-884	+17.3	-475

Table 5: power absorption reductions as a result of using the DRS mode

Speed, mph	Drag force reduction, N	Absorbed BHP reduction
40	89.9	2.2
60	202.3	7.2
80	359.6	17.1

28 counts. This, coupled to the observation of wool tufts showing partial flow separation across the rear flap, suggested that the flap was very close to, or at, its peak angle on the maximum setting, which no doubt verified the CFD analysis that led to the team adopting the chosen max angle.

Visual observation suggested that the flows were somewhat better attached to the rear flap's suction surface at 60mph than 40mph, so would the effects of this 1 hole flap adjustment be any different at 60mph?

Table 3 illustrates with a comparison against the baseline configuration at 60mph.

So the pattern of the results was broadly similar at 60mph to 40mph, but among various differences at the higher speed was a more efficient gain in rear downforce by going to maximum flap of 88 counts of downforce for 50 counts of drag, an -L/D gain of 1.76 compared to 1.63 at 40mph. This would seem to tally with the observed improvement in flow attachment at 60mph, although it has to be said that the other changes that occurred as the speed was increased from 40mph and 60mph must also have had an influence on the response of the rear wing to this adjustment.

DRS MODE

For the acceleration phase of the Formula Student competition, the team came up with a 'DRS configuration' in which the nose of the flap was raised significantly above its normal dual-element location. This adjustment could only be made in the pits. In this configuration the inner and outer sections of the front flaps were also successively reduced to their minimum angles, so in order to evaluate the effect of the 'DRS configurations', the comparisons in **Table 4** were with the flaps in the positions shown.

So, the DRS rear flap on its own produced a large 379 count decrease in drag together with the expected large shift in aero balance. Unusually, dropping the outer front flap reduced drag by a further 49 counts and attained a more equable balance at a much lower total downforce level.

To more usefully quantify the drag decrease in terms of reduced engine power absorption, the actual change in the drag forces can be equated to BHP absorbed. The following formula provides a good approximation:

BHP absorbed = 2Fv/1500

where F is the drag force in Newtons and v is the speed in metres per second (forgive the mix of imperial and metric units!) So, by tabulating the changes in the drag forces with and without DRS deployed and front flaps at minimum at different speeds, measured at 40mph only and extrapolated to 60mph and 80mph using the square law for the force increase), we come to **Table 5**.

In relation to the peak RPM power quoted of 87bhp from its Yamaha R6 engine, these savings in 'drag horsepower' that the DRS wing mode achieved are noteworthy indeed, representing an extra 8 per cent power available for acceleration at 60mph and over 19 per cent more at 80mph.

Next month we'll look at the effects of front wing adjustments – which produced some surprises.

Racecar Engineering *thanks the staff and students at the University of Hertfordshire Formula Student Racing Team*

Real Radical aero

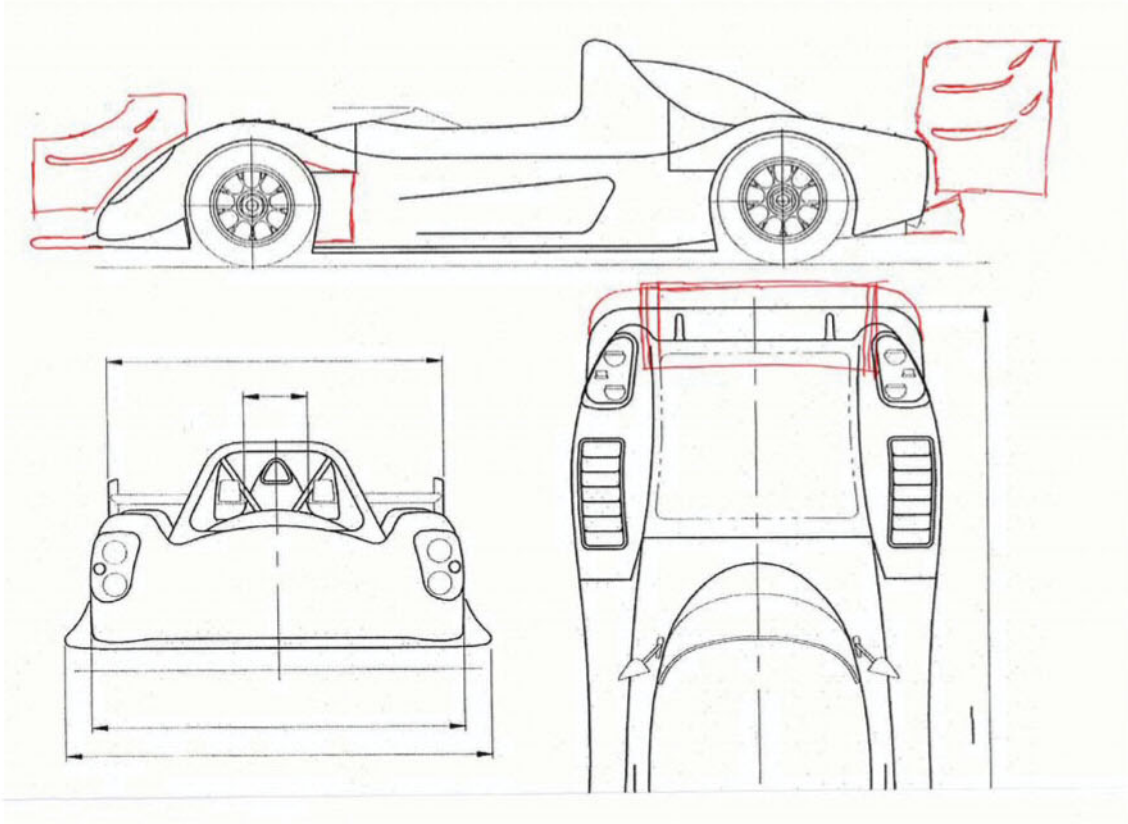
A unusual transatlantic collaboration almost quadrupled the downforce on the TMG/TRD Electric Radical. Here's how...

BY SIMON MCBEATH

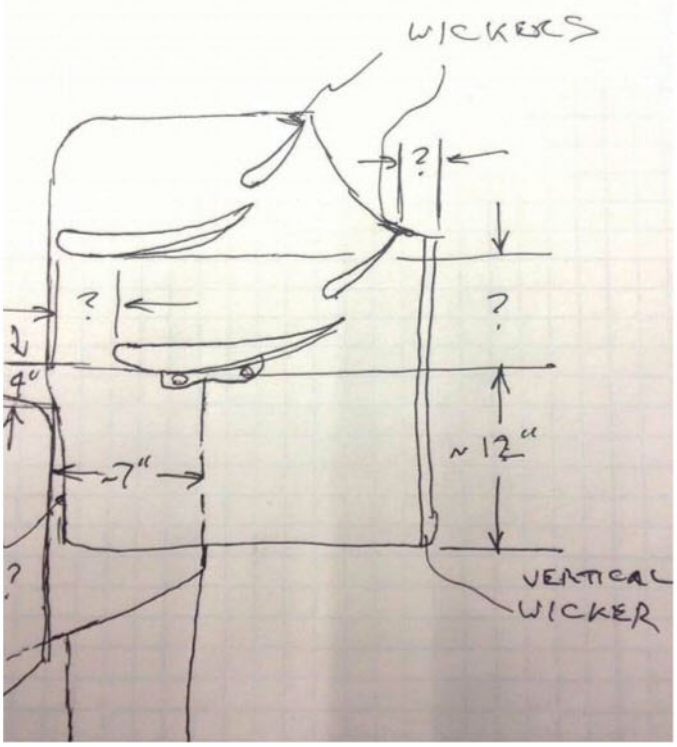
Having established a new electric car record on the Pikes Peak Hillclimb in 2012 on the newly paved course, Toyota set themselves a greater challenge: the target of bettering that time in the 2013 'Race to the Clouds'.

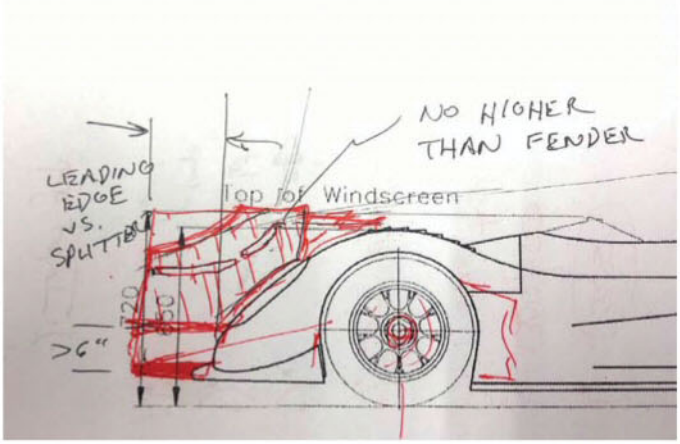
While TMG in Cologne got to work with drivetrain development – achieving power and torque increases of 33 per cent to 400kW (536hp) and 1200Nm (885lb.ft) respectively – TRD in North Carolina performed an aerodynamics overhaul of the TMG EVP 002.

In charge of this part of the project was Steve Wickham, vice president of TRD USA chassis operations, who explained at the outset that it was almost an 'out of hours' project with a modest budget and a tight timeframe. But given 2012's success, what was the motivation behind the aero upgrade?



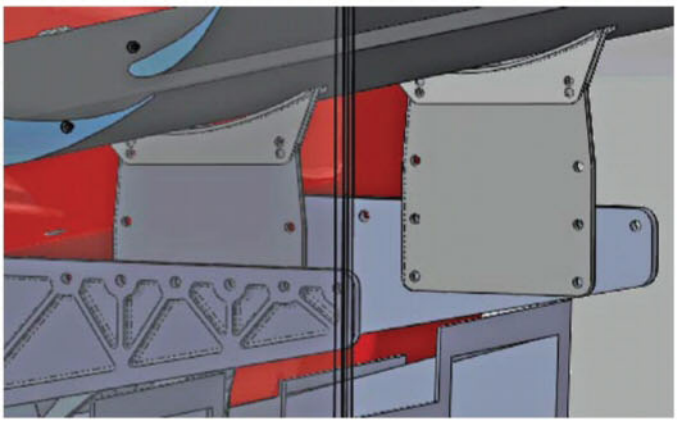
The first concept sketches illustrated a front wing in between the wheel arches and above a slightly extended splitter, and a dual tier rear wing above a slightly extended diffuser





Left: some of the topics discussed while trying to define the aero kit specification are highlighted with question marks
Above: the schemes at the front end were ultimately simplified with a full width front wing set further forwards

It was an 'out of hours' project with a very modest budget and a tight timeframe



Above: shortly after the car arrived at TRD from TMG in Germany, the wing kit was simply bolted on
Left: the rear wing mounts allowed for plenty of fore/aft and vertical adjustment

KEEPING COOL

Cooling brought its own special demands, as TRD race engineer Tom Smith explains: 'Although the cooling demands are lower than those of an internal combustion engine of equivalent power, the requirements are not insignificant. The motors are capable of 400kW. If the powertrain is 90 per cent efficient, 40kW must be rejected. Given the duty cycle and average speed of Pikes Peak, the average heat rejection requirement was actually about 20+kW. This is easy to deal with at a typical circuit at sea level, but Pikes Peak has particular challenges: hard acceleration at low speed and high altitude (air density is reduced ~30–40 per cent compared to sea level).

'In our case, there was an additional handicap – the radiators were removed from the sidepods to make room for batteries! We actually used the engine intake behind the driver's head as the radiator inlet duct, and the radiator was moved to the rear of the car. In addition, the electric powertrain demands low coolant temperature (<50degC) to allow high efficiency and full power. This, combined with the low average speed, meant that even with a very efficient radiator, we had to use powerful fans and still struggled to move enough air. In the end we supplemented with dry ice in the ductwork. The added power from running cool was worth more than the 3kg of extra weight.'

'We looked at the speed profile from the data and felt that we could make significant gains in cornering speeds with greater downforce, allied to the switch to full slicks in 2013,' Wickham explains. 'Don't forget, the original Radical downforce was reduced by up to 40 per cent at the top of the mountain, so just to get back to the standard car downforce level we needed more. In the end we got greedy and targeted a three-fold increase from stock at 100mph.'

This reduction in downforce at the top of the mountain was due to the nominal difference in air density between sea level and the top of Pikes Peak at 14,110ft (4300m). While the TMG EV P002's electric motors may have not have been affected by this, unlike the air-breathing internal combustion engines in the event, its aerodynamics (including cooling) were subject to the usual laws of nature. In fact, with the start line located at 9390ft (2863m), air density was already down by roughly 30 per cent relative to sea level, and with aerodynamic forces linearly related to air density, the forces available at a given speed would already be considerably reduced. A bold aerodynamic configuration seemed logical.

The next crucial aspect was the combination of budget and available time. 'As the programme was so condensed, we knew we had no choice but to come up with a bolt-on package,' Wickham admits. 'Ideally we would have liked to work with the whole car body aero as a package, but that was not realistic. Once you accept that this had to bolt-on, the options really fell into place. We did speak to some of our fellow engineers at TRD who had been involved in sportscar racing in the '90s and found some inspiration in the GTP cars from Toyota and Jaguar with the XJR-14. Looking back at reference material we saw that both manufacturers had run bolt-on front wings and multi-element rear wings that considered interaction with the rear diffuser. From there it was logical to come up with what we did in our early sketches.'

SOLID PARTNERS

It was around this stage, in late February 2013, that DJ Engineering became involved in discussions with Wickham and race engineer Tom Smith at TRD. 'I had been Googling images for high downforce aero in hillclimbing and came across the DJ Racecars website,' remembers Wickham. 'At the same time, Tom had been speaking to a good friend and colleague at Joe Gibbs Racing – Todd Bowland, whose father George races an autocross car with extreme downforce. Both avenues led to DJ Racecars and, as a result, contact with [this writer's advisory service] SM AeRoTechniques.'

DJ Racecars – better known as DJ Engineering Services Ltd – will be familiar to readers of *Racecar Engineering* as a UK-based constructor of hillclimb cars covered from time to time in these pages. They are also a renowned manufacturer of carbon racecar wings. High downforce multi-element wings had been supplied to Dan Wasdahl, a friend and competitor of the above-mentioned George Bowland, and three-time outright winner of the SCCA Autocross Nationals in his BBR (Bowland Boys Racing)

Top: the front wing was located forward of the original splitter lip
Above: the front wing mounts cantilevered off a sturdy pair of brackets which were attached to the nose box

Top: the rear wing assembly, together with the extended diffuser. The fans draw cooling air through the 'airbox' inlet to cool the electric motors
Above: getting ready to roll in the Windshear wind tunnel

Phantom DVS1. TRD contacted DJ Racecars to discuss which wings from the available portfolio would be best suited for the car's bolt-on needs, and discussions then expanded into broader aero topics relating to the deployment and location of the wings on the car.

There then followed a busy spell of exchanging 'back of envelope' sketches scanned and attached to discussion emails. Topics raised included the specific profiles recommended for the application; the vertical separation of the two dual-element rear wing tiers; the fore and aft position of those wings in relation to the extended diffuser; the overall height of each rear wing tier in relation to the roll cage (upper wing) and diffuser termination (lower wing), and the set back of the lower wing relative to the upper wing.

A dual-element front wing was also discussed, and there the points raised included the height and forward location, the span, the end plate design, and possible splitter extensions below the wing.

Realistically, as the proposed layout was more extreme than most sportscar applications, much of the discussion was of the 'finger in the air' variety, perhaps more kindly described as bringing knowledge and experience to bear on a new application. But when a request subsequently came through from TRD for estimated wing loadings, there was CFD data available on the selected wing profiles courtesy of ANSYS CFD-Flo. This wing data was generated on wings in isolation in freestream rather than on a car, and among the unknowns to be considered were the effects of all of the above mentioned aspects relating to the specific deployment of the wings on the car.

However, an estimate of 5300-6100N (1188-1368lb) total wing downforce at 100mph (160km/h) was provided, split roughly 30 per cent front, 70 per cent rear. This would add to front splitter and overall underbody downforce, the ultimate aim being to obtain slightly under 40 per cent at the front.

TRD then went into discussion with Radical at their Peterborough, UK, base to determine the chassis' capacity for the estimated loads involved, following which the one and only meeting of three of the parties involved took place in mid-March.

'Thanks to the open-minded approach and support from Radical, I arranged a meeting at their UK HQ with Del Quigley from DJ Engineering and Nick Walford, chief designer at Radical,' Wickham explains. 'We came to an agreement that we would design the wing mounts and DJ would make the wings. I asked Radical to make the rear wing mount structure as they had the jigs to make sure it fitted correctly. The car was in Germany at this stage, the structure was designed in the US without access to the car, and the manufacturing was in the UK. It was a relief when it all fit perfectly!'

Another key part of the above process involved DJ Engineering's chief designer Andy Smith, who turned the 'envelope sketches' into 3D CAD including mounting details. In liaison with Tom Smith at TRD, Andy produced the CAD for the bespoke rear endplates from which the requisite tooling and parts were then manufactured.

'The front wing mounting was a little more challenging,' says Wickham, 'but after looking at the options and sketching out a few ideas, Radical kindly agreed to send us drawings and the front nose crash structure in kit form so we could bond and rivet the appropriate mounting plates. Our race engineer Tom designed the parts and ran FEA prior to manufacture. He did a great job. All of the parts were designed and made without having the car as a reference. I was very relieved and impressed when everything bolted straight up. That's a testament to the collaboration between TRD, Radical and DJ Engineering.'

Wing data was generated on wings in isolation in freestream rather than on the car itself

GONE WITH THE WIND

The car arrived from Germany at TRD's North Carolina base in early May, leaving little over a week to convert it into Pikes Peak aero specification ahead of the scheduled wind tunnel test in the Windshear facility in nearby Concord, NC, on 16 May.

'We literally finished the last part and loaded the car on to the hauler to go to Windshear,' Wickham recalls.

