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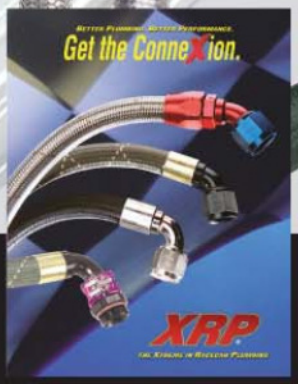

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There are two themes to this month's *Racecar Engineering* – Le Mans Prototypes and the World Rally Championship. After a spell in the late 1990s when Sportscars were making headlines in the mainstream media for a number of dramatic 'flying' incidents, the FIA/ACO quite correctly stepped in. Technical regulations were changed and the unscheduled flights became a thing of the past. Until this year, when a spate of similar incidents occurred that again saw Sports Prototypes becoming airborne. We therefore decided it was time to take a fresh look at the phenomenon and, in Simon McBeath's article in this issue, you will find the results of new wind tunnel work that goes some way to explaining what appears to be happening to these cars.

Moving from the specialised environment of the wind tunnel to the great outdoors, with the 2008 World Rally Championship now moving into its final rounds, we felt it would be appropriate to consider some of the issues facing this branch of the sport. In particular, how it proposes to deal with the matter of competing in places of natural beauty at a time when environmental consciousness is running at a high level. We therefore sought the views of a number of key individuals in the sport and they appear in our feature, Green Fields. We also take a close look at Subaru's S14 WRC challenger, which appears capable of propelling Subaru and Prodrive back to their winning ways.

As ever, we'd be interested to hear your thoughts on these topics, or indeed any of the other features in this month's issue of *Racecar Engineering*.

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Graham Jones

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FORMULA 2

Formula 2's low-cost motorsport vision

Significant interest from drivers as details of budget-conscious F2 for the 21st century announced

DETAILS OF THE all-new, Williams-designed Formula 2 car have been released and initial reports of the one-make championship providing low budget, top-level racing have also been confirmed – with a per-driver asking price of £195,000 ($333,000).

Incredibly, this is almost exactly the same budget needed for F2 when it was last a part of the mainstream international motor racing scene, as a multi-chassis discipline, in 1984. But MotorSport Vision boss, Jonathan Palmer, whose company has won the right to run the championship, insists there will be no problem working within this budget. This, he says, is largely because of the way he intends to operate the formula, which is to be a centrally run, arrive-and-drive championship – much the same as his Formula Palmer Audi championship has been run for the past 10 years.

'I would say about 50 per cent of the cost of a traditional F3 or GP2 team is spent trying to make one car faster than the other. But if you eliminate that then there is not one pound spent trying to make one car faster than another,' Palmer told *Racecar Engineering*, adding that there were further savings because of the way the championship will be centrally operated – rather than individual teams running the cars. 'There are tremendous economies of scale by running everything from under one roof,' he says.

As for the car itself (at the time of writing it had not been decided what it would be called) it is to be assembled at MSV's Bedford Autodrome facility. 'The car's design is by Williams, then URT is doing the tub, Hewland the gearbox and the engine will obviously be Audi. A few parts will be made by Williams, but most parts will be made by sub-contractors that MotorSport Vision and Williams choose between them,' Palmer explains.

The brief Palmer gave Williams – the car was originally going to be a 'Super-FPA' so plans were well advanced when the FIA put F2 out to tender – was for a car that would sit between F3 and F1 in performance, that was tough and durable, safe, and that was able to overtake.

Jonathan Palmer's FPA concept becomes the basis for new F2

With the overtaking brief in mind, Williams has come up with an aero package that, while it gives substantial downforce, has much of it generated under the car, which should help following cars get within striking distance without losing downforce, as there is less reliance on the wings.

The engine is the VAG 1.8T, as used in FPA, but an all-new, full-race version built by Mountune: 'It's based on the Audi 1.8 turbo block and head we're familiar with, but pretty much everything else is new. Unlike the FPA engine, which is a standard engine with a bigger turbo, the F2 engine is 90 per cent new in terms of components,' Palmer says, adding that the engine is another reason F2 is able to keep the costs low: 'By using a turbo engine based on a road engine, it is significantly less expensive than using a pure race engine.'

Other characteristics of the new F2 include an overboost button, as pioneered in FPA, which gives 10 six-second shots of an extra 50bhp per race, and cockpit-adjustable front wings – although this feature will only be available during practice.

The championship has further staked its claim to be a viable feeder formula to Formula 1 by announcing that the top three finishers will each receive F1 super licences and the winner will land a full F1 test with Williams.

Competition for race seats is expected to be hot, with some 105 drivers having expressed an interest in F2 at the time of writing. The first round is in May.

> "not one pound spent trying to make one car faster than another"

TECH SPEC

F2 QUICK SPEC

Chassis: carbon fibre survival cell tub to comply with 2005 F1 crash structures (head protection to 2009 F1 regulations)

Engine: Mountune-built VAG four cylinder 1.8-litre 20-valve, giving 400bhp at 8250rpm (450 on overboost), with all-new crankshaft, pistons, conrods, valves and camshafts; Garrett GT35 turbocharger; Pectel MQ12 ECU

Gearbox: Hewland TMT (designed specifically for F2) with six-speed paddle shift

Aerodynamics: designed using Williams CFD. F1 full length ground effect tunnels, 40 per cent of downforce generated by underside, expected 2000lb of downforce at 150mph

Williams-designed F2 chassis will feature 450bhp Audi turbo engine

INDUSTRY

Crunch time for motorsport this winter

THE MOTORSPORT INDUSTRY could be facing a nervous winter as the economic downturn starts to bite, despite little evidence of any adverse effect in the sector as the 2008 season comes to a close.