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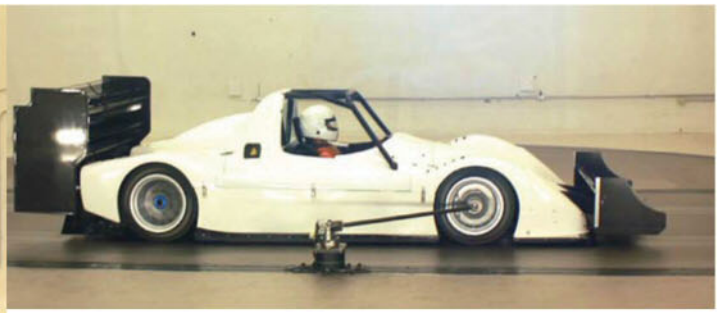


Left: more last minute adjustments. Above: testing under way

The first run of a wind tunnel programme on an untested configuration is always telling and tends to dictate the path for the rest of the session, despite any plans that might have been drawn up beforehand.

'It could not have gone better,' Smith says. 'We were hoping for something over 1250lb (5575N) downforce at 100mph with about 38 per cent on the front end.

'The first run average over the ride heights tested produced 1433lb (6390N) and 38.7 per cent front, so we were able to dive straight into development. It was an incredible day where everything we did worked, and we realised better than a 25 per cent gain from where we started.

'We raced Pikes Peak with 1768lb (7884N) and 37.4 per cent front,' Smith continues. 'That was the "mid-corner" values from the ride height map – the peak at high rake was significantly higher [though with greater front percentage]. Although we never tested the car in original form, data we got from Radical suggested we nearly quadrupled the downforce.'

After what was a very satisfactory wind tunnel session, the car ran for two days at the Carolina MotorSports Park at Kershaw, SC, with driver Rod Millen getting his first taste of the car in 2013 configuration.

'That test was more of a shakedown for the systems and to make sure the balance was good,' Wickham says. 'We reduced the maximum downforce as we were running at a lower elevation and did not want to fool ourselves.'

The week of the event in late June came around all too soon, with three practice days split between the upper, middle and bottom sections of the hill.

'We ran well and the car was balanced and fast,' Wickham recalls. 'You never get to run the full course in the week before race day, but our composite times in practice showed the car to be 40 seconds quicker than in 2012. My goal was 30 seconds. That composite time would have put us as overall winner last year!

'Unfortunately, you don't get to race in isolation and our competitors had also made significant gains. We qualified fourth in the EV class – and ended up fourth in the race.

'The race was run in changeable conditions, with the first two EV cars running on a very wet track. By the time we ran it was damp but drying, with a little rain in sections of the 12.4 mile course. Ultimately this was a disappointment competitively, but technically a great achievement. I am very proud of the team members, as it was a big effort in a short time.'

What's next for 2014? Wickham's wish-list includes 'more power and traction to win. It was clear that a 4WD system is required to put the torque that these electric cars generate to the ground, especially with the large number of hairpin turns.'

And on the aero side? 'I think we would run similar aero in a new design with maybe a little less drag.'

So can we expect a new design from Toyota for 2014? Watch this space.

THE WINDSHEAR SESSION

The Windshear facility in Concord, NC, must be one of the most sophisticated commercially available wind tunnels available to motorsport, with moving ground belt, rotating wheels and overall forces measured at the wheels. Although the EV P002's initial budget did not allow for wind tunnel testing, Steve Wickham managed to call in a favour with TRD's NASCAR aero group, securing a day of testing at Windshear to evaluate and fine-tune the car's aero upgrades.

The car's total downforce and aero balance were pretty much on target in the first baseline test, a satisfying vindication of the 'finger in the air' methodology that determined the EV P002's initial layout. TRD was able to spend the session mapping responses to changes of ride height, rake, wing angles and wing locations, plus a few additional bolt-on parts, during which process another 25 per cent plus of balanced downforce was obtained.

Increasing front wing flap angle produced forwards balance shift across the flap angle range, from 28.1 per cent to 37.8 per cent, but interestingly there was very little change in total downforce, with increasing front flap angle, the minimum being 1470lb (on maximum flap, suggesting the wing was past peak angle in this location), the maximum 1482lb (on hole #6 of 10 available).

Given that balance moved but total downforce did not (significantly), then rear downforce must have decreased as front downforce increased. Drag barely changed.

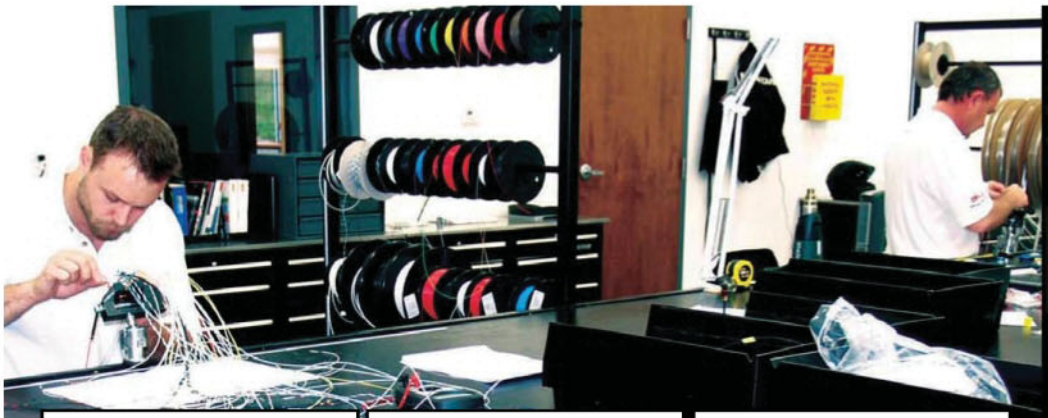
The rear wing was moved aft in 2in (50mm) increments and total downforce (+120lb in total) and efficiency or -L/D (+0.14 in total) increased with each rearward shift, although front percentage decreased with each rearward increment (-5.7 per cent in total). Raising the height of the rear wing assembly by 2in (50mm) also increased total downforce (by 85lb) and decreased front percentage (by 3.5 per cent) but -L/D remained unchanged.

Installing upper and lower front dive planes produced a modest increase in total downforce (11lb) and a 1.9 per cent increase in front percentage, but also produced 16lb more drag and a decrease in efficiency of 0.07.

A much more effective means of gaining front percentage came from adding 2in (50mm) 'front wheel opening wickers' – outward extensions of the front part of the wheel arch. They reduced drag by 5lb, added 61lb of downforce and 1.9 per cent front percentage, and also improved the -L/D by 0.14, an efficient result from a simple device.

Fitting the equivalent devices to the rear wheel arches also proved to be very efficient. 0.5in by 9in wickers added 37lb of downforce, 1in by 19in produced another 31lb of downforce, and finally 2.5in by 19in added another 15lb, and all for absolutely no change in drag, which took the -L/D to its highest level of the session at 3.20 and the balance to 37.4 per cent.

Importantly, given that the aero had to work from low speeds, a speed sweep in this final configuration showed virtually no balance shift with changing speed.



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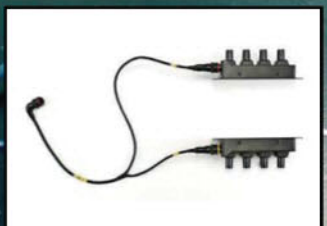

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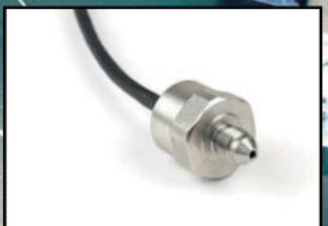

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Gathering data

Today's data acquisition systems glean more information about your car than ever – more, indeed, than you thought you needed

BY DR CHARLES CLARKE

Unofficial sources close to Oracle Team USA at the America's Cup reckon that one of the chase boats for Oracle was fitted with serious computer hardware that was analysing the data sent from over 300 sensors sited throughout the race boat. There was a server aboard the AC72 collecting a huge amount of performance data and transmitting it to the chase boat server. In addition they received shore data via 4G. Some 3000 variables were being checked 10 times a second from sensors that measured strain on the mast to angle sensors on the wing sail that monitored the effectiveness of each adjustment. All this while foiling at speeds that seemed to defy the laws of physics.

Because of the financial resources of Larry Ellison and the technical data mining capability of Oracle, they were able to turn a real slouch into a record-breaker in just over a week. The key was real-time data analytics – the ability to be able to find trends in real-time and compare current data with history in raw terms and in video and to be able to drill down through specific trends to increase performance. Allied to this, each sailor aboard Oracle had a PDA that relayed performance adjustments specific to his function as a result of the analysis.

All this is music to the ears at Buckingham, UK-based Racelogic, experts in matching data and video analysis to driver training and improved performance.

The company has recently released two new products within their range of motorsport GPS data loggers: VBOX HD and VBOX LapTimer.

VBOX HD brings together all of the driver development features from their existing products and takes video data logging to a new level by using Global Shutter technology, rather than employing a rolling shutter as used by the current crop of HD cameras. Rolling Shutters record video by scanning from the top to the bottom of the image. If the camera is being held completely steady this is fine, because the pixels it captures at the top of the picture will still be in line with those at the bottom by the time the scan completes, and as each frame is recorded the resultant footage looks smooth and consistent.

'But this doesn't work well in a racecar,' says Mike Broadbent of RaceLogic UK. 'The amount of vibration present in a racing environment means that the pixels fall out of line with each other as the images are scanned, which results in video that at best is distorted, but at worst it's almost unwatchable. It certainly hinders the usefulness or entertainment value of the recording.'

VBOX HD imprints each pixel simultaneously, and so records a completely solid picture with no wobble or distortion. When put to use together with Circuit Tools analysis software, driver coaching is methodical and highly effective.

VBOX LapTimer is a 20Hz GPS predictive lap timer and data logger, ideal for those that want to record data without going all-out on a video system. The bright display gives instant feedback as the lap is driven – providing an infinite set of split points, which allows drivers to make the finest adjustments to their line and see the results immediately. Because it uses GPS position, rather than distance, the predictive timing is accurate and consistent.

Electronz Ltd of Christchurch, New Zealand, offers ECUs under two brands: Link and Vi-PEC. While Link ECUs are a comprehensive solution in themselves, Vi-PEC ECUs offer an enhanced feature set for more advanced applications. A wide variety of ECUs are offered for wire-in, direct plug-in and power sports applications.

Several levels of wire-in ECUs are offered from the smaller G4+ Atom to G4+ Storm and G4+ Xtreme. Similarly in the Vi-PEC product range, i44 and i88 wire-in ECUs are offered.

The top five cars in the Canadian rally championship run Vi-PEC. Ben Diggles's Nissan FJ20 rail dragster is on Link, RIP's Mgawot – the fastest street GTR – is on Vi-PEC, while the New Zealand V8 Super Tourers (NZV8) recently adopted the Link Xtreme as the class ECU.

Pricing for ECUs ranges from NZD $1000 retail through to around NZD $3100.

PCLink tuning software offers all the necessary features to configure and tune an aftermarket ECU quickly and

Racelogic's VBOX LapTimer, a 20Hz, GPS predictive solution

The VBOX HD employs Global Shutter technology, which achieves better results in racing than a rolling shutter

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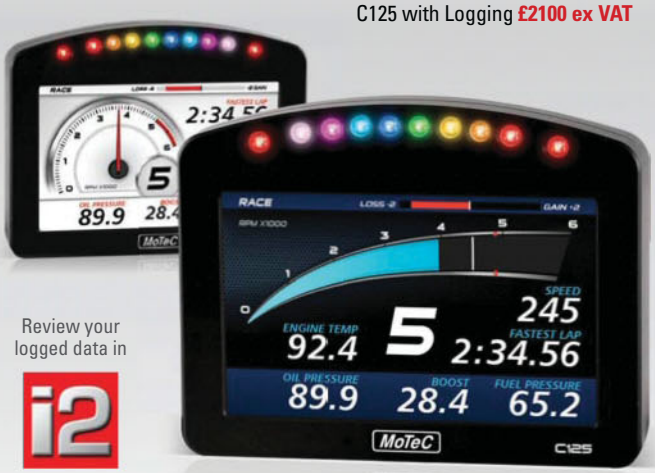

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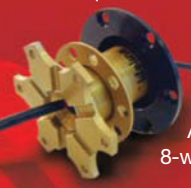

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Left: Vi-PEC Altezza Plug-in ECU from New Zealand's Electronz; right: Link's top-of-the-range engine management system – G4+ Xtreme

efficiently. It is designed with simplicity, productivity and ease of use, and features automated fuel tuning, fully customisable display layouts, sortable settings lists, large graphical indicators and time-saving table editing.

'Where PCLink really differs from other tuning packages is the inclusion of a fully featured data analysis package,' says Ashley Duncan of Electronz. 'This allows the tuner to integrate data analysis and engine tuning quickly and easily. Data can be captured inside the ECU and uploaded to PCLink with a single key press, or recorded directly to the laptop during dyno runs.'

The data can then be analysed using a variety of displays and graphs. Previous dyno runs, or track laps, can be overlaid for comparison. All displays can be customised to optimise the tuning situation, whether it be fuel, ignition, variable valve timing or any other type of tuning. PCLink can also capture data directly from some manufacturer's dyno controllers to analyse alongside data captured from the ECU.

'The real advantages of an integrated logging and tuning package comes in the ability to use logged data to correct tuning instantly without having to swap between logging and tuning packages,' adds Duncan.

As the cursor is moved through logged data, crosshairs are displayed on tuning tables to show where the ECU was operating at that point. Analysis views can be used to look at the data from a previous dyno run, and allow single click corrections to fuel tuning tables.

Real-time data and tuning tables can be displayed from the online ECU while analysing the logs to compare current and previous results.

A typical real world application is the correction of fuel tuning tables based on logged data. A tuner would record data while doing a dyno run. The data is plotted live on the screen during the run and at the end it can be analysed. Automated analysis then generate a map of actual lambda compared to target lambda. Cells in the map can be clicked to apply a calculated correction to the corresponding cell in the fuel table. Another run is then performed to check the results and the process is repeated if required. The data for tuning corrections could have come from a drag run, race log, road drive or any other previously recorded data.

'We are constantly encouraging and listening to feedback,' says Duncan. 'This varies from minor feature requests through to complete ECU development for special applications. While there is no clear direction that the overall market is going in terms of ECU technology, a definite trend has emerged for ease of use, time efficient installation and fast repeatable tuning. This is an area in which our products excel.'

MCLAREN CONTROL UNITS

According to Dr Peter van Manen, MD of McLaren Electronic Systems, the significant change in Formula 1 this season has been the switch from the TAG-310B to TAG-320 master control unit at the heart of the standard ECU. This doubles the number of loggable parameters to 1000 and gives the teams access to a maths application layer within the unit. Here they can run complex algorithms created using Matlab Simulink models. The new unit was introduced this year in anticipation of the new 2014 V6 GDI turbocharged parallel hybrid engines with exhaust gas energy recovery.

Teams are still using the HSL-500 High Speed Logger for additional data acquisition, including engine vibration and combustion monitoring.

'Formula 1 teams continue to use vTAG Server for their heavy-duty real-time analysis during races'

In NASCAR, and the second year of running electronic fuel injection, teams have got accustomed to having engine data logging in the TAG-400 engine control unit. Before the start of 2012 there was no data logging during the race events. There are no chassis parameters logged at present.

'As far as data analysis is concerned, the Formula 1 teams continue to use our vTAG Server for their heavy-duty real-time analysis during the races,' says van Manen. 'This supports multiple input/output models, created using either Matlab Simulink or Dymola, and is used variously for engine life monitoring, tyre degradation and fuel usage. vTAG Server uses telemetry data as its inputs and broadcasts derived (virtual) data to the users in the garage.'

'There is often far more information logged than a user can take in or use,' says Jamie Augustine of MoTeC Australia. 'Often teams have hundreds of different channels from a variety of either sensors, or calculations that rarely get looked at.' The information is often not intended to be looked at in every instance, but can help diagnose an issue, or provide a possible performance gain when you go looking for something specific.

Teams are now used to logging the current draw of all of

GPS APPLICATIONS IN MOTORSPORT

When people talk about GPS the first thing that springs to mind is the domestic satnav. While this is the most well known application of GPS, it is only a small part of what the system is capable of.

A good quality standalone GPS has a positional accuracy (under favourable operating conditions – wide open space, antenna positioned with clear view of sky and large proportion of the horizons) of 1-2m. By using a trackside 'reference' GPS base station and a radio link to the moving receiver, this can be improved to better than 1m.

The good news is that although positional errors of 'normal' GPS are in the range of 1-2m, the change in position error over a typical 2 minute lap is much, much smaller. As a result GPS is very good for lap timing. With GPS the position of the car is known to this accuracy all the time, not just once a lap as it crosses the optical beacon, or track strip.

This gives the user far more freedom in terms of sector, or split times. In addition, comparison of the driven line from lap to lap is another forte of GPS systems and can be achieved to a very high level of accuracy and repeatability.

'This is where combined video and GPS data logging systems really come into their own, such as our VIDEO4,' says Dr Andrew Durrant, technical director at Race Technology Ltd. 'Video is used for precise visual feedback and GPS is used for data synchronisation, lap timing, lap to lap repeatability of racing line, and high accuracy speed measurement.'

Far more useful for motorsport is the availability of accurate speed data. The PurePhase systems from Race Technology calculate the velocity independently from the position by using the carrier signal or the Doppler shift. Speed accuracy is equal to or better than 0.1mph.

While position and velocity are the main outputs, there are also a number of other derived outputs available including acceleration, track gradient, corner radius and motorcycle lean angle. Note that while acceleration and deceleration may also be calculated using GPS, accelerometers are usually preferred because they give a faster dynamic response. This data is available with complete immunity to events such as wheel spin, lift and lock up, which would give inaccurate data if using wheel speed sensors, or changes in track surface conditions which can lead to inaccuracies when using optical speed sensors

There are several challenges for GPS in motorsport. The level of acceleration and the high rate of change of acceleration (jerk) causes problems for receivers not optimised for this kind of application.