At least that's the message from industry insider Chris Aylett, CEO of the Motorsport Industry Association (MIA), who told *Racecar*: 'There's very little practical evidence that the downturn has hit the motorsport industry as yet. But we now have the winter to come to terms with it all. I think it's that period of time, and what happens in the financial markets, that will reflect positively or negatively on what happens in motorsports next year.'

Meanwhile, at grass roots level, the position seems similar, Robin Knight of the 750 Motor Club saying, 'We've seen little impact on grid sizes so far, but it's very early to gauge the results. Yes, money has become a bit tight during the course of the year and we have noticed a very slight tailback in the level of entries, but the majority of competitors seem to be determined to finish the season. The club will be taking whatever action it can to keep costs as low as possible for next season. It is a concern.'

> "each country is reacting in different ways"

GLOBAL OUTLOOK

Aylett, whose MIA organisation represents 300 motorsport businesses, with a collective turnover of £4bn ($7bn), also said he would be 'amazed if by next spring we do not see some job losses,' adding that the close ties the industry has with the car manufacturers and the finance sector are bound to have a knock-on effect. 'When you're talking about car sales dropping 20 and 30 per cent and in certain brands 40 and 50 per cent, that's a worry,' he said. 'Our major partners in motorsport are the automotive industry, and they have been massively hit. On the other side of it, our new sponsor partners, which have replaced tobacco, are the financial services sector. With those two having been savaged, and continuing to be so, and then for us to emerge out the other end without a scratch, I would be surprised.'

However, Aylett was optimistic that many motorsport companies could weather the storm, particularly those with a global outlook: 'Companies who only trade in the UK, for example, may be in for a harder time than those who have spread their net internationally. Because each country is reacting in different ways [to the downturn] those that are strong and are being aggressive about looking overseas for business are offsetting the risk and are likely to see this out better.'

BRIEFLY...BRIEFLY...BR

EMBASSY CLOSES DOORS

LAT

The Embassy Racing team has become an early victim of the global economic crisis, team boss Jonathan France closing the outfit after just one season with its own LMP2 prototype. France said he had, 'taken the decision to re-direct his finances due to the global economic downturn'.

GP3 PUT BACK to 2010

The new GP3 series, which is to be a feeder formula for GP2 (see V18N11), will not now hit the tracks next year, but will be launched in 2010 instead. There has also been a re-think on re-branding the Formula Master cars for use in the series and an entirely new car is to be made. As yet there is no news on who will build the car, but it is known it will be powered by a 2.0-litre engine giving 250bhp.

GREEN PRIX

Ben Johnston, who raced as an amateur in Formula Atlantic in 2005, is said to be looking at buying the Panoz DP01 cars that Champ Car used throughout its last season. Johnston already owns a number of final generation Reynard Champ Car racers and is planning a two class, arrive-and-drive race series, entitled 'Green Prix', based around both sets of cars – each packing Cosworth engines.

TANKS VERY MUCH

Stewart-Haas Racing announced it has scooped US Army sponsorship for its no 39 car, Ryan Newman's Chevrolet Impala, for 2009. The car will run in a black and camouflage livery. This is the third major sponsor Stewart has managed to entice from another team, in this case DEI, and means Stewart-Haas has already sold about 80 per cent of its available sponsorship space for next season.

SEEN BBR PHANTOM DVS-1

Dan Wasdahl's 2008 Tire Rack SCCA A Modified Class Solo title-winning 'Darth Vader Special', which was partly developed by *Racecar*'s aerodynamics man, Simon McBeath, using ANSYS FloWizard. The car is propelled by a 220bhp, two-stroke snowmobile engine and has an aero package that includes a fully skirted flat undertray and 15-degree diffuser, a three-element front wing and four-element rear wing.

Rupert Berrington

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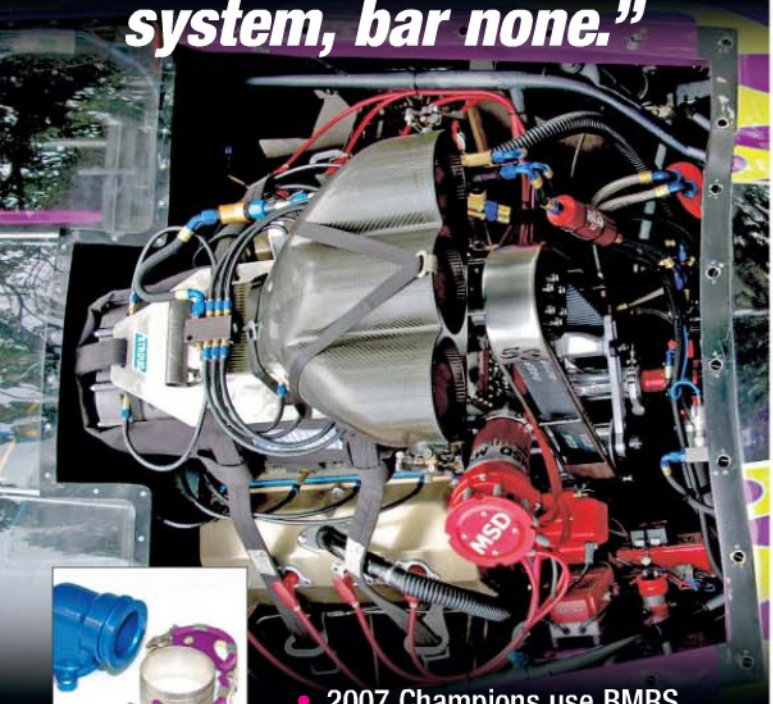

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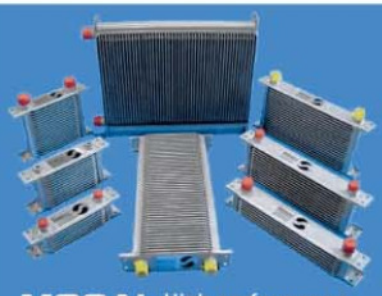

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FORMULA 1

Why Mark was sparking

Did Singapore tram knock Mark Webber out of Grand Prix?