Background electrical noise is also a common issue. A weak GPS signal is easily jammed by radio interference. In a racecar environment there will often be a high density of electrical systems such as a powerful ignition systems, voice and data telemetry systems and video systems – all of which can cause problems. The best methods of limiting this issue are the correct choice of GPS antenna and antenna location. Generally speaking, the larger the antenna, the better the signal. Mounting the antenna on a metal ground plane – such as the roof of a tin top car – also helps to improve satellite reception.

Vibration is a real problem. Not only is this a potential problem for the mechanical durability of electronic systems, it also affects the system accuracy. A GPS receiver needs to keep very accurate time and this is done using a resonating quartz crystal. If external vibration affects the timing crystal, the accuracy of the GPS is degraded. Careful design of the GPS data system and sensible mounting arrangements help in this regard.

Modern systems are capable of combining inertial data with GPS data. By combining the two data streams, the race engineer has a data system with steady state accuracy, fast dynamic response and a high degree of immunity to dropouts in the GPS signal. If a vehicle passes under a bridge it can lose GPS lock for a second or more, leading to invalid GPS data. When using a system that combines GPS and inertial sensors, there will be no loss of valid output data. The DL1 from Race Technology is an example of a system that combines GPS with accelerometer data. Such a system performs very well, and it costs little more than just a GPS receiver. Race Technology's SPEEDBOX INS combines GPS data with three gyros and three accelerometers.

A further advantage of this system is that in addition to position and velocity, you also get the vehicle roll, pitch and yaw as well as vehicle slip angle and all other 'vehicle states'. This can be used for optimising chassis and suspension setup as well as diagnosing vehicle handling issues. In combination with shock absorber sensors this data can be used as the input to equipment such as seven post rigs for chassis and suspension development.

With GPS, the position of the car is known all the time, not just once a lap as it crosses an optical beacon

Race Technology's SPEEDBOX INS can combine GPS data with three gyros and three accelerometers

their in-tank fuel pumps, pressure pumps, gear pumps, fans and the like. It is rare that a team will look at these items each time that they run the car, but if – for example – they start getting a fuel surge issue, they can quickly select the 10 channels describing the state of the fuel pumps to help diagnose the issue.

While this is not a new development, today's teams want this diagnosis to be done while the car is still in the event. The two ways to do this are to notify either the driver or the pit crew.

In lower cost installations, it is often only the driver who can see any 'data' live, via the display. To this end, MoTeC has built the new C125 and C185 colour displays. These have been built to overcome some of the issues associated with the increase in the number of available channels in a car's setup.

'Previously, with the "pre-printed" display, we had to try to estimate which channels you might want to display, and provide labels for them in specific locations,' says Augustine. 'This worked well when people created far fewer channels. With the numbers we see today, people need greater flexibility in displaying many channels in an easy to understand form.'

MOTEC MINUTIAE

The new colour displays all have variable labels for any of the displayed channels. There is also the new Display Creator software that is used to customise the screens further, so that users can create entire pages dedicated to a function. One page showing all of the fuel pump current, level and pressure information. One page showing the state of the fans. One page to show the state of the injection system, and another for Lambda, exhaust temp and pressure.

'Drivers can now get far more detailed and targeted information at their fingertips while driving the car,' says Augustine. 'Just as importantly, the new C125 and C185 with Display Creator can choose to select one of many pages when a particular error occurs. So the display may have 20 different layouts, but the driver will only

see them when a problem occurs. For example, the fuel page may only be displayed if there is a low fuel level warning, or if one of the pump's current draw goes out of range. In this way the new colour display range takes the difficulty of hundreds of channels and breaks it down into small usable bites for the driver.'

In higher end applications, this is taken a step further with the use of telemetry. The new T2 telemetry system allows all telemetry data to be treated as normal logged data within the MoTec i2 application. 'This is where the pit crew take over from the driver to receive a large number of channels and use them to diagnose issues,' says Augustine. 'Within T2, the teams can setup many numbers of pages for different tasks, similar to what can be done with the display – a page for fuel, ignition, exhaust, voltage, etc.'

The new feature of this type of telemetry is that it is all logged data. The system can be used to zoom out, and look into the history of the issue or go back and see when the issue started to happen. T2 also has a complex alarm system that can automatically 'watch' all of these hundred or so telemetry channels live, and alert the crew of an issue well before they might have noticed it themselves.

The C185 retails in the UK for £2900 ex VAT. A 500MB logging upgrade and advanced functions upgrade retail for £608 each, while I/O upgrade and pro analysis upgrade options are £760 each.

Bosch's C60 data logger can help to implement any race strategy successfully

MoTeC's versatile C125 colour displays can show a wide range of data fields

BOSCH LOGS

All of Bosch Motorsport's products can operate standalone through standard interfaces, but the beauty of the Bosch systems is that they can be integrated by a single manufacturer and it all works straight out of the box – they boast of being a 'one-stop-shop' that offers a variety of products for data logging and analysis.

In Bosch's eyes, generating data is about sensor technology, So, the more precisely you know what your vehicle does, the better you can optimise it. To do that you need reliable data and sensors to provide it. To this end they offer a complete programme of the most varied sensors for capturing engine and chassis data. All Bosch vehicle electronics and every Bosch sensor can be configured using their all-in-one software, RaceCon. Offering straightforward PC connectivity from the control unit, it is easy to handle and allows you to access all of the compatible components.

Using a series of the company's specially developed data loggers – the C50 and C60 – alongside displays and control units with integrated data loggers, any strategy can be implemented successfully.

The Bosch software solutions for data analysis, WinDarab V7, provide the flexibility for analysing all types of data, with a multitude of calculations and display formats available.

'Regardless of whether you transfer your vehicle data in the box, via CAN, K-line, ethernet, or online using telemetry, we provide the appropriate solution,' says Annett Fischer of Bosch Engineering GmbH. 'With different wireless systems, and on request, on-site telemetry service with its own relay station, we ensure reliable and safe online data transfer on every race track.'

The conspiracy theorists will continue to speculate in America's Cup Land over what Oracle were really up to, but one thing is clear – to paraphrase Greg Norman – the more data you can analyse effectively, the luckier you get.

WHICH SYSTEM IS RIGHT FOR YOU?

Data acquisition systems answer questions, so the first task is to determine what questions you want to be answered. Are you wondering about the engine operating environment, and its overall health? Or do you want to understand the difference in control inputs from two different drivers? Do you need to know the temperatures, pressure, position or force of a particular component?

From this, you can determine what you might measure to provide those answers. You might start with capturing data from an ECU – engine speed, temperatures and pressures, perhaps a wide-band lambda value to indicate fuel mixture. Ditto if you need driver inputs: throttle position, brake pressure and steering wheel angle or perhaps steering torque, or gear lever pressure. There is almost no limit to what can be measured on the chassis – suspension positions and forces, tyre temperatures and pressures, ride heights, aerodynamic pressures, yaw rates, brake temperatures.

Usually, this is about where a budget creeps in – you may have to prioritise what answers you can afford to discover with your own empirical testing. With your list of measurements in hand, you can then determine the information resolution (smallest detectable change) and how often you need to data to be updated (sample rate). One degree and once per second for most fluid temps is fine, but if you're trying to optimise damper response over a kerb, you may need to measure damper position to .1mm updated 1000 times per second.

Next, examine the specs of the various data logger systems within your budget – do they have the capabilities you require? There may be other considerations – do you have existing data from one brand, or for amateurs? Is there a popular system where you might be able to share data (or at least get some user-to-user support) from other drivers?

Finally, evaluate the hardware and software features to determine the best fit for you. Download the software from the vendor website, look at the sample data – pretend you are answering your own questions. How easy is it to find those answers? Are you more comfortable using one brand over another?

A data system can be a large investment, but properly selected it can outlive a racecar, moving from one race programme to the next and expanding to answer new questions.

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Four-quadrant, fully active aero

Formula Student has proved to be a hotbed for engineering innovation – and one Texas university has used the open rules to come up with a unique aero package

BY JAMES P MERKEL AND DR BOB WOODS

The UTA wing solution is a five-element configuration with a slat, main plane and three flaps

The collegiate competition known as Formula SAE and Formula Student offers incredible engineering educational opportunities for students and prepares them for the motorsport – and indeed any other – industry. The rules are very open in order to encourage creativity and innovation. The University of Texas at Arlington has been at the forefront of some of this innovation, with the introduction of a combined hand clutch and shifter mechanism that allows for two pedals and left foot braking, the first introduction of electronic fuel injection, carbon composite wheels, the first full aero package with multi-element wings, several iterations of unsuspended aero packages, and now the first fully-active four-quadrant aerodynamic package.

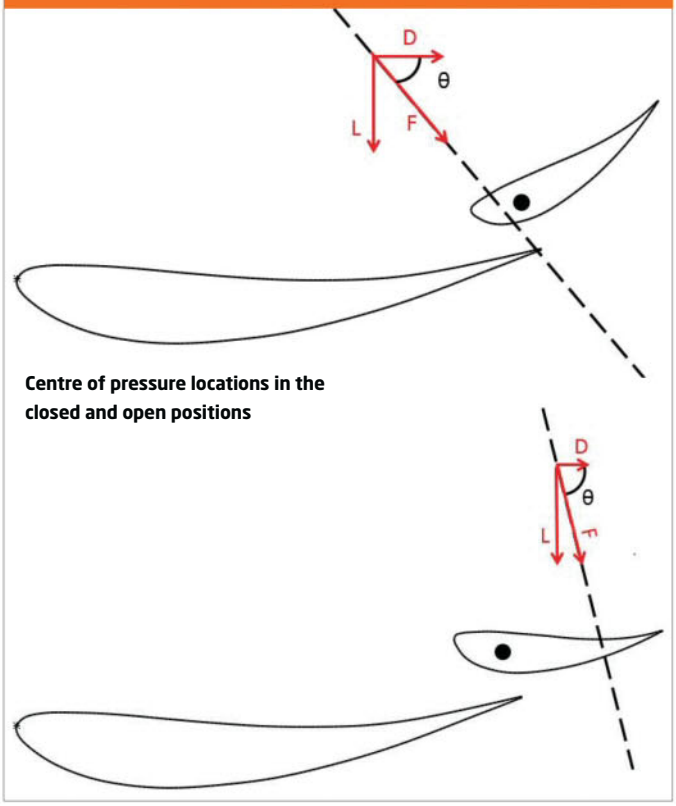
In Formula Student, wings and aerodynamic devices increase the downforce on the tyres and hence increases cornering and braking ability. This results in a net gain in points. There is a direct tradeoff between the downforce and the inherent drag that aerodynamic devices produce. In almost all racing series (except DRS in F1), moveable aerodynamic devices are prohibited. That is why FSAE is so important – we can do things that are technically correct in terms of engineering, but are prohibited by rules in other series.

The UTA wings have evolved into a five-element configuration with a slat, main plane, and three flaps. In 2011, the rules committee relaxed the rules regarding wing placement as well as minimum radii, which prompted massive aerodynamic developments for many teams.

UTA proceeded with a clean-sheet wing design which consisted of a two-step process. The first step was to start with an existing profile that had good lift and drag for low Reynolds numbers, and then modifying the wing profile using an inverse design technique to optimise the pressure distributions. Once we were happy with the wing elements, the second step was to develop an in-house genetic algorithm in CFD that put the elements in a grid placement, and then iterated their position and angle of attack to determine the optimum configuration of each flap that would maximise the lift coefficient, both in ground effect and free stream, for the front and rear wing.

The overall lift and drag coefficients for the wing profiles in the open and closed positions

FIGURE 1



Centre of pressure locations in the closed and open positions

are given in the following table. The front wing uses the same profiles, as the rear only operates in ground effect.

	CL	Cd
closed	4.27	1.56
open	1.78	0.30

The 2013 UTA FSAE car weighs 430lb and its modified 450cc single engine produces 59HP. With the wings closed, the maximum speed of the car is 70mph and with the wings open the maximum is 94mph. Even though top speeds are not seen on an SAE course, opening the wings in a straight line increases the acceleration by 0.1g at 40mph and 0.2g at 60mph.

In the active aero design, the top three flaps are moveable and can be set to fully open for a low-drag configuration, to a closed position for maximum downforce – as well as anywhere between. The flap positions are actuated by servo motors from the RC hobby industry.

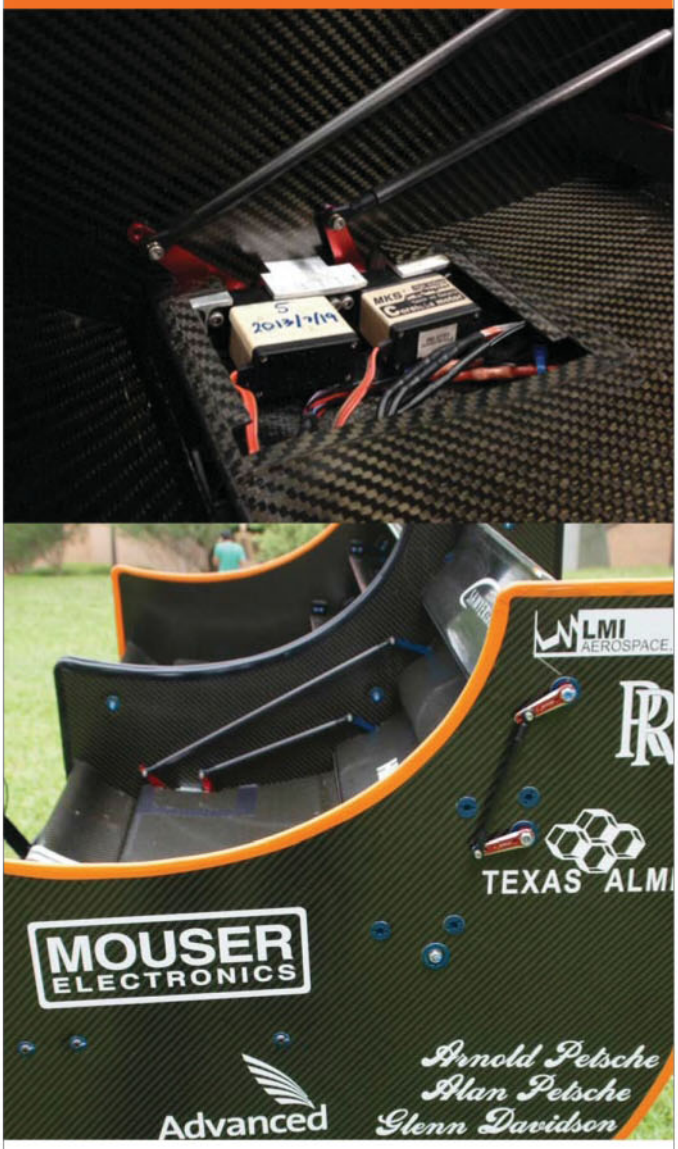
PIVOT LOCATION

The pivot location for the flaps is carefully selected using the local centre of pressure of each flap in the closed and open positions. In the closed position, the centre of pressure is near the front of the flap. In the closed position, the centre of pressure is near the back side of the flap.

The pivot location is placed between these two centres of pressure. This has several advantages for the articulation of the elements. First, the torque required to open and to close the wings is minimised and the two are equal. Reducing the torque will increase the speed of actuation. The CP location will also ensure that the elements can stay in their final positions aerodynamically without requiring any torque from the servo. Note that the wings in **Figure 1** are used for illustration only and do not represent the final design.

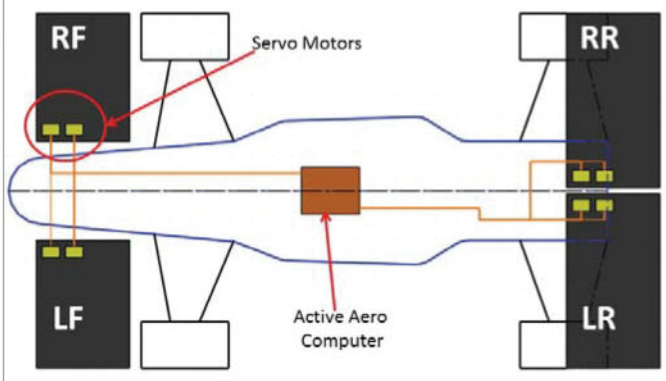
Figure 2 has photos of the rear wings illustrating the location of the servos and the mechanism connecting the flaps to the servos. The first flap is controlled by one servo, and since the top two flaps do not have as much moment on them, they are both controlled by the second servo and coupled together on the outside of the wing.

FIGURE 2



Implementation of active aerodynamic wings

FIGURE 3



Four wing quadrants of the 2013 FSAE car

With the wings open, the car can brake at 1.5g without any additional assistance

The wings are split into quadrants as shown in **Figure 3**. The front split is natural since the flaps are on either side of the front nose. The rear wing has a central end-plate to provide the rear split.

This allows for several control configurations. For acceleration or no significant braking, the wings could stay open to minimise drag. When the lateral g approaches the mechanical grip limit of the tyres, the inside quadrants of the front and rear wings could close. When the lateral g increases further, all four quadrants of the wings could close to produce maximum downforce. When the braking g exceeds a certain level, the rear wings could close.

The wings themselves are controlled by a microcontroller that takes in inputs from the car. We use lateral and longitudinal g as well as wheel speed to proportionally control the wings for a given track scenario. Each wing quadrant is then positioned according to a lookup table where we can dictate the wing position based on these parameters.

AERO ANTI-DIVE

We are studying different tuning control schemes and quantifying their benefits on track. One such effect that has proved beneficial is aerodynamic anti-dive during braking. With the wings open, the car can brake at 1.5g without additional assistance. If the braking g increases above a certain level, we can close the rear wings and put more downforce on the rear tyres. In addition to the increased drag, the lift and drag of the rear wings will generate 900lbs ft of torque about the front tyres of the car at 45mph to reduce dive. This is enough to squat the car uniformly at higher speeds than actually pitch the nose down. This also makes braking at high g more stable.

Closing the inside wings in a turn also provides an anti-roll effect. At 45mph with the inside wings closed, the wings produce a moment of 480lbs ft about the laden tyres.

The effects are very clear on the track and seem to be a correct engineering solution to enhance the use of aerodynamics on a racecar.

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Simulating to search for optimum stability

Armed with an equation, a couple of accelerometers, and common sense, the canny user can work out the stability of any car – a great tool for all engineers

EQUATIONS

Equation 1

$$C_m = \frac{-S.M}{\bar{c}} C_L + C_{m\delta e}\,\delta e$$

Where:

C_m	pitching moment coefficient
S.M	the static margin, the distance between the lift vector and the centre of gravity of the aeroplane
C_L	lift coefficient of the aeroplane
$C_{m\delta e}\delta$	moment coefficient due to the elevator
$\bar{c}$	mean chord of the wing

Equation 2

$$stbi = \frac{\partial N}{\partial a_y} \cdot \frac{1}{m_t \cdot g \cdot wb}$$

Here we have:

stbi	= the stability index
N	= lateral moment of the car in Nm
a_y	= lateral acceleration in g
m_t	= total mass of the car in kg
g	= acceleration due to gravity in m/s^2
wb	= the wheelbase of the car

Equation 3

$$N = \left((1 - wdf) \cdot a_{yf} - wdf \cdot a_{yr}\right) \cdot g \cdot wb \cdot m_t$$

Here we have:

N	= lateral moment of the car (Nm)
wdf	= weight distribution of the on the front axle (%age/100)
a_{yf}	= lateral accelerometer reading at the front of the car (g)
a_{yr}	= lateral accelerometer reading at the rear of the car (g)
g	= acceleration due to gravity (m/s^2)
wb	= car wheel base (m)
m_t	= total mass in kg

Equation 4

$$stbi = \frac{\partial N}{\partial a_y} \cdot \frac{1}{m_t \cdot wb}$$

$$= -295.58 \cdot \frac{1}{1340 \cdot 2.675}$$

$$= -0.0825$$

BY DANNY NOWLAN

Over the last couple of years, I have discussed a concept for classifying racecar stability, known as the stability index. This refers to a direct measure of the moment arm between the centre of the lateral forces acting on the car and the centre of gravity location. Before getting to the practicalities of this, it would be wise to review what the stability index is, and what it means.

The stability index is the automotive equivalent of the static margin and neutral point that is used extensively in aircraft longitudinal dynamics. The static margin is effectively the moment arm between the centre of lift of an aircraft (the neutral point) and the centre of gravity. This moment arm effectively determines the stability of the aircraft. Mathematically, an idealisation of the moments acting about the centre of gravity is given by **Equation 1**.

In summary, if the Static Margin – or S.M – is greater than zero, the centre of lift is behind the centre of gravity and the aircraft is stable. Essentially, you give it an input and it will return to a stable condition. If the static margin is zero then the aircraft is said to be neutral. That is – you give it a disturbance and it keeps on going. If the static margin is less than zero then the aircraft is unstable. If you give it a disturbance/input, it will snap out of control.

The automotive equivalent of the static margin is the stability index. This can be defined as **Equation 2**.

According to Milliken's racecar vehicle dynamics and my book, *The Dynamics of the Race Car*.

- **if the stability index is less than zero the car is stable**
- **if it is zero the car is neutral**
- **if it is greater than 0 the car is unstable**

While the concept of the stability index is pretty straightforward, calculating it can be very challenging. The challenge lies in calculating the lateral moment.

Table 1: GT GT3 parameters

Parameter	Value
Mass	1340kg
Front weight distribution	45.7%
Wheelbase	2.675m

Table 2: F3 calculation parameters

Item	Description	Value
Fm_1+Fm_2	Sum of traction circle radius for the front	5000N
Fm_1+Fm_2	Sum of traction circle radius for the rear	7000N
dC/da	Slope of the normalised slip curve	10
a	Distance of front axle to the cg	1.6m
b	Distance of rear axle to the cg	1.1m
wb	Wheel base	2.7
M_t	Total mass of the car	545kg

The most straightforward way to calculate the lateral moment is to fit lateral accelerometers to both axles

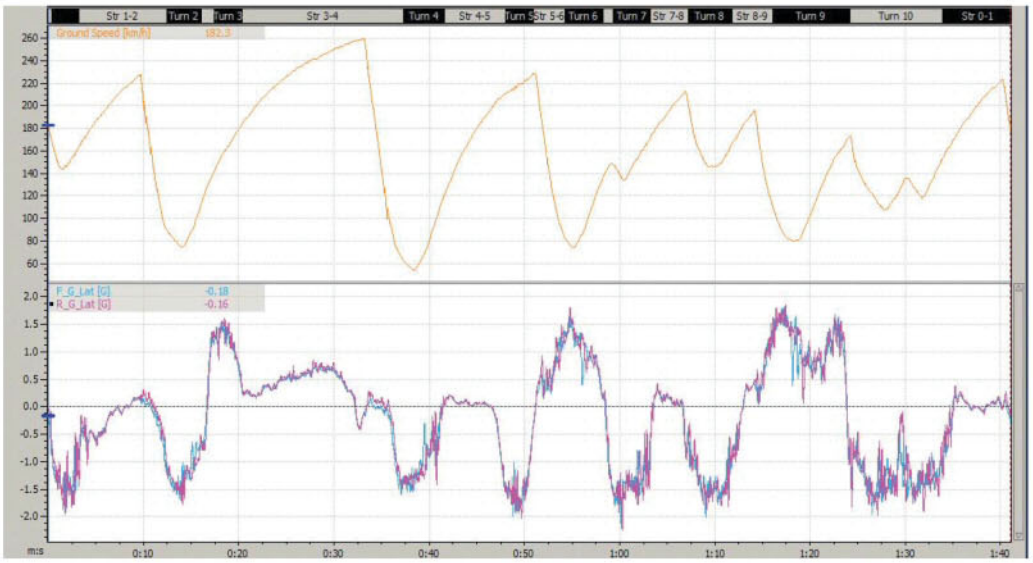


Figure 1: plot of lateral accelerometers and speed for a GT GT3 car

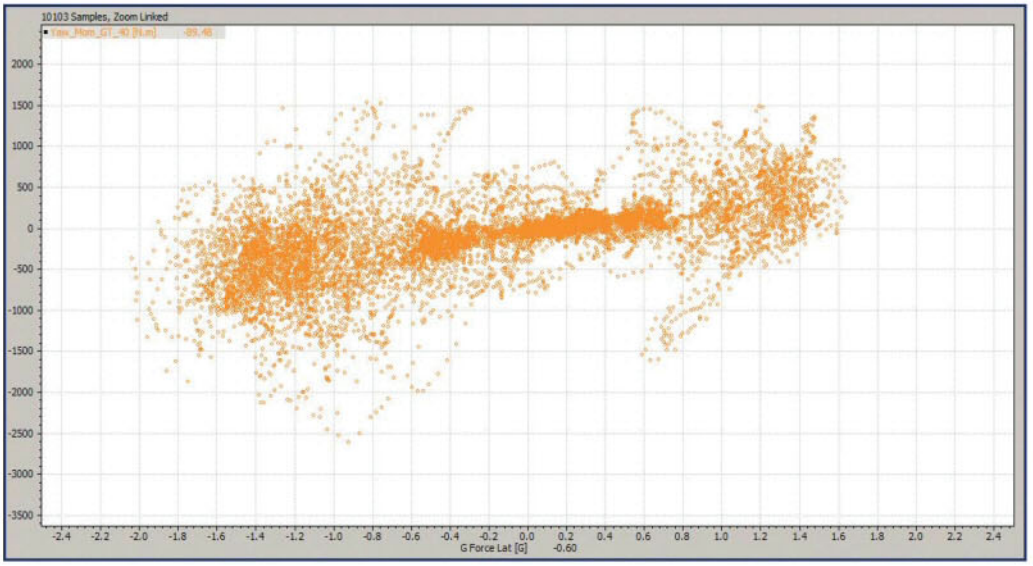


Figure 2: plot of lateral moment vs lateral acceleration for a GT GT3

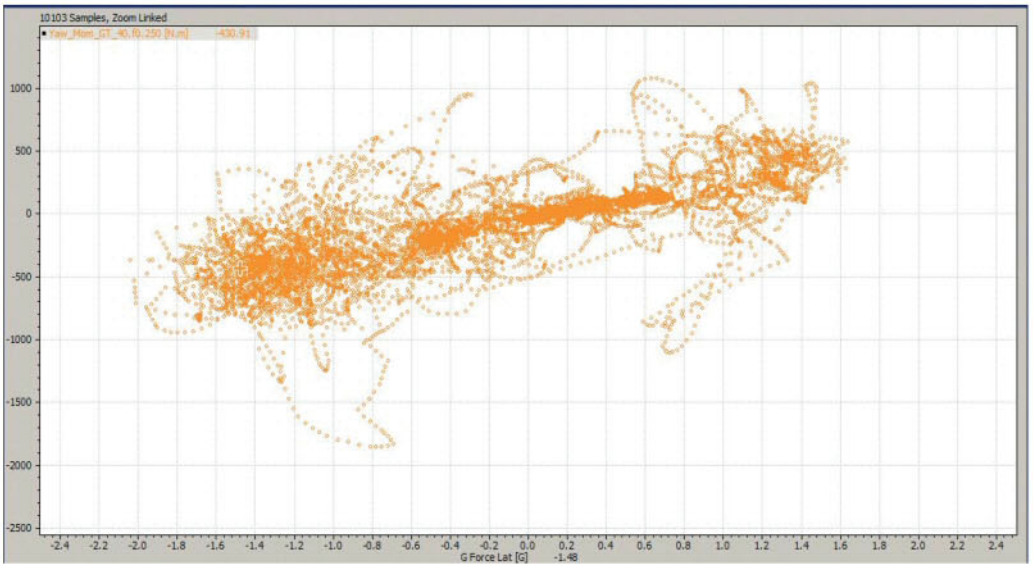


Figure 3: plot of lateral moment vs lateral acceleration filtered at 4Hz

One way is to have a yaw rate sensor and to measure the yaw rate derivative. This can be fraught with problems. The other way is to have strain gauges fitted to the suspension component arms. This can work relatively well on an open wheeler – but in this instance you are at the mercy of the quality of the strain gauges.

However, the most straightforward way of doing this is fitting lateral accelerometers to both axles of the car. In this case measuring the lateral moment becomes really simple. This is shown in **Equation 3**.

It would be wise to take a moment to consider the validity of what we are looking at. Let's consider how an accelerometer works. Typically you have a piezoelectric device that is moving. This creates a movement which in turn generates a voltage. This voltage is proportional to the acceleration or forces applied around it, which is typically what happens at each axle of the car when a force is applied.

However, the real clincher comes from looking at actual data applied when accelerometers have been fitted to both ends of the car. The data I'm about to present to you is from a Ford GT GT3. The relevant details of this car are summarised in **Table 1**.

Being a mid-engined car, most of the mass is located in the middle of the car. There is a bit of mass hanging over the rear axle, but not a lot over the front. This all being said, let's look at a data trace from a lap with the accelerometers fitted to the front and rear. This can be seen in **Figure 1.**

The first plot is speed and the second plot is front and rear lateral acceleration. The front lateral g sensor is shown in blue and the rear lateral g sensor is shown in purple. While the values are similar, there are very distinct and repeatable differences between the two traces. What all this means in plain English is that not only is **Equation 3** valid, we're about to see how we can use this to evaluate the stability index.

In order to evaluate the stability index, we need to be looking at the slope of lateral

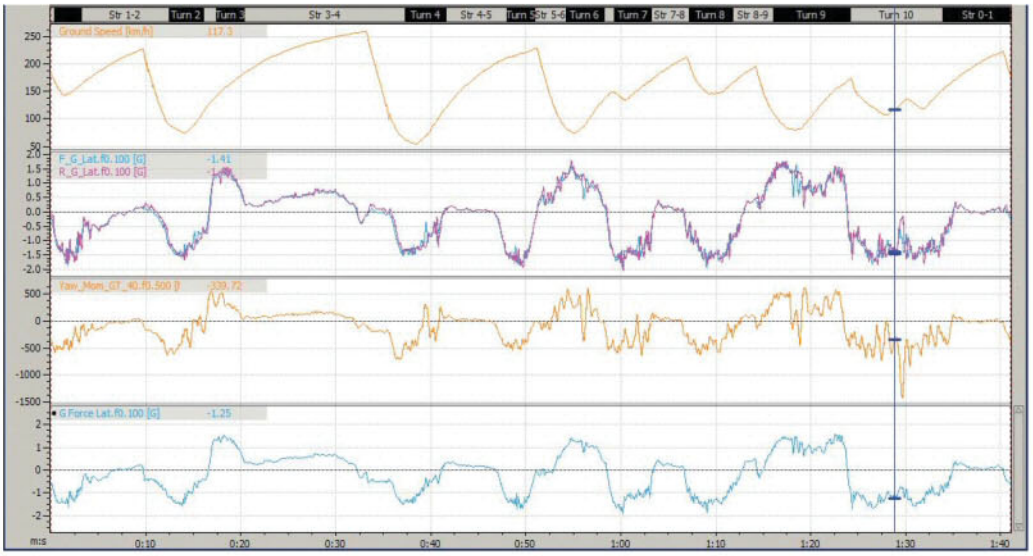


Figure 4: time plot of lateral moment and lateral acceleration

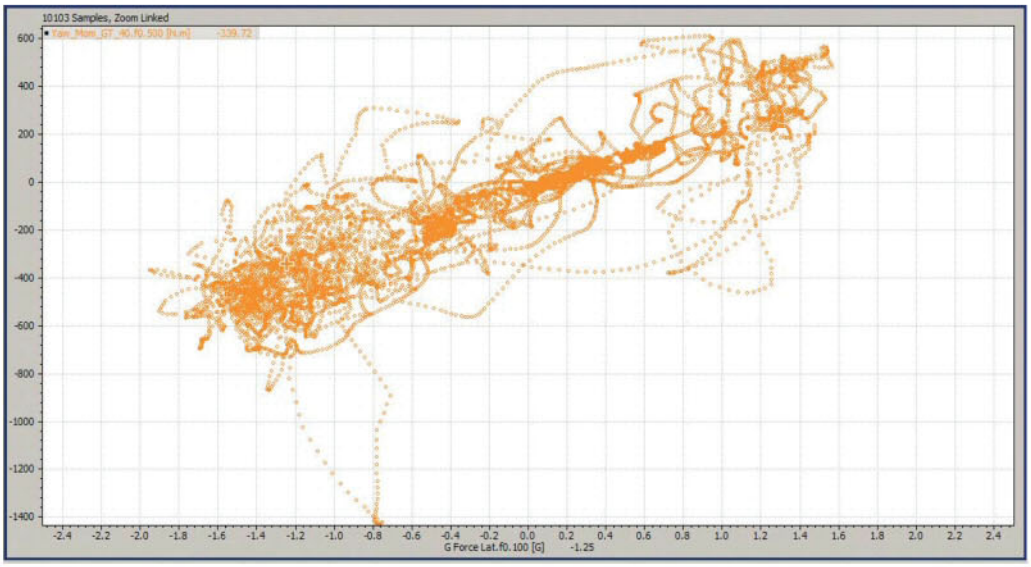


Figure 5: revised plot of lateral moment vs lateral acceleration with further filtering

moment vs lateral acceleration. The slope of this curve gives us the stability index. For the GT GT3, this plot of lateral moment vs lateral acceleration is given in **Figure 2**.

Just a quick note on **Figure 2**: the math channel should be expressed as Nm/g. I've set it up this way to make calculating the stability index easier. When this goes up, it indicates stable behaviour given that the lateral accelerometers are positive in a left-hand turn. However, when plotting this out, things become a little fuzzy around the edges, which muddies the waters.

To resolve what is going on at the limits of performance we need to do a bit of filtering of the signal. However, the question has to be asked – how much? To resolve this we are going take a bicycle model of an F3 car and put in some rough numbers to see where we are. Our goal here is to see the magnitude of the natural frequencies we are dealing with. The parameters for our calculation is shown in **Table 2**.

Solving for the eigenvalues and eigenvectors for the bicycle model of this, we wind up with a natural frequency for the yaw mode. This is what the driver would feel with the car understeering/oversteering, of about 8.7 rad/s or 1.4 Hz.

Consequently, applying a 4Hz filter to the data clears up things considerably. This is shown in **Figure 3**. As can be seen, a lot of the noise that was seen in **Figure 2** has been filtered out here and a definite straight line has emerged. The slope of this line is the stability index. It is sloping positive upwards, and given the fact the lateral acceleration is positive for a left-hand turn. This is absolute iron-clad proof that the car is stable and driveable.

The last step of the exercise is to curve fit this data to determine the stability index. All you need to do is perform a data export at 50Hz, plug the numbers into something like Microsoft Excel, and conduct a curve fit. Doing this for the data in hand yielded a slope of 295.58 with an R squared value of 0.5528. At first that might not seem that impressive, but if you were to expand **Figure 3**, that slope is right down the line between +/- 0.8g which shows that we are on the right track.

Also, if you expand that line to the upper g limits, the points are right in the middle which shows a clear and distinct trend. The last point in the exercise is to calculate the stability index – this is shown in **Equation 4**.

What this all means is that the centre of the lateral forces is 8.25 per cent of the wheelbase behind the centre of gravity.