LAT

Red Bull initially suspected static electricity as the cause of Webber's gearshifting problems

WHILE SOME MISCHIEVOUS types might have waited for the floodlights to go out during Formula 1's first ever night race, it was problems with other electrical systems that stole the show at the inaugural Singapore Grand Prix.

Most bizarre was Mark Webber's tram troubles. It was suggested by the Red Bull team after the race that Webber's retirement was due to static electricity caused by a nearby tram. Apparently the gearbox selected two gears at once when the Moog valve controlling the shift was triggered after what team boss Christian Horner described as a 'momentary electrical surge'. It's true a tram line runs beneath the track at the corner where it happened, and Red Bull thought this was possibly the cause of the surge. Singapore tram officials later responded that this was not possible.

Yet the most high profile electronics problem actually had more to do with over-eager fingers – a Ferrari crew member triggering the green light on the team's hi-tech pit signalling equipment before the fuel nozzle had been removed. For the next race, Ferrari reverted to a lollipop. That's one problem licked then.

NASCAR

Happy days for Hayes

NICK HAYES HAS departed from his position as director of R and D engineering with Earnhardt Childress Racing Engines. 'I am looking at other opportunities both in America and Europe at this point in time,' he says. 'I originally joined what was then Richard Childress Racing to set up an engine research and development group within the organisation. My contract was for six months, but I enjoyed the challenge and the people I was working with so much I stayed for what amounted to three and a half years. When I left I felt we'd assembled a world class group of people and one I remain on good terms with.' Hayes recently attended the energy efficiency conference at the ALMS and Indy Car races in Belle Isle and also continues to operate the UK-based consultancy company, Nhanse, he formed before moving stateside.

CAUGHT

LAT

Juan Pablo Montoya's Chip Ganassi Dodge *(above)* was stripped of its pole position at Kansas Speedway after the technical inspection revealed the no 42 car was running gas pressures on the rear shock absorbers 10lb over the allowed 57.

Crew chief Brian Pattie said: 'It kind of sucks because we have worked really hard the last two or three months on our programme to run well at the mile-and-a-halfs [ovals]. The shocks haven't been worked on since I started here.'

PENALTY: BUMPED OFF POLE AND DOWN TO 42ND ON GRID

NASCAR penalised three teams in the Truck Series following a scuffle at the New Hampshire Motor Speedway on 13 September. Two Germain Racing team members were barred for one race, Mark Hillman and his brother and crew chief, Mike Hillman jr, with jr also fined $2500 (£1500). From the Red Horse Racing Toyota driven by David Starr, William Divel was also barred for one race and fined $1500 (£870). All three were placed on probation through the end of the year, while Starr was fined $10,000 (£6000) and placed on similar probation.

PENALTY: ONE RACE BAR / PROBATION
FINE: $1500 - £10,000

It was also announced that the no 30, no 11 and no 9 Craftsman Truck Series teams have been penalised due to their involvement in a post-race altercation on pit road at the same event. Two other crew members were fined $1000 (£580) each – Rick Gay for Red Horse and Jason Overstreet for Germain. Additionally, Germain crew members Brandon Hopkins and Tony Jilson have been placed on probation until 31 December, as have the teams themselves.

PENALTY: PROBATION UNTIL 31 DEC
FINE: $1000

LAT

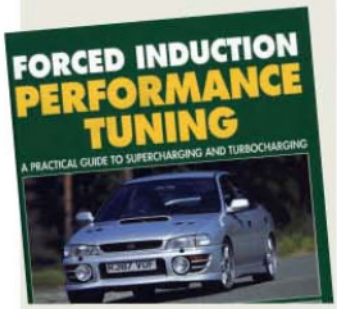
BOOKS

Forced induction performance tuning

A practical guide to supercharging and turbocharging

A Graham Bell

Haynes Publishing/£25/$49.95; ISBN: 9781859606919



Turbocharging seems to be one of the current favourite subject areas for writers of technical motoring books, so this title by A Graham Bell sits in an already crowded market. However, this considerable tome proves a very useful addition on the subject.

Bell gives a thoroughly comprehensive look at all areas of forced induction, from the selection of turbos through to anti-lag strategies and engine mapping, whilst explaining the physics and mathematical theory of turbocharging in a logical and clear fashion. Additionally, Bell also covers nitrous oxide injection in considerable detail, although this is probably only relevant to the drag racing fraternity.

Despite the majority of the content being aimed at road car applications, the theory and practical explanations are equally valid for racecars and the level of detail is excellent, even going as far as providing diagrams and instruction for header design, with a broad range of case studies, from a Renault F1 engine through to Saab's variable compression ratio experimental engine.

Forced induction performance tuning provides the engine tuner or builder with a wealth of information in a clearly laid out, well-written volume, making it a must have for the workshop bookshelf.

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We have lift off

Another spate of airborne Sports Prototypes has prompted both knee-jerk reactions and more measured responses. *Racecar* joins the debate with some wind tunnel data

BY SIMON MCBEATH

Racecar Engineering has published two articles on the topic of flying prototypes in the past, both written by our technical consultant, Peter Wright (V9N7 and V13N5). In essence, both highlighted the fact that Sports Prototypes have very large plan areas and, if the underside is exposed to the airstream at a sufficient angle of incidence and a high enough speed, then taking off is pretty well inevitable. So, with this in mind, perhaps all we can hope to do is lessen the frequency with which this happens. But how?