One thing that needs to be commented on is the noisy nature of this signal. As the car is going over bumps and being subjected to other disturbances – such as driver inputs – these trends will not fall on a perfect line with an R squared value of 1. However, from **Figure 2** we could start to see a trend emerge and by **Figure 3** the curve fit was in the middle of the plot. While not perfect, it was a clear sign that we where on to a good thing.

I filtered the yaw moment signal at 2Hz and the lateral acceleration signal at 10Hz. The plot from the lap is shown in **Figure 4**.The two plots to pay attention to here are the third and fourth. The third plot is lateral moment, and despite the heavy filtering we can still see good stable variation which shows us that we haven't over-filtered the signal. The last signal – which is the a_y plot – has been filtered at 10Hz which has tidied this up. The revised x-y plot of this can be seen in **Figure 5**.

SLOPE STUDIES

In this case the slope shifts to 293.4 and the R squared value is now 0.74. Given the close correlation of the slope that we achieved with **Figure 3**, this shows us that this is something that should be seriously considered in any analysis work.

When the car is being driven on the edge, the natural steer vs actual steer plots will complement each other. If there is a difference, then that's your cue to do a bit of digging.

Using accelerometers on both axles of the car is a very expedient and powerful way of determining the stability index and driveability of the racecar. The procedure is very simple: attach the accelerometers, use **Equation 3**, filter the yaw moment data at 4Hz and play with the filtering of the lateral acceleration and moment signal.

Aquila's social engineering project

The latest car from the popular Danish firm has been designed with input from fans and enthusiasts – and the winning bodywork design will be unveiled at ASI

The name Aquila may not immediately spring to mind when you think of current racecar constructors, but the small Danish firm has continually impressed with its products in recent years. It first came to prominence with its Formula Ford Zetec design which this publication described as 'probably the most innovative Zetec-engined racecar ever built'. It followed that up with a sports racing car, called CR1. This is now regularly seen at the head of the field in a number of open sportscar championships, such as the GT Open series.

Now the company is following up with a brand new sports racing car – the Adamo.

'At the Autosport Show last year we felt that we needed to introduce a new model, so we asked people there what they wanted to see,' explains Paul Hill, head of sales and marketing at Aquila. 'Our main goal was to create the customers' car, an affordable car based on that direct market research.

'A new trend was spotted by our marketing team, which was the need for a smaller, lighter, less powered sportscar. This trend appeared bigger than we originally thought. Not everyone wants a two-seated all-out high-powered V8 sportscar like the CR1 sports GT. So we sat together and planned the best way to start such project. We discussed finding the right suppliers, the level of performance, the competition, potential customers and we found ourselves coming up with the same question. What do our customers actually want?'

The survey revealed that 67 per cent voted for the car to use a single seat, 73 per cent voted for an aluminium monocoque, 93 per cent voted for the car to use sectional bodywork like the CR1, and the majority asked for an Inline 4 engine delivering between 200-250hp.

SAFETY FIRST

'The chassis has been designed around keeping the driver safe while following regulations and guidelines that all modern racecars must use in order to compete,' continues Hill. 'We will use a crash box in the front of the car which has already been successfully tested through computer simulation, a very rigid monocoque alongside FIA grade equipment such as the fire extinguisher and fuel cell.

'The car itself will use many of the same concepts currently used on the CR1. For instance, sectional bodywork was indicated as one of the most loved aspects in our survey. Other traits we will duplicate on the new car are the mechanic-friendly, universal and non-handed parts, simple design, and low-maintenance features to encompass race budget-friendly ideas. As with the CR1 we will aim to give the car a superior centre of gravity over our competition and gain an advantage on track. We will not be developing any carbon fibre diveplanes, flooring or splitters. As racing enthusiasts, we admire low budget racing and believe parts that are likely to receive frequent damage should not be expensive to replace. That also means strictly no 10,000rpm motorbike engines!'

The car will use the Hewland FTR transmission which is almost a standard fit in this type of car. Power will come from a Toyota 3ZR-FET, which is a 3ZR-FE with a turbo added for racing use. 'Dampers and brakes are not yet decided. However, due to the nature of our marketing we no longer need to go out and approach companies about their products,' says Hill. 'At the start of the project we were very busy negotiating with suppliers, but more recently we have been receiving frequent emails from companies wanting to be involved in the project. With main components organised, early indications suggest that we will hit our weight target of sub-600kg, which will give us a competitive power-to-weight ratio.'

But while the chassis concept was complete, it still lacked bodywork, a gap that Aquila has solved with a fascinating and innovative initiative. 'While hundreds of ideas for the car's styling have been thrown around the office, one idea from the design team topped them all,' says Hill. 'The best way to truly make our next product the true customers' car, is to let our fans design the bodywork!'

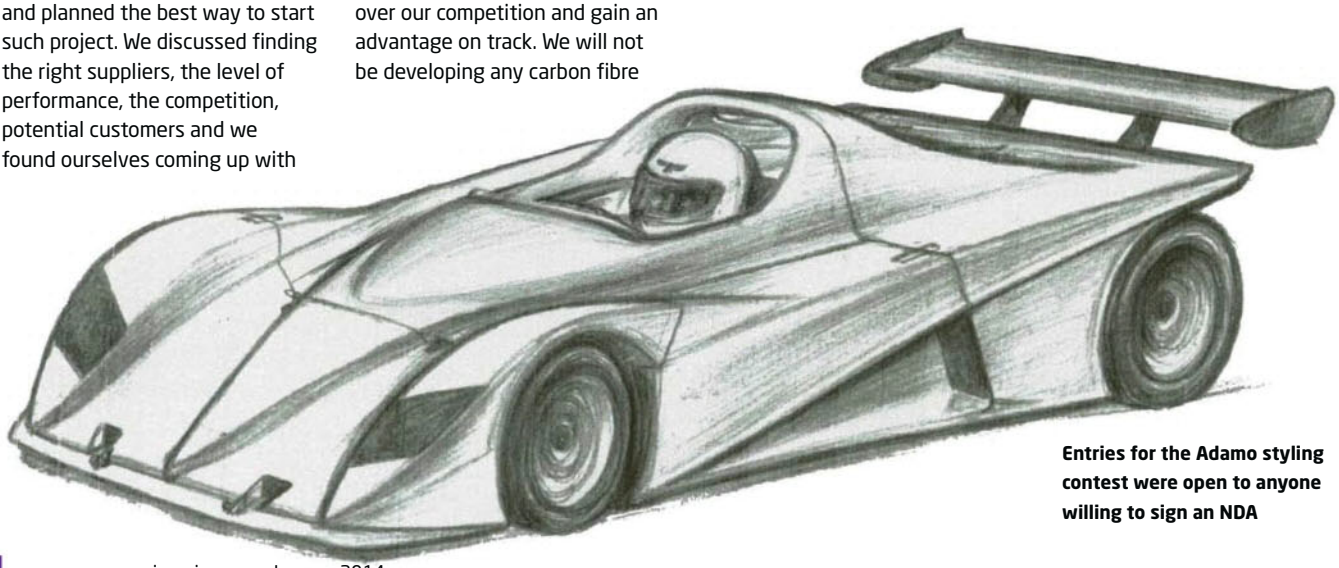
Aquila held a competition open to anyone willing to sign an NDA. 'We wanted to attract anyone from amateur designers, bored engineers or even skilled enthusiast with a flair for design and styling. Equality was important in the process and so any questions asked by entrants were made public so that all entrants could see the answers to questions asked by their competitors.'

After entrants signed the NDA, they were supplied with a CAD model of the complete car, or on request entrants could get a three-view chassis drawing to scale from.

Once completed designs were received, the Aquila staff judged them based on legality, attractive aesthetics, efficient aerodynamics, low manufacturing costs, low repair and maintenance costs as well as practical use and user friendliness.

Seven designs were shortlisted, and the finalists are: Alexander Hastrup, Anders Lynge, Chris Williamson, Lars Roug, Matthew Storie, Michael Witus Schierup and Niels Peter Kofoed.

The winning design for the new car will be revealed at the Autosport International Show.



Entries for the Adamo styling contest were open to anyone willing to sign an NDA

SHOW-STOPPERS

DEBUTANTS

Spanning every possible application and level of motorsport, a growing list of over 50 first-time exhibitors will be present at Birmingham's NEC in January for Autosport International 2014.

Representing an unmatched opportunity to see what will shape the new season, more than 400 exhibitors have already booked their place at the show, where over £1bn worth of new business was generated in the motorsport and high-performance engineering industries earlier this year.

On the two dedicated trade days, 9-10 January 2014, Hall 9 will host Autosport Engineering in association with *Racecar Engineering*. Among the new exhibitors, EEC Performance Systems will launch its f-POD Intelligent Race Fuel Bowser (see p83).

Utilised in a variety of sectors, ANSYS offers a full suite of industry-specific engineering simulation software, while other local, first-time exhibitors include JTinnovations, ML Electronics Ltd, Nexus (GB) Ltd and ODU UK.

Germany, Italy, the USA and Czech Republic are represented through the likes of AC Tech GmbH, Aliant UltraLight Battery, Injen Technology and CaseLiner.

Innovation will be on display across all four days in Hall 8's Trade and Technical Area, including companies such as Hifi Filter, KAPS Technology, Minitec and Performance Engine Components.

Meanwhile, the dedicated National Motorsport Area in Hall 7 is set to host newcomers including BTN Turbo and VisionTek. Look out, too, for represenation from the Atom Cup, following its successful maiden season in 2013.

'It's exciting to see so many new exhibitors booking their place at the show,' says Autosport International Show director Ian France. 'It's also a great sign of the strength of the industry, both locally and globally.'

'Across our new and existing exhibitors, a diverse range of companies will join us at the NEC, and there are many new product launches in the pipeline: I'm looking forward to walking around the show in January and seeing everything first-hand.'

GENERATION NEXT

Autosport International will again help the next generation of Adrian Neweys and Ross Brawns find their way into the sport, with a dedicated Careers in Motorsport section, alongside the show's networking opportunities and the scope to see the industry's latest developments.

A host of universities, colleges and specialist training providers will be at the show across the four days in Halls 7 and 8, ready to provide insight and advice to visitors considering a career in motorsport.

Oxford Brookes University, University of Dundee and University of Central Lancashire are among those to have already signed up.

'It's about networking as much as promotion,' says Dr John Calderbank, principal lecturer at University of Central Lancashire. 'On the trade days, we can meet racing championships and teams, and chat with students that have applied to other universities.'

The UK motorsport sector employs approximately 40,000 full and part-time staff, including 25,000 engineers. Many companies, such as DC Electronics – which launched its Motorsport Electronics Engineer Training Programme at the 2013 show – offer training and employment opportunities.

Students undertaking an engineering or motorsport related course and aged 18 or over can register for Autosport International's trade days for £26. For the show's public days, 11-12 January 2014, tickets are available from £20.

So why delay? Visit **www.autosportinternational.com** now for trade registration.

In association with Racecar engineering

Be part of the future of energy-driven motorsport and automotive development

The world's leading high performance low carbon conference returns to Birmingham NEC on 8 January.

Hosted by the Motorsport Industry Association (MIA), and now in its eighth year, the International Low Carbon Racing Conference has long been recognised as a powerful forum for those at the forefront of vehicle-based energy efficient innovation. It gathers leading figures from bodies such as the UK Automotive Council, from motorsport, automotive and beyond under one roof for an entire day of announcements and in-depth panel discussions covering past successes, new ideas and developments, future plans and new business opportunities.

The 2013 conference attracted more than 170 delegates from in excess of 100 organisations, and this year looks to be even more successful.

Distinguished names from previous panelists have included Alejandro Agag (Formula E), Ulrich Baretzky (Audi), Ben Bowlby (DeltaWing Racing Cars), Nick Fry (Mercedes AMG Petronas F1 Team), Tony Harper (Jaguar Land Rover), Patrick Head (Williams Grand Prix Engineering), Thomas Laudenbach (Porsche), Richard Parry-Jones CBE (Automotive Council), David Richards CBE (Aston Martin, Prodrive) and Graham Stoker (FIA).

The day's proceedings will be underscored by a stunning in-room showcase demonstrating the very latest low carbon advances, and allowing all in attendance to explore cutting-edge vehicles and technology from some of the leading names in motorsport and automotive, up-close.

The central theme for 2014 is the now-proven success of alternative energy powertrains, on racetracks and roads across the globe. The past 12 months alone have represented a key milestone in this energy-efficient journey, bolstered by significant international achievements in Le Mans, Pikes Peak and others.

This is a trend set to continue into 2014 and beyond with leading global race series including Formula 1, United SportsCar and World Endurance Championships placing even greater emphasis on energy efficiency and, of course, Formula E launching in September.

With mainstream automotive also fully embracing the genuine value of motorsport, a rapidly increasing number of production cars from the likes of Audi, Jaguar, Nissan and Volvo – to name only a few – boast 'race-bred' low carbon innovations.

As such, motorsport – both as a powerhouse of innovation, and a vehicle to promote change – has had a significant impact which transcends industrial or international boundaries.

Visit the MIA's eighth international Low Carbon Racing Conference to celebrate this success and learn – first-hand – how this is set to continue into the future. You'll be able to express your views and ideas, direct questions to expert panelists, and experience the very latest innovations.

For further information, contact **Carrim Bundhun** (carrim.bundhun@the-mia.com) or visit **www.the-mia.com** to secure your attendance.

AT's redefined dry sump system

AT Power, in conjunction with GB Enterprises, has designed and redefined the Mitsubishi 4G63/4 Dry Sump System.

With 800-1000bhp now becoming the norm for this engine and speeds in excess of 10,000rpm, AT has redesigned all areas of the kit.

Recently the company has designed kits that have internally driven pumps, which completely eliminates the need for vulnerable external belts and pulleys.

Its sump design has also taken on a new ethos with internal scavenge galleries, which means that the pan can be shallower with no external trough, and – more importantly – there is significantly less pipework and less chance of a leak path.

The pump itself has been mounted on to the pan and in the front cover which houses the

drive for the pump – removing the need for a mounting bracket.

The pressure stage is now at the front of the engine, along with the PRV for ease of adjustment and packaging. This does not exceed the packaging of the commonly used ATi Super Damper.

The kit has been machined completely from Aircraft Grade Billet aluminium and comes complete with a set of ARP fasteners for fitting.

Visit AT in **Hall 9, stand E490** or see **www.atpowerthrottles.com** for more info.

Brand new Tec from ATL

On display at ASI will be a number of new racing fuel system products from ATL – Aero Tec Laboratories. The Bletchley, England-based firm manufacture composite bladder devices and fuel transfer systems.

First up is their new Saver Cell Cap (pictured). It is lightweight and made from billet-machined alloy, and boasts an improved sealing mechanism. With a comfortable grip, it's designed for ease of use and has a sporty look and anodised finish which will complement all racecars.

Next in the new lineup are revamped internal collectors. Featuring a 3-litre capacity, they have ATL one-way trap doors and guiding vanes, which direct and trap fuel under acceleration and cornering force, yet retain fuel under braking forces.

The collectors can be supplied with single or double quick-

release pump mount straps, for quick and easy pump installation and removal, and can be retro-fitted to any ATL Saver Cell from 30-170 litres.

Also on display at ASI will be ATL's new I/D FIA/ACO refuelling rig hose. Featuring a smooth bore for improved speed, and an integral helical electrical bonding coil, it's supplied in 5m or 10m lengths and is fuel resistant to high concentration e-content fuels.

Visit ATL at **stand 8405** or see **www.atlltd.com**.

One-piece carbon wheels

Autosport International will host the UK launch of the world's first one-piece carbon fibre wheel to enter production, through Australian firm Carbon Revolution.

It uses carbon fibre reinforced plastic (CFRP) – a super-strong and lightweight material, typically three times stronger and stiffer for its weight than steel, aluminium or titanium.

The CR-9 Series offers weight savings of 40-50 per cent over aluminium equivalents, with 19-inch wheels weighing as little as 7kg, to deliver improved performance and fuel economy.

Initially aimed at top-end motoring, with vehicles such as the Porsche 911, Audi R8, Lamborghini Gallardo and McLaren MP4-12C, motorsport is firmly in the future plans, along with aerospace applications.

With its background in advanced materials R&D and vehicle engineering, the carbon composites specialist's first wheels appeared in Formula SAE competition nearly a decade ago, and its technical partners include the local Deakin and RMIT Universities.

'We look at it as an efficiency technology,' said Brett Gass, Carbon Revolution's engineering director.

'When you can look at two-to-four per cent fuel economy savings by a bolt-on, retro-fittable technology, the auto industry should be very interested in that.

'From a vehicle dynamics perspective, if you want to improve performance efficiency, this is the place to start. When you do the materials selection, you want something that doesn't fatigue, is robust and doesn't corrode – and here we came up with carbon fibre.'

Visit **www.carbonrev.com** or **Stand 6575, Hall 6**.

Quaife's new range for 2014

RT Quaife Engineering Ltd, a long-term ASI exhibitor, will be debuting a portfolio of new high-performance drivetrain products for the 2014 season on stand number 8500.

Arguably the most exciting of Quaife's 2014 range is a five-speed sequential gearkit for the Mitsubishi Lancer Evolution V-VIII models. Designed to offer ultra-rapid gearshifts while retaining the original gearbox casing to reduce cost and improve packaging, the unit features an uprated five-speed geartrain and replacement tailcase which houses a state-of-the-art Quaife sequential shift mechanism.

Quaife will unveil the pre-production version of a sequential gearkit for the new Lotus Elise S Cup R, which uses the 1.8-litre 2ZR-FE Toyota engine. Quaife's design offers six close gears with bespoke internals inside the original Toyota maincase and a large choice of ratios – making it ideal for circuit use.

Switching to the ever-popular Ford marque, the production version of Quaife's QKE38Z Ford IB5 sequential gearkit for Fiesta, Focus and Ka models will also be on display, as will the definitive version of the innovative QBM1M in-line four-speed sequential transmission which incorporates a drop gear package for fine tuning on oval circuits.