Wright is now the president of the FIA Safety Commission, the body that has overall responsibility for safety in

(again...)

motor racing. And in July, after some seven separate incidents in 2008 of prototypes becoming airborne, it was reported that the FIA is to undertake another study into the problem. The last such study was carried out by Piper Design in 2002/3, and was summarised by Wright in the second of his articles (see V13N5). This study, as long-term readers will undoubtedly recall, followed the end-over-end flips that befell a number of cars in 1998/9 – most memorably, the trio of Mercedes CLK GT1 cars at Le Mans in 1999. The project led to new regulations being adopted by the FIA/ACO from 2004 onwards, with alarming incidents like those in 1998/9 becoming a thing of the past.

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Top: Stefan Ortelli in the Courage LC70 at Monza (top) taking off after a spin
Bottom: Peugeot 908 crashes at Silverstone after making contact with a Porsche and then lifting off

A THING OF THE PAST?

Indeed, in spite of the seven occurrences that have been reported this year, it could still be said that the 1998/9-style flip-overs *are* a thing of the past because, according to observations made about the 2008 incidents, none of them actually resembled those terrifying, nose-lifting moments at all. This is not to say that the current problems are not alarming – of course they are, and they deserve thorough and objective investigation. A brief look at race reports, however, seems to demonstrate that there were two common factors involved: first, each was initiated either by a mechanical problem or by a driver error, and second, each saw the car go sideways prior to leaving the ground (one quite clearly flipped when it dug sideways into a gravel trap and so falls outside the 'possible aerodynamic causes' group altogether). These circumstances are not like the 1998/9 incidents at all, other than the fact that the cars left the ground.

So what, if anything, can be done to lessen the frequency of such occurrences? The Piper Design project addressed the issue of lift and overturning moments pretty thoroughly, and the 2004 regulations that took up the recommendations of that report saw to it that, among other things, the cars adopted the lateral underbody venturi profile now seen on all current LMP cars. This sought to increase the 'critical speed' required for take-off when at yaw angles around the 90-degree mark – ie when travelling sideways. But – and note that it was only presented as a means of increasing take-off speed, not eradicating take-offs – sudden changes in the car's attitude caused by other inputs, like bumps, kerbs, tyre deflation or suspension collapse, that raise the leading edge of the car (which would be one side of the car at 90-degrees yaw) into the airflow direction could clearly still see high pressure air pack underneath and launch a car, rather than generate the hoped-for low pressure and reduction of lift when in this attitude.

Furthermore, one of the things that the summary in V13N5 told us was that, although the new aerodynamic configuration adopted for 2004 certainly improved matters by reducing the 'overturning moment' under certain conditions of yaw and roll, that moment could still exceed the 'returning moment' developed by the counteracting vehicle weight when at yaw angles of between 45 and 90 degrees, and in the 'collapsed tyre/suspension' scenario. The speed just had to be in excess of 200kph in the 90-degrees yaw case. Go back again over the 2008 incidents and one can't help but surmise that these conditions may have been met in some, possibly even most, cases.

> **"the yaw moment, though positive, was too small to have a significant stabilising effect"**

So why were we surprised? Was it simply that the absence of this type of incident since 2004 made us forget that they could still happen? Did we just get complacent, thinking the new rules had cured the problem altogether? Or are there other

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The Eco Racing Radical SR10 used for the tests in MIRA's wind tunnel. Note boundary layer fence in the foreground

At 50-degrees yaw and with the right front corner jacked up by 48mm 'into the wind' the SR10 was producing lift, not downforce, as well as significant pitch and roll moments

In the straight-ahead position, the modest roll angle dialled in for the test scenarios can be clearly seen

aspects of this year's flips that are not yet fully understood? It is probably not unreasonable to conclude that a sudden spate of incidents points to other contributing factors, for example escalating speeds, but we shall need to wait for the findings of the official investigations to see if that was the case.

WIND TUNNEL TESTS

Meantime, it so happened that in July 2008, *Racecar Engineering* had the opportunity to join in a day's full-scale wind tunnel testing at MIRA with the Eco Racing Radical SR10 LMP1 car run by Ian Dawson. A productive day's quest for improving cooling, overall efficiency and balance was followed by some necessarily brief but interesting glimpses of the aerodynamic forces and moments when the car was put at various yaw angles.

First, let us get the 'fixed floor' objections out of the way. Yes, the fixed floor of the MIRA wind tunnel means that airflows are not fully realistic under a ground-effect racecar. And yes, the wheels are stationary. But keep in mind too that a *real* racecar, complete with all its various cooling systems and internal airflows, is a more realistic test subject than many a wind tunnel or CFD model. So there are pros and cons here.

One physical limitation, however, was that the car could only sensibly be put at a maximum yaw angle of 50 degrees. While it might have fitted across the test section at 90 degrees, MIRA's chief aerodynamicist, Angus Lock, felt there would have been excessive interference from the sides of the tunnel to the flow around the ends of the car. In addition, the boundary layer fence, which initiates fresh boundary layer at floor level ahead of a test car, was removed to prevent it clashing with the front of the car as the car was rotated through higher yaw angles. Boundary layer fence removal was shown to cause roughly seven per cent reduction in measured drag and four per cent reduction in total downforce (mostly seen at the rear) when compared with the 'with boundary layer fence' case at zero yaw.

Two conditions are reported here to illustrate this toe-in-the-water exercise. First, the car was run from zero to 50 degrees yaw in 10-degree increments with the chassis set 'flat' side-to-side. The datum rake was 35mm front ride height measured to the splitter at the side of the nose and 85mm rear ride height measured to the rear-most point of the central keel in the underbody. Second, the car was run at the same yaw increments with the front right corner (leading when at yaw) jacked up to 83mm (the maximum achievable from pushrod and spring platform adjustment) which put the left rear to 40mm, corresponding to about 1.3 degrees of roll measured across the front. Essentially, the front right corner was raised by 48mm, which might simulate an instantaneous attitude after hitting a shallow kerb or small bump, for example.