Quaife will also unveil new Automatic Torque Biasing differential applications at ASI 2014, including a fitment for the Subaru BRZ/Toyota GT86 coupes.

For more info see **www.quaife.co.uk** or visit **stand 8500**.

Latest Variohm sensor

The new Hall Effect sensor from Variohm EuroSensor has a programmable angle and a well-proven design, and is absolutely ideal for all extreme motorsport applications.

With its characteristic curve, a choice of housing materials and shaft options, the Euro XP series angle sensor offers the motorsports user a wide range of built-in and optional features that maximise its cost-effective use in position feedback applications – taking in sequential gearbox, throttle and steering angle measurement.

The Euro XP has an industry-favoured ratiometric output from a nominal 5V DC supply and a redundant dual-track 360-degree measuring range which can be factory programmed for angles from 30-360 degrees for both range and curve. It's highly accurate and can provide an independent linearity of +/- 0.5 per cent of each signal range, with repeatability to better than 0.2 per cent.

The sensor element – supported in a robust bearing arrangement – is available in a choice of anodised aluminium or high temperature-resistant plastic-sealed housings that both meet IP67 environmental ratings and may be used at short-term ambient temperatures up to 150degC.

Visit Variohm at ASI in **Hall 9, stand E280** or see **www.variohm.com** for more details.

Intelligent race fuelling

Weighing specialists EEC Performance Systems have announced their new f-POD Intelligent Race Fuel Bowser. Designed with input from one of the UK's leading single-seater teams, it has addressed all of the issues it was tasked with. With a UK base and technical support, it claims to offer much more than anything else on the market.

The 10.2in full-colour touchscreen PC, combined with EEC's inspired, step-by-step graphical instructions, means that the f-POD is easy to use, making refuelling errors a thing of the past.

The f-POD can run multiple drivers simultaneously, recording a data history, which is available to view instantly on screen and to download via USB.

EEC's patented ATC system ensures that the f-POD weighs fuel accurately at any circuit in the world without the need for recalibration.

With safety a priority, all of the electronic components and battery are housed in a sealed steel cabinet to eliminate any possible spark risk. The pump utilises an explosion-proof motor and ancillary components are ATEX approved. The f-POD is CE marked and meets all current applicable directives.

Visit EEC at the Autosport International exhibition **stand E342**, or see **www.eecperformancesystems.com** for more information.

Corsa engine dry sump kit

AT Power, alongside their new Mitsubishi 4G73/4 Dry Sump System (see left), has also added to its range with a Dry Sump Kit for the Vauxhall X16 XE engine, commonly used for the Super 1600 class in Rallying.

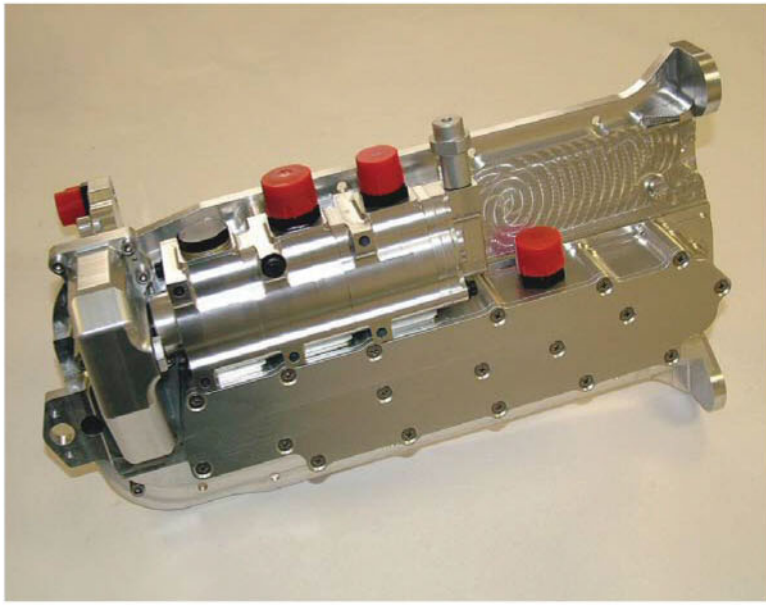
This kit has been designed to lead the way in the future of dry sump engines. With a semi-integrated pump that locks into the scavenge trough of the sump pan, you can see just how compact this kit really is.

It's lightweight and compact and machined from billet aircraft-grade aluminium. There are no external drive pulleys or belts, and no external scavenge hoses or fittings required from pump to sump.

The pump is internally chain-driven, and is duel ported for a stable oil flow at higher RPM, while there are ARP fasteners throughout the pump.

AT Power's full range of kits also take in Ford Duratec and Sigma, as well as the Vauxhall 20-litre XE, Honda K20 and Mitsubishi Evo.

Visit AT in **Hall 9, stand E490** or see **www.atpowerthrottles.com** for more info.



TICKET INFO

Trade registration for Europe's largest dedicated motorsport trade show is available now exclusively through the show's website – **www.autosportinternational.com**.

With Thursday and Friday 9-10 January 2014 exclusively reserved for members of the industry, and taking in Autosport Engineering in association with *Racecar Engineering*, registration starts from £26, and includes a Trade Directory.

Trade group discounts are available, with tickets £24 for groups of 11 to 20 people, £23 for groups of 21 to 50 people and £22 for groups of more than 51 people.

Marussia secures long-term Formula 1 future with new deal

Marussia believes that the new agreement it has signed with Bernie Ecclestone will not only secure its place on the Formula 1 grid, but will also help it attract further sponsorship.

The Banbury-based outfit is the last of the 11 Formula 1 teams to sign the deal with Ecclestone, which is thought to amount to a commitment from Marussia to race in F1 until at least 2020.

While the details of the deal are confidential, it is believed that Marussia will now gain a guaranteed payment if it does not finish in the top 10 of the constructor's championship – a result that would qualify it for a share of F1's prize fund. This is thought to be a feature of the agreements other teams have signed and is known in the sport as a 'Column 3' payment.

Marussia sporting director Graeme Lowdon said that the benefits of the agreement went far beyond the Column 3 payment, however, and that among its main advantages would be one of perception when it came to finding sponsorship. 'I think in all honesty the biggest difference is how we're perceived in the outside world,' Lowdon said. 'It was a very strange situation when most of the teams in Formula 1 – in fact, all of the teams – had an agreement with the commercial rights holder, apart from our team.

'It quite clearly would lead to questions when we're looking at potential partners and sponsors for the future. Probably the biggest thing is that external perception. We're perceived to be on the same grid and in the same pitlane as every other team now, and it's removed some of that uncertainty and will allow us to focus on what we should be focusing on, which is going racing.'

At the time of writing Marussia – which started its F1 life as Virgin Racing – was 10th in the Constructors' standings, in front of fellow tail-end team Caterham by dint of one 13th place finish.

LAT

The new deal is thought to commit Marussia to F1 until at least 2020

Dallara celebrates new Indy Lights chassis deal

Dallara has strengthened its near-monopoly in top level world single-seater racing with the confirmation that it has been chosen as designer and constructor of the next generation Indy Lights chassis.

The Italian company's design, which is to be called the Dallara IL-15 and is scheduled to race in 2015, was chosen over two other proposals for the new spec chassis – the current racecar, also a Dallara, has been used since 2002.

Dan Andersen, the owner and CEO of the company which runs Indy Lights, Andersen Promotions, explained that Dallara clinched the deal because its proposal was cost-effective, contemporary and safe, while also being capable of reaching the 200mph speeds required.


LAT

The old car (pictured) is scheduled to be replaced in 2015

Anderson said: 'The new Dallara IL-15 Indy Lights racecar will offer great style, current technologies and of course Dallara's well-earned reputation for building safe, reliable racecars. We are pleased with the final pricing structure and the various discounts provided by Dallara, and believe our teams and drivers will get excellent value and a terrific racecar.'

The IL-15 comes with a number of price incentives, such as a measure to give teams contesting the 2014 championship a reduced rate on chassis if they order a new 2015 car by March of 2014.

Dallara is also to hold a 'January sale' to allow teams to stock up on spare parts at lower prices before the start of the season, as well as offering to spread costs over a three-year period to defer initial ownership expenditures.

Dallara will now also present a $25,000 prize to the Indy Lights champion at the close of the season.

The company is set to build its new Indy Lights car at its Indianapolis factory and testing is to start in August of 2014.

The news that Dallara has been given the Indy Lights contract once again confirms the company's place as the major player in the sub-F1 single-seater world, with its cars making up the grid in all the major championships bar Auto GP (Lola), while its F3 machines are also dominant across the globe, both in numerical and performance terms.

New TOCA entry licence scheme applauded by teams

British Touring Car Championship team bosses have welcomed the introduction of entry licences for race teams wishing to take part in the hugely successful tin-top series.

Teams will now have to obtain a TOCA BTCC Licence (TBL) before they are allowed to compete in the championship, in a move that's aimed at recognising the commitment of current teams while discouraging others from lodging entries which fail to materialise – something of a problem at the start of the 2013 season.

There will be a maximum of 30 TBLs available, each of which is in effect a franchise, at no cost to the teams, and these will be dished out in line with the following order of priority. Firstly, existing teams that competed in at least 50 per cent of the 2013 season with NGTC cars will have an automatic entry for the same number of cars in 2014.

After that, existing teams with two or more NGTC cars will also have priority for one additional entry. The next in line for inclusion would be existing cars, followed by new entries.

Teams successful in gaining TBLs will be expected to compete in all the races in each season entered. Any team missing two events will lose their licence, although teams will be allowed to sell their TBLs to another outfit for a single season, subject to TOCA approval.

Also, in an effort to cut down on the seat swapping that became a feature of the 2013 season with some squads, each team will now only be allowed to make one change of driver per season.


LAT

BTCC team bosses welcomed the move. John Welch, team principal at Welch Motorsport, told *Racecar*: 'I think it's quite a good thing. There's been a lot of grief to get the new generation cars up and running and sorted out technically. We've been involved with this for three years, and it's been quite hard graft. I think TOCA has come up with this idea to reward the people who have been in from the beginning, so at least we've got a bit of stability for a business.'

Dynojet team principal Frank Wrathall was also in favour: 'I think TOCA had to do something. It's a discredit to a championship when you've got teams putting out different drivers in each round – it looks shabby.'

Market forces nudge DTM further east

Two classic race tracks have been cut from the DTM calendar for 2014 to make way for circuits which better suit the marketing needs of the competing manufacturers.

Both Brands Hatch and Zandvoort are now to be replaced with races in Hungary and China. The Hungarian race will take place at the country's Formula 1 venue – the Hungaroring – while the location for the Chinese race has yet to be decided. Moscow and Spielberg (Austria) will retain their places on the calendar.

DTM boss Hans Werner Aufrecht said that while Brands and Zandvoort had proved great venues for the series, Hungary and China offered new marketing possibilities. 'We witnessed great races at these circuits and have to say thank you for the good cooperation,' he said. 'In 2014, however, we want to turn towards other interesting markets.'

The DTM last raced in China in 2010 using a Shanghai street track, but for 2014 will race either in Shanghai or at the Guangdong circuit. 'The Chinese car market is one of the fastest growing markets of the world and, therefore, it has got major significance for our manufacturers,' said Aufrecht.

The numbers back up Aufrecht's claim, with German car-makers currently leading the way in China. The most recent figures show that German-brand sales in the country reached 223,500 units in July, which represented a combined market share of 26.6 per cent.

Aufrecht also said that the level of Eastern European interest in the DTM was partly the reason for taking the series to the Hungaroring. 'The Formula 1 circuit meets the highest standards and Eastern Europe also has a lot of DTM enthusiasm. In addition, our three manufacturers – Audi, BMW and Mercedes-Benz – have got plants not far from the circuit.'

But Aufrecht also said that the championship's German heartland was still important: 'DTM most definitely has got its roots in Germany. Therefore, we won't touch the number of German rounds on the calendar.'


LAT

The DTM will no longer visit Brands Hatch (pictured) or Zandvoort

CAUGHT

Williams was fined €60,000 after a front wheel fastener came off Pastor Maldonado's car during second practice for the Indian Grand Prix. The size of the fine was deemed fitting by the stewards as the team had been punished for a similar offence at the preceding Japanese Grand Prix.

The stewards discovered that the front right wheel fastener had been cross-threaded and had not engaged the primary retaining plunger. An FIA statement on the matter said: 'The stewards noted that in this case the wheel had been retained on the car (unlike the similar incident in Suzuka) and that the cross threading of the wheel fastener contributed to the fastener coming off the car.

'While the stewards accept that improvements to the wheel retaining system had been implemented, the team need to ensure that both the wheel and its fastener are fully retained on the car.'

FINE: €60,000

Ford sticking with Aussie V8s for 2014 despite sales woes

Ford has said it will continue to race in the Australian V8 Supercars series for at least another year, ending speculation that it would pull out at the end of the 2013 season.

The Blue Oval has been a mainstay of the series since the inception of V8 Supercars (V8S), but this year doubts about its future participation grew after Ford announced it would cease to manufacture its Falcon car – with which it competes in V8S – in Australia, with the model due to be discontinued completely by 2016.

This followed poor sales for the iconic brand in Australia in recent times, with figures plummeting to the lowest point in the Falcon's 53-year history in July, when just 594 were sold. This was 37 per cent lower than the same period in 2012, when 941 Falcons were purchased. Ford's Australian operation has also reported a AUS$600m ($560m) loss since 2008, AUS$141m ($132m) of this in 2012 and a whopping AUS$290m ($271m) in 2011.

Its poor financial performance led Ford to decide to close its Australian manufacturing operation earlier this year, with the loss of 1200 jobs, and to cease production of the Falcon, the car now used in V8s and also the Ford most closely associated with the championship historically.

With the above in mind, Ford said it would consider its future in the sport beyond 2013 on 'data' alone, so there was some relief in V8S circles when Ford Australia president Bob Graziano announced that the company has renewed its backing of Ford Performance Racing (FPR), which has been its main factory-backed team for a decade. However, Graziano would not comment on the length of Ford's commitment beyond 2014 or the level of funding.

Nevertheless, V8S CEO James Warburton said the news that Ford would remain in the sport was very welcome. 'This is fantastic news for the FPR team and the legions of Blue Oval fans,' he said. 'As the Car of the Future platform continues to attract newcomers to the grid, it's terrific that Ford has confirmed its ongoing commitment.'

LAT

SEEN: PILBEAM MP100

Pilbeam has released images of the car that will take it back into LMP2. The MP100 is said to be intended for teams looking for a car which is straightforward to run and at reasonable cost, while being capable of class leading performance in the category. The car retains some features of the MP93, its predecessor in LMP2, but also greatly improved aerodynamics together with suspension changes which became necessary in order to make the most of the increased downforce. The first MP100 will be powered by a Mountune 4-cylinder turbo engine and will be run by South African team Zoo Racing, which has aspirations to run at the Le Mans 24 Hours. The car is to begin its testing programme at the beginning of 2014.

Chime buys motorsport marketing giant JMI

Chime Communications PLC, a company in which athlete-turned-London Olympics boss Lord Sebastian Coe plays a prominent role, has acquired motorsport marketing company JMI.

As a result of the purchase – thought to have cost Chime close to £44m – JMI will become part of Chime's sports marketing division, CSM Sports & Entertainment.


LAT

The acquisition of JMI gives Chime, which is listed on the London Stock Exchange, both a foothold in the global motorsport marketplace as well as a presence in the USA for the first time.

JMI was founded by Zak Brown (pictured) in 1995 and employs approximately 130 people in the US, UK and Hong Kong. It operates mainly in F1, NASCAR and IndyCar.

Lord Coe, executive chairman of CSM, said of the deal: 'This is the most sizeable acquisition CSM Sport and Entertainment has made to date and signals our strategic entry into the exciting world of motorsports and the important US market.

'This is a deal that makes sense for CSM Sport and Entertainment on multiple levels. It will bring value to shareholders, clients and employees alike, as motorsports and the US are two untapped areas for CSM Sport and Entertainment – to be truly global we have to be in them. On top of that, Zak's record and leadership in driving major sponsorship deals will be a significant boost for our overall business.'

Brown – a well-known GT racer and the boss of the United Autosports GT team – will remain CEO of JMI within the Chime Group, heading up a new motorsport division, while he is now also global head of business development within CSM Sport and Entertainment.

'This is the most exciting moment in JMI's history,' he said. 'CSM Sport and Entertainment was the perfect choice to take JMI forward and we couldn't be more delighted that our futures are bound together. We recognised the synergies from the start and the potential for our clients and our people is massive.'

Motorsport big cheeses team up with e.dams

Alain Prost has joined forces with well-known team boss Jean-Paul Driot to run a team in the new for 2014 Formula E Championship, while the series has also plugged into another F1 connection with the announcement that Super Aguri will be on its grid.

France's first FE team will be called e.dams and it joins leading IndyCar outfits Andretti Autosport and Dragon Racing, UK-based Drayson Racing and Chinese team China Racing among the 10 teams to be put forward to the FIA for final approval by its World Motor Sport Council.

The new team will be supported with logistical and technical assistance by top European squad Dams (Driot Associés Motor Sport). Based near Le Mans, Dams boasts almost 25 years' experience with numerous team and driver titles to its name including three International F3000 championships, two A1GP titles, two Auto GP titles, two GP2 Asia titles and one team and two GP2 drivers' titles. The outfit has also expanded into Formula Renault 3.5 where this year it claimed the team and drivers' championship in only its second season.

Driot said of the new FE venture: 'Getting involved with the FIA Formula E Championship was an obvious choice. Being the race enthusiast that I am, I was immediately convinced by this new concept of using fully electric single-seater cars and believe it will shape the future of motorsport. The implementation of new technologies, in the heart of the most beautiful cities in the world and in front of a young audience, lays the path for a new form of motorsport, which is innovative and respectful to the environment. I am extremely proud to be a part of this new challenge.'