RESULTS AND OBSERVATIONS

Table 1 and figure 1 show the results of the first yaw sweep, with the chassis set flat laterally, while table 2 and figure 2 show the second sweep, with the right front corner jacked up by 48mm.

Downforce obviously decreased as yaw increased over the increments tested in both configurations shown here and it is apparent that downforce had changed to lift by 40 degrees with the chassis flat laterally, and by about 38 degrees when the right front corner had been jacked up. Front lift appeared at around 32 degrees when flat or about 27 degrees with the right front corner raised (Note: yaw angles between zero and 10 degrees showed initial *increases* in downforce).

The front lift generated at 50 degrees yaw at 160kph (roughly 100mph) implies that the speed would need to be 2.44 times as high, or 391km/h (243mph), to overcome the static weight of 4160N at the front, this speed falling to 358km/h (223mph) when the right front corner was raised. Nevertheless, the trend suggests that lift would continue to increase with increasing yaw angle, as indeed was shown in the summary of the Piper Design report in V13N5.

Drag is not shown here,

YAW SWEEPS

TABLE 1

Datum rake (35mm front, 85mm rear measured to diffuser keel), no roll

Forces in Newtons (N), moments in Newton metres (Nm), all at 160kph, with the chassis set flat laterally. Vertical forces are given as downforce so lift is shown as negative. Ignoring proper convention, moments are all shown as positive for simplicity

Yaw	Total Df	Front Df	Rear Df	Total Side force	Front Side force	Rear Side force	Roll moment	Pitch moment	Yaw moment
0	3119.1	1258.0	1865.4	27.5	9.9	17.7	0.6	868.7	11.3
10	2698.6	1122.9	1575.6	802.8	383.8	418.0	229.3	647.3	50.4
20	1799.4	566.7	1232.7	1610.7	740.3	870.4	674.2	952.4	186.0
30	858.5	123.7	734.8	2274.5	1041.1	1233.5	1101.8	873.9	275.1
40	15.0	-391.1	406.1	2647.8	1263.5	1384.3	1491.3	1139.9	172.8
50	-717.2	-696.6	-18.5	3198.0	1499.8	1698.2	2083.6	972.5	283.7

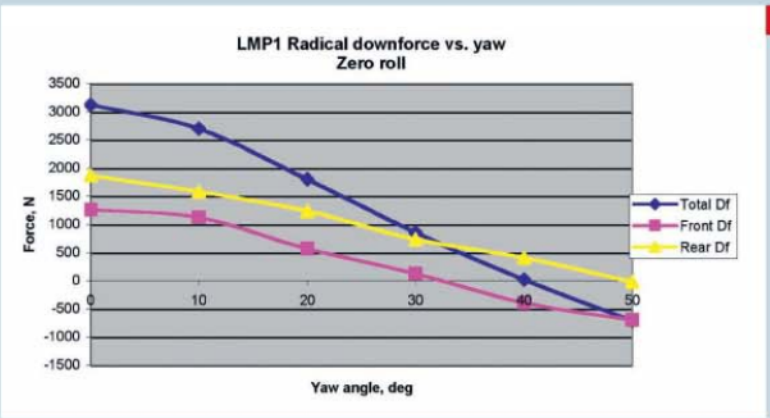

Figure 1
Plot of aerodynamic forces with the chassis set flat laterally

TABLE 2

Force and moments with the right front corner raised by 48mm

Front left ride height = 40mm, front right ride height = 83mm, equivalent to 1.3deg roll at front

Yaw	Total Df	Front Df	Rear Df	Total Side force	Front Side force	Rear Side force	Roll moment	Pitch moment	Yaw moment
0	2401.9	547.5	1854.4	-10.4	-18.0	7.6	57.3	1868.8	36.6
10	2286.0	545.6	1740.4	780.4	364.7	415.8	322.9	1708.5	73.1
20	1692.2	268.0	1424.2	1613.8	742.4	871.4	819.0	1653.4	184.4
30	769.9	-104.6	874.4	2243.2	1028.1	1215.0	1194.0	1399.9	267.2
40	-131.2	-525.1	393.8	2650.5	1275.9	1374.6	1661.4	1314.0	141.2
50	-884.3	-830.3	-54.0	3185.1	1512.2	1672.9	2257.2	1110.1	229.9

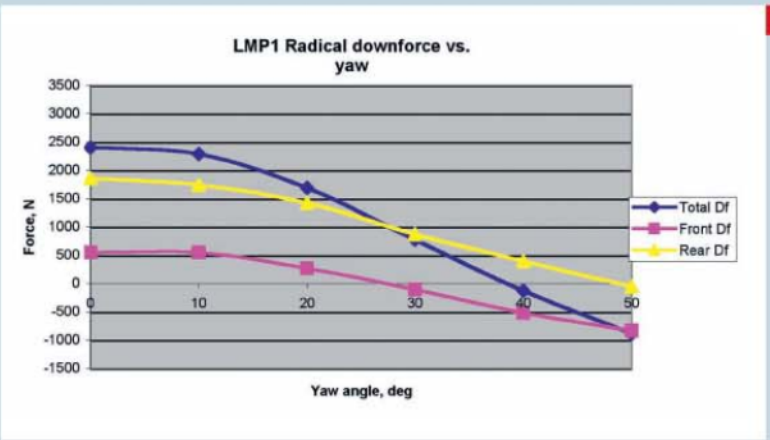

Figure 2
Plot of force with the right front corner raised by 48mm

and because of the way the underfloor balance functions, with load cells under each tyre contact patch, the total rearward force would be found by adding the rearward components of the measured drag and side force. This is of no real interest here, other than to say the total rearward force increases with yaw angle because of the increasing 'frontal' area being exposed to the airflow.