Meanwhile, former F1 outfit Super Aguri is also to enter FE, with a team called Super Aguri Formula E, or SAFE, headed by former F1 driver and eponymous team owner Aguri Suzuki. The team will be based in the UK to begin with, although there are plans for a Tokyo HQ in the future.

SEEN: ZYTEK LMP1 ENGINE

Zytek has built an LMP1 engine to the 2014 WEC fuel-flow regulations. The normally-aspirated unit incorporates technology from the company's V8 ZRS-03 engine – as used in Renault World Series FR3.5 – and it will also benefit from advanced control and drive-by-wire technology.

An optional electric hybrid system will also be offered. The transmission-linked system is based upon the Zytek F1 KERS derived package currently raced to great effect in Japan in the Honda SGT-300 CRZ.

Zytek chairman and founder Bill Gibson said: 'Zytek are fully supportive of the drive to introduce and develop fuel efficient hybrid powertrains through the motorsport arena. The 2014 FIA [and] ACO regulations present the perfect opportunity to combine technologies developed across the Zytek Group to provide a single source of engine, ERS and control systems within the constraints of a realistic budget.'

Motorsport embroiled in Venezuelan currency scandal

Motorsport has found itself at the heart of a currency scandal in Venezuela, with prosecutors in the country launching investigations into several unnamed parties said to be involved in the sport.

The Venezuelan Government suspects that some of the country's race drivers have been claiming far more US dollars than is necessary to pay for their seats, and then selling off the surplus on the black market.

Because of strict currency controls that have been in place for the past 10 years, there is now a shortage of dollars at the official rate of 6.3 Venuzuelan bolívars, and profits to be made for those who can access them at that rate, then sell them on within Venezuela.

Athletes are able to claim much more than the amount allowed to regular travellers, while those competing in motorsport regularly claim the most, which is unsurprising given the cost of the sport. However, some of the claims have been astronomical – even by racing's standards. It's been reported that one driver claimed $936,277 for a single Grand-Am test. It's also been suggested that some of the claims have been falsified, by forging the signature of the sports minister.

The attorney-general's office said investigators from Cadivi – the state currency board – and Sebin, the national intelligence agency, were collecting 'items of criminal interest' including documents and official seals from the Sports Ministry.

The Venezuelan sports minister, Alejandra Benítez, has told Venezuelan newspaper *Ultimas Noticias* that she was informed by a state bank that her signature had been forged on more than 60 requests for dollars. Most documents involved motorsport and had initially escaped closer inspection because of the high costs involved in motor racing.

Benítez, a former Olympic fencer, said: 'There was one racer who, in a year-and-a-half, was approved for $66m. Two drivers were claiming in a year what it costs us to take a whole team of more than 600 athletes to events.'

The drivers under suspicion have not been named.

BUSINESS INTERVIEW - BRUNO MICHEL

The director's cut

As GP2 goes into its 10th season, the series' CEO tells us how he intends to cut costs for the teams that fill the F1 feeder formula's grid

Since its inception in 2005, GP2 has been remarkably successful. Not just by its own measure of achievement, with all but two of its champions graduating to F1, but also by its uncanny knack of seemingly being able to ride out the financial storm that has buffeted the world since 2008. Yet it would be wrong to think that GP2 is immune to the downturn, for despite full 26-car grids in 2013, there were also signs that the recession was beginning to bite.

The most notable of these were the loss of two teams due to financial issues, one of which was past champion iSport, the other Ocean. While all spaces vacated were soon filled by others, there was no hiding from the obvious – teams were beginning to find the going tough. The question was: what was GP2's boss, Bruno Michel, going to do about it?

Michel came into motorsport in 1993, as general manager at the Ligier F1 team. He went on to run the SuperTech F1 engine programme and to manage drivers, but since 2005 he has devoted his time to GP2 – the series he created with Bernie Ecclestone and Flavio Briatore – and also to GP3 since 2010.

GP2 is actually owned by FOM (Formula One Management), and it operates out of its Biggin Hill base in the UK. But, according to Michel, it's GP2's more overt ties to F1 that are the secret to its success. 'I think it has been successful for several reasons,' he says. 'Number one is that we have a car that is as close as possible to Formula 1 – and we have great racing, taking place in front of the Formula 1 community, because we are racing at many F1 race weekends.'

But it costs to race in front of the movers and shakers of F1. Michel would not be drawn on GP2 budgets because, quite reasonably, he does not want to go on record saying that a drive in his series will cost x amount, when a team is trying to get y amount from a driver. However, talking to teams, it would seem that about £1.5m would be about right for a reasonably competitive seat.

That isn't pocket change, even in high-profile motor racing, so perhaps it's no surprise that teams have found it difficult to fill seats in recent years – though interestingly this has only been the case since 2011, Michel insists. What's perhaps more surprising is that when teams have moved out of GP2, there have always been others ready to jump into their place. This has not necessarily been like-for-like switches, however, and Michel has noticed a change in the character of the teams in the formula in recent years.

'At the very beginning, all the teams were motor racing teams who had been in the business for a long time,driven by engineers and motor racing people. Now we have a coexistence of those existing teams and entrepreneurs who are there because for them it's a business, and they want to invest in it as a business. And I think it's quite interesting to have both.'

Some of the new teams are playing the long game, willing to make a loss in the short run, because they have the money behind them. But other teams might not have that luxury. It is with these teams in mind that Michel has set out to reduce costs by a 'significant percentage' – although again he would not be drawn on a specific amount.

GP2's three-part cost-cutting programme sees the chassis

Bruno Michel (left) will reduce the number of flyaway races in 2014 to cut costs, and says he favours 'floataway' events such as Abu Dhabi (below)

frozen for the next three-year cycle – the first time this has happened – reduced parts costs, as well as alterations to the calendar. The first of these moves is the most fundamental, says Michel. 'We'll keep the same chassis, which is going to make a massive difference, because for the teams, the chassis has been completely amortised. There is no need to add up an amortisation of the chassis in the cost of the season for the drivers, so that will make a big difference.

'We've also been in discussions with Dallara, and it's helping us to cut down the costs of the spare parts, knowing that we can keep the same chassis. I told them that the tooling and the moulds and everything will probably be amortised on their side, so we were expecting a gesture from them, which they did.'

It's the same for engine supplier Mecachrome, which has trimmed its lease prices. But it's not all about the hardware, and much of the cost-cutting is focused on the season schedule, and the difficulties related to following F1 around the globe. 'We will cut the calendar because this is another way to reduce the costs. We went to four flyaway races in 2013. The maximum we will go to in 2014 will be two. I don't know next year exactly how many races we will have, but we will not go to Malaysia and we will not go to Singapore, because it costs a fortune for us in freight.'

Yet while flyaway is not so good, float-away is a different matter entirely. 'Every time we can take the boat, we take the boat ... This year, to go from Singapore to Abu Dhabi, we put everything on a boat. This can save hundreds of thousands. All the teams were amazed how much money we can save.'

While GP2 won't be supporting F1 quite so often in 2014, Michel says that it's still important to keep the connection, which has always included an aesthetic element. In 2014, F1 cars might look significantly different, thanks to the change in formula, and with this in mind Michel says there's a chance of a cosmetic change to the GP2 Dallara in 2015, in the shape of an updated body package, to make sure it still looks like an F1 car. There will not, however, be a change to turbocharging until at least the end of the next three-year cycle, as Michel says he's very happy with the current Renault 4-litre V8.

Interestingly, Michel's other series – GP3 – changed from turbo to normally-aspirated while also getting a power hike in 2013, so that it now sits between F3 and GP2. Michel cites this example when he is asked about what the future might hold for GP2. 'The important thing is to always listen to the market, and to be able to be flexible and to understand what the market is asking. That's exactly what we did with GP3 in 2012. We changed completely the definition of the car, the performance of the car, and we knew that that was the right positioning to go, and GP3 has enjoyed a massively successful 2013.

'I can't tell you where GP2 will be in 10 years' time, but it won't be the same – we're constantly changing things to ensure we are in the right place.'

Mike Breslin

'We've been in discussions with Dallara, and they are helping us to cut down the costs of spare parts'

UAT

RACE MOVES

Mike Coughlan has returned to the NASCAR Sprint Cup, the former chief technical officer at Williams – a post he left in the summer – signing up with Richard Childress Racing as its technical director. Coughlan, who has also worked at Ferrari, McLaren, Benetton and Arrows in F1, previously worked with Michael Waltrip Racing in NASCAR in 2010 and 2011.

Nick Bunting has quit the post of chief executive of the Motor Sports Association, the sport's governing body in the UK, after just six months in the job. The MSA said Bunting, who had previously filled a similar position with the Rugby Football Union, had left by mutual consent. **Rob Jones**, the MSA's general secretary, has now been appointed as acting CEO at the organisation.

Former Super Aguri F1 men **Peter McCool** and **Mark Preston** are to have key positions in the new Super Aguri Formula E (SAFE) outfit. McCool is to be technical director while Preston will be team principal. The commercial side of the organisation will be overseen by **Ferry Spijkerman**.

Graham Macdonald is now the CEO of the Caterham Group, with overall responsibility for all arms of the business including the F1 team. Macdonald has been promoted from his role as CEO of Caterham Cars. **Tony Fernandes** remains co-chairman, as does **Kamarudin Meranun**.

Ben Bowlby has been called in to help out with the aerodynamics on Nissan's Altima V8 Supercars. UK-based Bowlby, who has worked at Lola and Ganassi during a long and distinguished career and is now director of Nissan Motorsport's innovation department, has most recently been associated with the company's Zeod RC electric racecar.

Mark Bailey, who has been involved in Formula 3 at various levels for over two decades, will no longer run a team in the UK's F3 Cup. The outfit he ran will now be guided by **Mike Gale** under the Gale Force Racing banner. Gale intends to run four cars in the club/national-level F3 series.

Former NASCAR crew chief and engine builder **Waddell Wilson** has been presented with the 2013 Smokey Yunick Award in recognition of his achievements in the sport. Established in 1997 by legendary car owner and mechanic **Henry 'Smokey' Yunick**, the annual award recognises an individual who's come from humble beginnings and gone on to make a major impact in the motorsport industry. Wilson's engines powered drivers to more than 100 NASCAR Sprint Cup Series victories. He retired from the sport in 2000.

Peter Digby (above), managing director of transmission company Xtrac, has been named Global Director of the Year and overall winner of the Director of the Year Award, by the UK Institute of Directors. Digby was presented with the two awards in recognition of his leadership of an 'exemplary motorsport and automotive business', and for the consistently high level of export sales Xtrac has sustained since its formation 30 years ago.

Veteran IndyCar race engineer **Bill Pappas** has joined the Rahal Letterman Lanigan team, where he will look after **Graham Rahal**'s car. Pappas, who has enjoyed a 25-year career in IndyCar, has previously worked at Dale Coyne Racing, Walker Racing, Panther Racing, Hall Racing and Chip Ganassi Racing. Pappas replaces **Gerry Hughes**, who has taken on a new position at the team as head of development.

NASCAR has reinstated former Sprint Cup crew member **Eric Maycroft** after he successfully completed its Substance Abuse Policy Road to Recovery Programme. Maycroft was banned from all NASCAR competition in August 2013 after he violated the US stockcar governing body's strict substance abuse code.

Mike King has stepped down from his position as chief announcer on the Indianapolis Motor Speedway Radio Network in order to focus on family and other business responsibilities. King joined the network as a pit reporter in 1995.

McLaren boss is happy with team's head-hunting

McLaren team principal Martin Whitmarsh has said he is pleased with the team's ongoing recruitment drive, which has so far resulted in the defection of two key people from Red Bull to the Woking team.

The team has recently signed Red Bull's chief aerodynamicist Peter Prodromou**,** who will start at McLaren at the end of the year after his Red Bull contract expires. Unconfirmed reports also claim that another senior Red Bull aerodynamicist, Dan Fallows, is also set to join McLaren.

Prodromou previously worked at McLaren from the early-90s, becoming the head of aero in 2000. He then moved to Red Bull in 2006, at the same time as Adrian Newey.

Whitmarsh has admitted that McLaren is recruiting in order to lift it out of its current streak of poor race performances – this year looks set to be its first winless season since 2006. 'We're here to win and this year's fallen short of that,' Whitmarsh said. 'So, when those things happen you reappraise your organisation, the resources, and you try harder. So, we've been going through that process and that's meant we've been out recruiting and we're pleased with some of the work that we've done.'

Red Bull will not allow Prodromou to start work at McLaren early, however, and its team principal, Christian Horner, says he will remain working with the team until the end of the year.

Hulman & Co owner bolsters executive team

IndyCar and Indianapolis Motor Speedway (IMS) owner Hulman & Co has made two key appointments to its motorsport division as it strives to find more sponsorship for both the series and the race track.

Ex-Ford marketing exec CJ O'Donnell is now Hulman Motorsports' chief marketing officer, while Jay Frye, whose experience in the industry includes setting up the Red Bull NASCAR team, will serve as chief revenue officer.

Of the appointments, Hulman CEO Mark Miles said: 'We've set a new strategic direction for our motorsports entities, and Jay and CJ are both top performers who will help us take big leaps forward.

'Among their immediate goals are to add sponsors for IndyCar and IMS, improve our level of fan engagement and develop strategies to build alignment among our teams, drivers, venues and sponsors.'

SPONSORSHIP

The **Hendricks Motorsports NASCAR Sprint Cup** car that is driven by **Dale Earnhardt Jr** will continue to be sponsored by the **US Army National Guard** in 2014. It will be the primary sponsor at 20 races, including the Daytona 500, while it will also be an associate backer for the remaining 16 events. The National Guard has been linked with Hendricks since 2007.

NASCAR Sprint Cup outfit **Richard Petty Motorsports** has picked up a new sponsor for the 2014 season, with the **Twisted Tea Brewing Company** coming onboard as an associate sponsor on Marcus Ambrose's car. The company will also be the car's primary sponsor at next season's autumn race at Dover International Speedway.

NASCAR Camping World Truck Series team **ThorSport** has signed a deal with **Nextant Aerospace** to sponsor its Johnny Sauter-driven truck for 12 events in each of the next two seasons.

RACE MOVES

Formula 1 race director **Charlie Whiting** is to be the guest speaker at the Motorsport Safety Fund's annual Watkins Lecture at January's Autosport International Show. The Watkins Lecture is in honour of the late **Professor Sid Watkins**, who spent many years as F1's safety and medical delegate.

Alan Cornock's well-known single-seater sales company, FCS, has now branched out into sportscars by becoming a factory-approved outlet for previously owned Radical SR3s, SR8s and other Radical models. Cornock was once the boss of the Royale Formula Ford marque.

Todd Parrott is no longer a crew chief at NASCAR Sprint Cup outfit Richard Petty Motorsports, after he was suspended by NASCAR following a violation of the sport's strict substance abuse policy. **Greg Ebert** will be taking over Parrott's duties on the famous No 43 car until the end of the season.

NASCAR Camping World Truck Series crew member **Marshal Faust** has been indefinitely suspended from all NASCAR competition for violating the US stockcar governing body's strict substance abuse policy.

Former Mercedes motorsport boss **Norbert Haug** has taken up a new job at Paravan Technology Group, a German company specialising in vehicles for disabled people. Haug, a former journalist, was at Mercedes for 22 years, until he was replaced by **Toto Wolff** at the end of 2012.

Lotus issued an apology after the Indian Grand Prix after a fruity radio conversation between chief engineer **Alan Permane** and driver **Kimi Räikkönen** was aired. The Finn was holding up team mate **Romain Grosjean** when a frustrated Permane transmitted: 'Get out of the f***ing way!' Raikkonen's response was: 'Don't f***ing shout at me!' Räikkönen moves to Ferrari next year.

Alejandro Agag will no longer be a part of GP2 in 2014 as he concentrates on Formula E – he is the CEO of Formula E Holdings, the company behind the new FIA championship for electric racecars. Agag's team, Addax, has now been replaced by Campos on the GP2 grid. **Adrian Campos** originally sold his eponymous GP2 team to Agag back in 2008.

LAT

Audi WEC race engineer **Leena Gade** (above) took an active part in the UK's Tomorrow's Engineers Week 2013 at the start of November. Gade, who engineered the Le Mans-winning Audis in both 2011 and 2012, said the reason she became involved in the initiative was 'to inspire the enthusiasm of female students for engineering subjects, because this type of education opens up fascinating career opportunities'.

Well-known McLaren shareholder **Mansour Ojjeh** was doing well as he recovered from a double lung transplant as *Racecar* went to press. Ojjeh owns part of TAG, a Luxembourg-based holding company with interests worldwide, while he is also a long-time investor in McLaren. He has been suffering from IPF lung disease for the past four years.

Marcy Scott, director of marketing and promotions at NASCAR venue Atlanta Motor Speedway, has died after a long battle with cancer. Scott had been at the Atlanta Speedway for eight years and before that worked with a number of teams and sponsors in the sport. She was 42.