But the side force values *are* interesting, and particularly their front-to-rear distribution, which gives rise to the yaw moment. As Lock pointed out during the test, the yaw moment (see figures 3 and 4), though positive, was too small to have a significant stabilising effect. It will be recalled that a larger minimum rear end plate area was mandated in the 2004 regulations in an effort to increase yaw stability but, at the same time, the rear overhang was also shortened, which may have mitigated the stabilising benefit from bigger end plates.

YAW MOMENTS

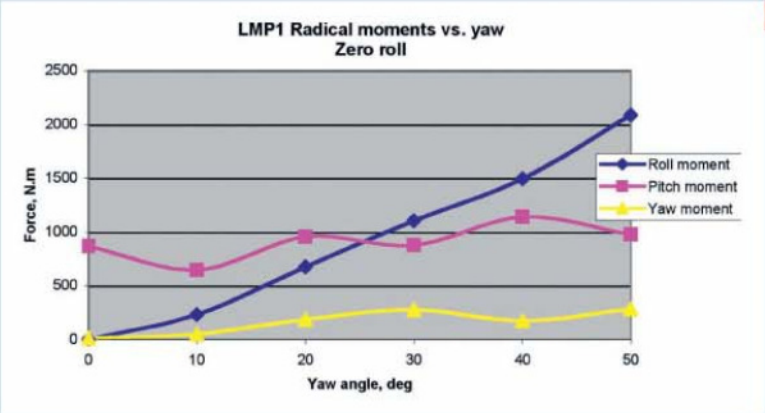

Figure 3
Plot of moments with the chassis set flat laterally

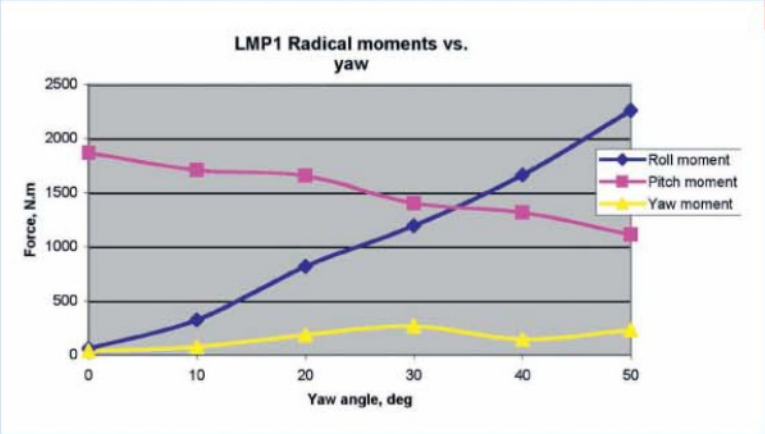

Figure 4
Plot of moments with the right front corner raised by 48mm

FURTHER DISCUSSION

It is clear then that the roll moment increased as yaw increased, and it seems reasonable to expect this trend would continue to higher yaw angles, no doubt peaking at 90 degrees yaw. This may be significant in the context of the recent flips when travelling sideways at speed, and is an aspect that larger rear end plates would likely exacerbate, as will any high up bodywork elements. Lock also suggested that maybe the closed rear wheelarches were not helping because when at yaw air is more readily able to enter and potentially pressurise these cavities, and while this would add drag and help slow the racecar, it would also increase roll moment.

The pitch moments were positive (towards the rear) and reasonably significant in each case though, interestingly, the pitch moment reduced with increasing yaw angle when the right front corner was raised, having started high because of the much reduced front downforce at low yaw angles in this configuration.

Within the limitations of the yaw angles tested, it would appear that this trial mirrors parts of the initial Piper Design work, while also highlighting some other aspects of the aerodynamics of LMP cars that could have contributed to the instabilities involved in the recent spate of incidents. In themselves, none of the effects measured would appear to be enough to get the car airborne, unless speed was very high, although something like a puncture on a fast straight could potentially do it. However, the progressive loss of lift, especially at the front as yaw increases, the consequent pitching moment, and the roll moment that increases (presumably) towards 90 degrees yaw could all contribute to altering the attitude of a Sports Prototype such that it can rotate (lift the leading edge) and generate sufficient lift to get airborne when other disturbing inputs create yaw, pitch and roll, even at lower speeds.

Lock maintained during this session that there are some fairly simple methods of reducing the roll moment when at higher yaw angles that would be relatively insensitive to small 'nose-up' angles. He suggested, for example, that this might involve dispensing with the lateral venturi shape in favour of a laterally flat underside, but with a protruding running board. This would help counteract the roll moment by creating high pressure low down on the sides of the car when the car was sideways to the airflow, the running board acting like a splitter.

> **"the roll moment increased as yaw increased"**

Increasing the stabilising yaw moment is something else that could be of benefit too, but in trying to avoid increasing the roll moment when at yaw, this might better involve increases to low down body side area at the rear rather than high up end plates. Perhaps lowering the whole rear wing and end plate assembly would be beneficial. And mandating rear wheelarch louvres would help reduce pressure build up in the wheel wells and reduce the overturning moment when the cars get to larger yaw angles.

While this is only speculation, what is certain is that this exercise prompted discussion, suggesting there are plenty of improvements that could be trialled at full scale in a wind tunnel. Notably, one of these 'improvements' is *not* to 'remove all aero devices from the bottom of the cars', as one prominent luminary was quoted as saying after the Le Mans race.

So can the occurrence of prototypes becoming airborne be completely prevented? It seems improbable. But improvements that decrease the frequency of these events could almost certainly be made, so the outcome of the FIA's investigation is awaited with great interest.