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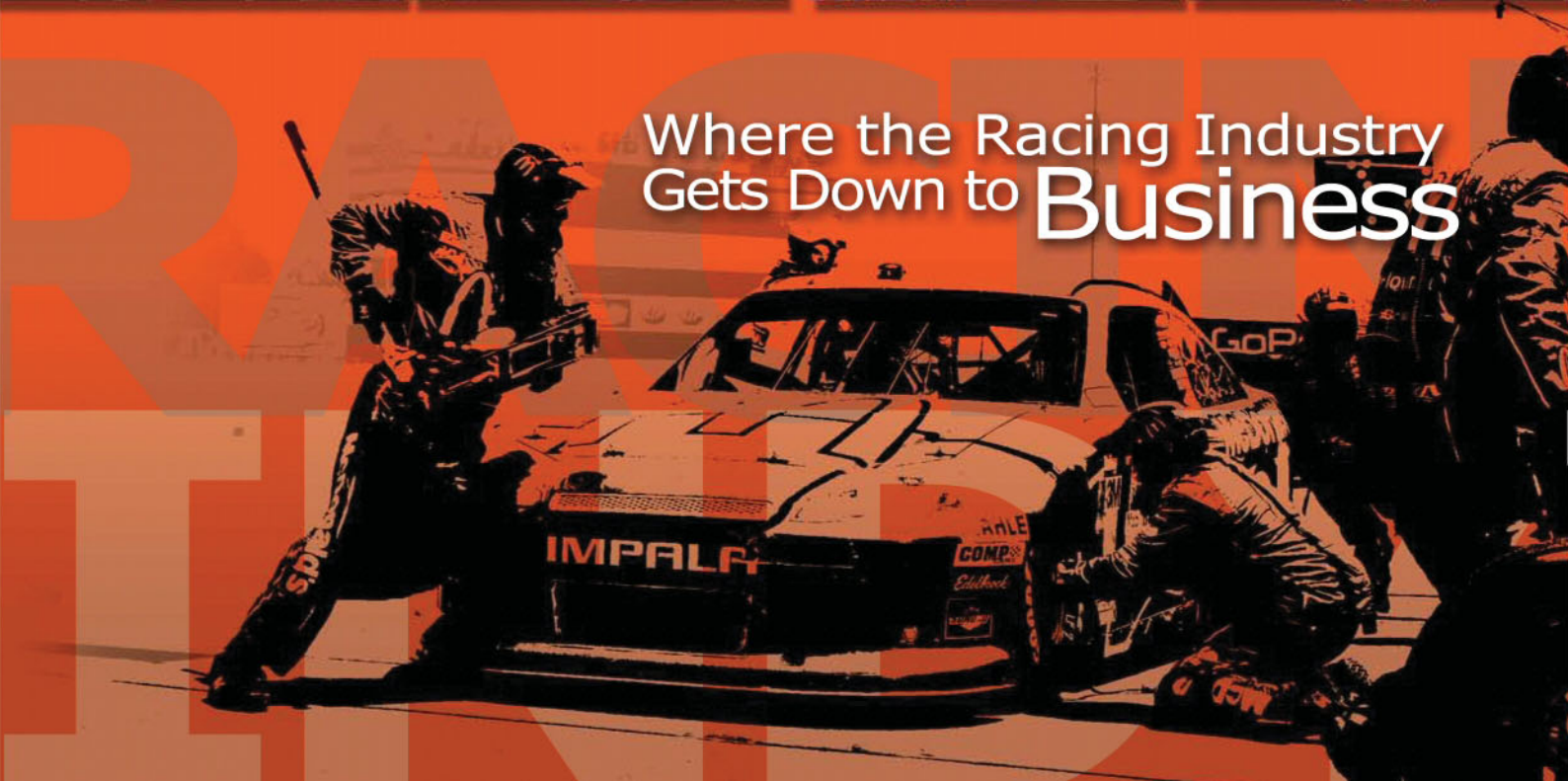


Red Bull jobs up for grabs as Academy applications open

The Infiniti Performance Engineering Academy, which offers a two-year work placement with Formula 1 team Red Bull Racing, is now open for applications.

Infiniti's Academy (see *Racecar V23N11*) aims to select two winning candidates from partner universities and colleges worldwide to complete a 12-month assignment with the 2013 championship-winning team.

The successful applicants will work alongside Infiniti engineers at Red Bull's Milton Keynes factory and they will also spend time at Infiniti's nearby Technical Centre in Cranfield.

The opening for entries was announced by Infiniti Europe, Middle East and Africa vice-president Fintan Knight, Red Bull driver Mark Webber and the team's head of car engineering Paul Monaghan during a special event in Dubai.

Monaghan said: 'Engineering is so crucial to performance with today's Formula 1 cars, so we're always looking to attract and nurture new talent to become the leading engineers of tomorrow. Having the Infiniti Performance Engineering Academy supporting us in this continual search will help us ensure we benefit from some of the world's best budding new engineers, while giving a fantastic opportunity and potential career boost to those wanting to make it in Formula 1.'

The talent search is open to all students from across the world at pre-selected partner universities and colleges. Applicants must be entering their final year of education or graduating in 2014, be fluent in English, and be available to work in the UK for a continuous period of 12 months from September 2014.

Applications can be made at www.infiniti-gp.com/engineering

BRIEFLY

Renault F3 return

Top French motorsport engineering company ORECA is working on a new Formula 3 engine in conjunction with Renault. The engine is being built to the new regulations, which keep to the traditional F3 air-restricted 2-litre engines, but allows for bespoke units rather than just engines based on production blocks. ORECA is currently developing the new powerplant at its engine facility at Magny-Cours. The engine is expected to make its debut either in 2014, when the FIA European F3 Championship runs to the new rules for the first time, or in 2015.

Hexis exits

French GT team Hexis Racing is to shut up shop at the end of the season as the company behind it – the Hexis adhesives group – has decided it now needs to concentrate its expenditure on its expansion, rather than on the race team. The FIA GT Series final race at Baku, Azerbaijan, was due to be its final fling, although team boss Philippe Dumas has said there is a chance the squad might be sold, so it could still return to competition in some form.

GT86 rally car

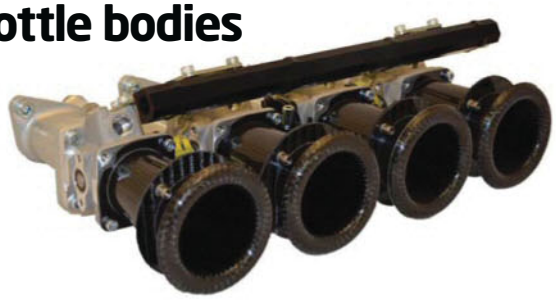
Toyota is to develop a GT86 R3 rally car as part of its customer motorsport programme. The rear-wheel-drive sportscar – which is to be called the TMG GT86 CS-R3 – will be converted to R3 specification and will be made available to customers in 2015. Upgrades required for R3 include a six-speed sequential gearbox, while Toyota also says its build will modify the base car to the maximum level permitted by the regulations. The rally car will be targeted at private customers and will be eligible for all FIA-sanctioned rallies, up to and including the World Rally Championship.

Forza factory

It's been reported that Ferrari is planning to build an all-new three-storey factory, which will accommodate the 700 or so staff who work exclusively for the company's F1 operation. The factory comes on top of huge expenditure by the Scuderia to completely renovate its wind tunnel and build a new driver simulator over the past year. The new investment is part of a concerted effort to relieve the team's continuing F1 world championship drought.

THROTTLES

Titan Motorsport lightweight throttle bodies



Titan Motorsport recently unveiled its all new range of lightweight throttle body kits. The subject of extensive design and testing, the kits are available to fit a wide range of common engine applications thanks to a selection of bespoke inlet manifolds.

The throttle bodies are constructed from cast aluminium and are supplied with fuel rails to accept either a Pico- or Bosch-type injector. With focus on producing a lightweight system, Titan has worked with a leading composites company to develop carbon fibre trumpets that reduce overall assembly weight and maintain optimum airflow across the composite surface.

The manufacturing process used offers exceptional finish on both sides of the material and aesthetically. Each system has been developed with engine builders specialising in their field, to ensure that the design, setup and final systems meet the demanding and exacting requirements of the industry.
www.titan.uk.net

ELECTRONICS

Cosworth range expands

Cosworth Electronics provide premium data aquisition, power management and engine control systems. New to their range are the MQ12DI direct injection ECU, a CCW carbon steering wheel, configurable IPS48 power management unit and ICD dash logger.
See the website for more.
www.cosworth.com

PIT TOOLS

Greaves Tyre Scraper

Greaves 3D Engineering's latest addition to their range of top quality pit and garage tools is the Greaves 3D Tyre Scraper. It offers a practical, ergonomically-designed solution to the management of part worn tyres, and is a much more efficient device than other tools used for this process in the past. The product is in the final stages of testing and will be on sale for delivery in January.
www.greaves3d engineering.com

SENSORS

KA Sensors range for 2014

Sensor manufacturer KA Sensors recently unveiled a raft of new products for 2014. First up is the KATD Series of dual axis accelerometers, which are designed for true inertial measurements on race vehicles or automotive test vehicles. The use of low bandwidth sensing elements ensures that high frequency vibration from transmission components, or similar, do not affect the measurements, therefore allowing only lower frequency signal components to be detected and measured.

Also now available are the KTSM series of turbo speed/temperature sensors, which are designed for direct installation on to the turbo casing.

Sensing is by the eddy current principle to detect the blades (titanium or aluminium) as they pass by the sensor, and the unit may record up to a maximum speed of 400,000rpm.

Other additions to the range are improvements on two commonly-used positional data sources – linear potentiometers and laser ride height measurement, available in 9.4mm, 13mm, 15mm or 19mm diameter. Miniature sizes are available, as are compact designs for use in restricted spaces, with measurement ranges spanning from 12.5-300mm.

The RHL3 series of laser ride height sensors features a small diameter visible laser, which is reflected off the track surface to a precision CCD detector to determine height from the ground.

The measurement rate of 750Hz and linearity between 0.2-0.5 per cent ensures a fast and accurate recording of real-time car data. The supply voltage is a common 11-30V, which is readily available on most data logging systems, while the analogue voltage output is 1-5V.
www.kasensors.co.uk

TRANSMISSIONS

Xtrac 117 4WD transmission

The new 117 4WD transmission from Xtrac has been designed for use in T1 Cross Country Rally/Raidcars competing in series such as the FIA Cross-Country Rally World Cup and the Dakar Series.

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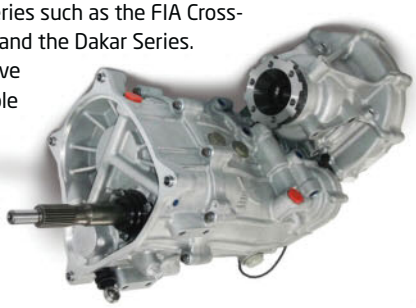
www.xtrac.com



DATA LOGGING

BJR Technology L-Sys 2

The new L-Sys2 from BJR Technology is an integrated GPS Digital Dash and 10Hz Data Logger, a user-friendly yet powerful system intended for club racing and trackday enthusiasts. Kits with everything to get you started are priced from £425 inclusive.
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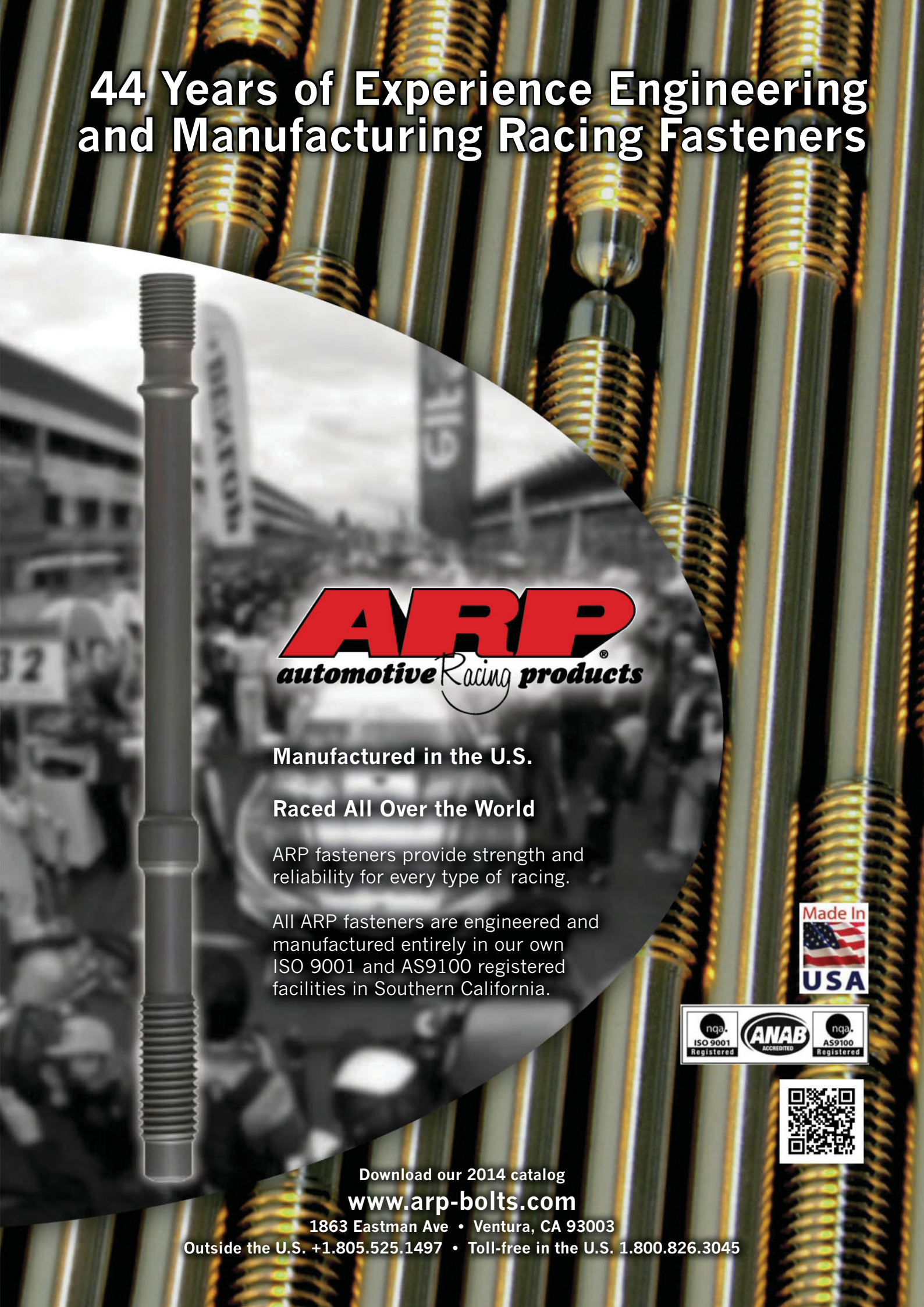

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The FIA GT Series headed out once again into the land of the unknown when it visited Baku, Azerbaijan, for a street race on a brand new circuit. It is not the first time that the series has explored new territories; it was also the first to head out to Zhuhai in 1994, to Dubai, to Bucharest and to the majestic circuit of San Luis, Argentina. Each of these experimental projects met their end when there was a change of government, or if the money dried up. In the oil rich land of Azerbaijan, however, series promoter Stéphane Ratel sees a long-term future.

'You have to go to new places,' insists the Frenchman. 'I was the first in Dubai, I was the first in China – I was the first in so many places. Either you stay between Silverstone and the Nürburgring and everything goes fine, or you venture a bit further to new street circuits.'

Baku is in the land of the unexpected. Security at the race was particularly visible, especially around the spectacularly large national flag that dominated the skyline, 70m by 30m, apparently, that flapped mesmerisingly slowly in the breeze. Police were even put in charge of the golf karts that were chartered to take the media from the Crystal Hall – that in 2012 hosted a round of the Eurovision Song Contest, an epic evening of warbling and make up – to the paddock. One policeman got bored of waiting when there was no running on Friday, and so amused himself by practising his handbrake turns outside the press room.

Washing the track before cars ran on it was a mistake – the water froze on Saturday morning

It was an adventure of sorts – the local driving put the Italians to shame for its creative use of lanes, and speed, although the award for daft stunt of the weekend was a police car driving against the flow of traffic on a five-lane one-way street. Yet it is here that Ratel is hoping to create a world-renowned GT street race that will rival that currently hosted at Macau.

Racing at the former Portuguese province celebrated its 60th birthday this year with its usual mix of Formula 3, World Touring Car Championship, GTs and motorbikes, and it is hard, at this stage, to see the Baku circuit taking the GT mantle from it. Even the promoter stopped short of making that sort of promise. 'I don't know if I am going to be alive next year, but if I am we will meet here again next year and if our friends can again have the final in Baku, I will again be happy to organise it,' he said. 'But, because this year I am hosting the final of the series, next year I will not settle for anything less.'

Ratel has put the Baku city challenge on the calendar again for 2014, on the first weekend in November – which hopefully will be see warmer weather. But the organisers have a little to learn before then. Washing the track before cars run on it was a mistake – it was so cold that the water froze on Saturday morning and drivers feared that they might do the same again on Sunday before warm up. They did, and apparently used detergent to scrub off all the rubber marks left by the cars on Saturday.

There was criticism of the circuit layout – with slow chicanes installed to avoid speeds creeping up too high – and of the construction. Drivers were calling for Tecpro barriers to be installed between the tyres and the concrete. 'It's like street racing 20 years ago,' said one team manager. One of the organising team was just fearful of who would be held responsible in the event of a big accident, and hoped that it wouldn't be them.

There was no doubting the size of the crowd – clearly local promotion worked. Local taxi drivers asked which days the racing was on, although I suspect that was more to do with figuring out when the track would be closed than because they wanted to come and see it. For Ratel, however, the oil-rich country could be the place that hosts the Spa 24 hours of the GT Sprint Series.

'I think that there is potential here around the first weekend of November to have a big feature that will have a tremendous success,' said the Frenchman. 'Here, you are between Europe and Asia, so it could be a big World Final.

'If you do an event over a small number of years you cannot do anything but if you do it like Macau over 10 or 20 years, you can make it big, with the manufacturers doing things. It can become a blue riband event that we need for sprint GT racing. Azerbaijan is not an important market for the manufacturers, but it is an important landmark and a beautiful city.'

The authorities paid for four tonnes of freight per car, offered €20,000 per car to compete, booked flights and hotels, and offered up a prize fund of €175,000, including €100,000 for the winner of Sunday's Championship race. That led to an entertaining first corner. The finances are there, for now. Whether or not the city can provide a long-term home for the GT finale is another question entirely.

EDITOR
Andrew Cotton

PAGID RS

Brake control from green light to chequered flag.

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