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FIRST PRINCIPLES

Simon McBeath is an aerodynamic consultant and manufacturer of wings under his own brand of The Wing Shop – www.wingshop.co.uk. In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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Chickens and eggs

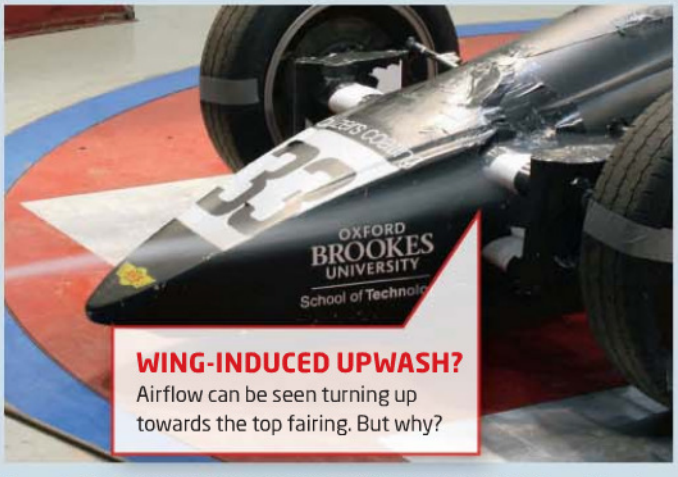
The distinction between cause and effect is not always immediately obvious. But a little CFD helped solve one small riddle from the wind tunnel

A conundrum has been nagging me since mid-2007: what made the Formula Vee suspension fairings shown in V17N12 generate more positive lift than the front of the car was already creating? And you know what, I might have found an answer.

The idea of these fairings was simple – tidy up the airflow around the mandatory circular and box section front suspension in order to reduce drag. The results were surprising – drag barely changed (actually it went up by about one per cent with fairings in place), but more curiously, total (positive) lift increased by 8.5 per cent and front lift went up by 23 per cent. Actual forces were quite small, that 23 per cent representing only about 46N (10lb), but this still seemed curious.

The smoke plume in the photo above illustrates how the airflow approaching the horizontal fairings between the nose and the front wheel was turning upwards. In that previous Aerobytes we supposed that this might have been wing-induced upwash, showing that positive lift was being generated by the symmetrical aerofoil section fairings.

What we didn't do was look at the flow without the fairings to see if the up turn was present then, which would have ruled out the fairings as the cause. However, a few months later we visited the wind tunnel with a Spectrum Formula Ford and again this upturn in the flow approaching the much slimmer front suspension was noticed. It was, I confess, some time before the probable cause dawned – that the airflow is converging between the side of the car and the wheel, and the ground is in the way, so inevitably there is an amount of upturn through this narrowing gap. This, of course, would see the airflow encountering the fairings at an upward angle, so it should therefore come as no surprise that they added some positive lift.



WING-INDUCED UPWASH?
Airflow can be seen turning up towards the top fairing. But why?

Simon McBeath

Formula Vee racecars carry mandatory obtrusive VW Beetle-based front suspension. Fairing this in increased positive lift in the wind tunnel

> **the airflow is converging between the side of the car and the wheel**

TESTING THE THEORY

Would this theory stand up to further investigation? To test it out, a CAD model of a very basic Formula Vee car with roughly the same dimensions as the AHS Challengers originally evaluated in the wind tunnel was assembled. Cylinders and box sections to represent the bulkier components in the front suspension supplemented a central fuselage and four wheels. Two 'faired' options were prepared, one had the transverse cylindrical beams replaced by short chord symmetrical aerofoil sections, the other had the vertical box sections replaced by aerofoil sections of the same profile as the transverse ones. The models were then run in Ansys FloWizardTM CFD software.

Figure 1 overleaf shows the flow vectors on a vertical plane about half way along the front suspension and the predicted flow directions compare well with the smoke plume in photo 2. Figure 2 shows from above the flow vectors on a horizontal plane between the two transverse beams, and it can be seen how the

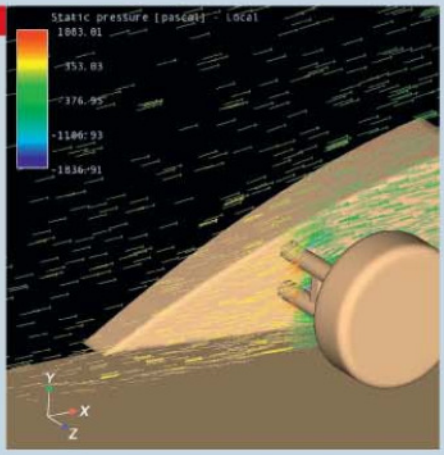


Figure 1
This CFD (half) model shows a similar flow pattern to that seen by the smoke plume in the wind tunnel

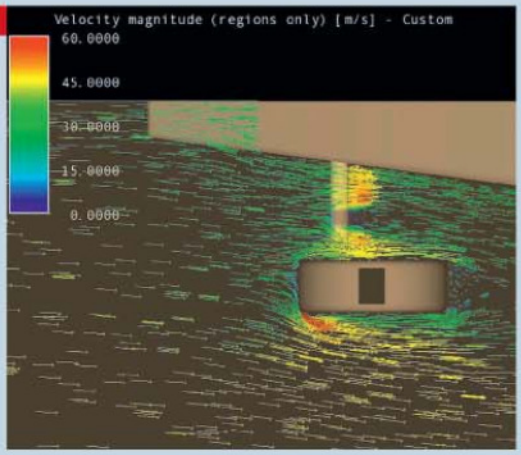


Figure 2
From above, the convergence between the chassis and the wheel is apparent

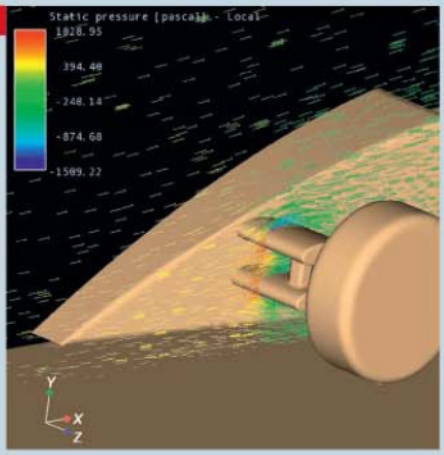


Figure 3
With fairings added 'around' the transverse beams, lift increased

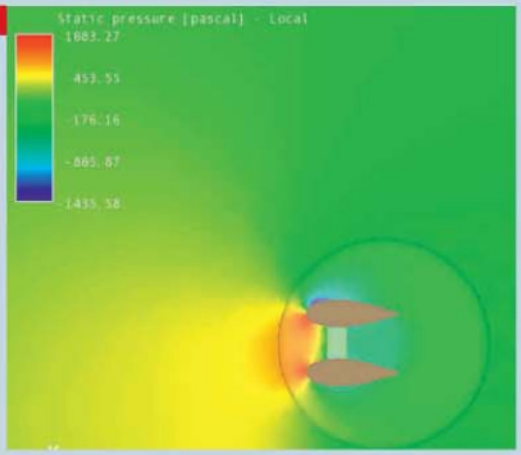


Figure 4
Static pressure plot around the faired beams shows reduced pressure above and elevated pressure under the nose of the top fairing

flow converges between the wheel and the chassis side which, as mentioned earlier, would have the effect of inducing an upturn here. This all supports the notion that the airflow is compelled to turn upwards here.

Figure 3 shows a similar view to figure 1 but the model now sports fairings 'around' the transverse beams. The flow directions appear very similar, but it can be seen that there is low static pressure (blue colouring) above the upper beam. Figure 4 shows the pressure patterns more clearly in side view. The overall pattern around the pair of beams shows lower pressure above than below, and the region of high static pressure at the 'nose' of the upper beam is on the underside. Both these factors would contribute to positive lift.

Table 1 shows the results. Note that the forces are lower than those measured in the wind tunnel and, if only because of the simplicity of the CAD model, they should not be directly compared to the wind tunnel data.

TABLE 1

Comparison of forces at 100mph between 'bare' and faired front suspension on a Formula Vee-like model, analysed in FloWizard

	Drag, N		Lift, N	
	Bare	Faired	Bare	Faired
Body	169.6	162.2	23.6	36.6
Front wheels	149.4	152.0	82.8	84.8
Rear wheels	36.6	37.8	23.6	24.8
Front suspension	88.2	64.2	2.1	61.2
Total	443.8	416.2	132.1	207.4

TABLE 2

Comparison of forces at 100mph between bare front suspension and a faired vertical box section

	Drag, N		Lift, N	
	Bare	Faired box section	Bare	Faired box section
Body	169.6	170.4	23.6	16.0
Front wheels	149.4	151.2	82.8	83.0
Rear wheels	36.6	36.6	23.6	24.4
Front suspension	88.2	81.6	2.1	10.8
Total	443.8	439.8	132.1	134.2

LIFT AND DRAG REDUCTION

This simple exercise did show the hoped-for reduction in drag, most of which apparently came from the suspension modification. Likewise, the change in lift (although other regions of the car also saw changes to their lift contributions). And while the drag benefit did not appear on the real racecar in the wind tunnel, there was a significant increase in lift that mirrored the generic prediction of the CFD.

So with the flow approaching the suspension at the angle it does, symmetrical horizontal aerofoil section fairings are always going to induce lift. Given that the wind tunnel showed no drag benefit, this is probably not a modification worth pursuing!

However, what about putting an aerofoil-shaped fairing around the vertical box sections of the suspension? Surely this would reduce drag without adding lift? Table 2 shows the results of a CFD run on this configuration. Drag was indeed reduced by a small amount – 0.9 per cent relative to the unfaired configuration – but lift again increased very slightly. But given the unlikelihood of these variations being matched in reality, it cannot be said whether this idea is worth following up. Certainly, the flow vectors showed the flow is tidier around the fairing, but the wake of the box section doesn't seem to persist for long in this region of converging flow, which perhaps means the box section's adverse impact on drag is less than it might otherwise have been.

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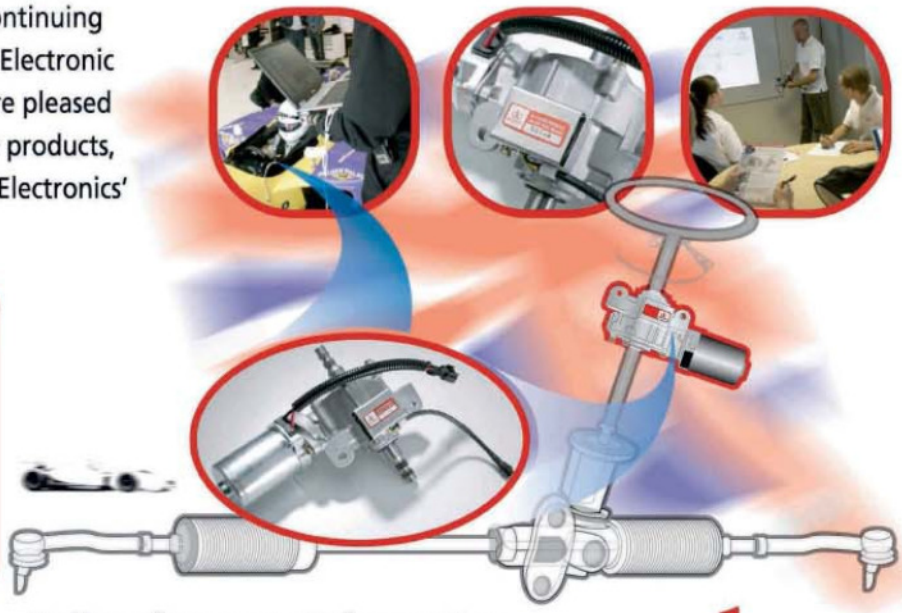

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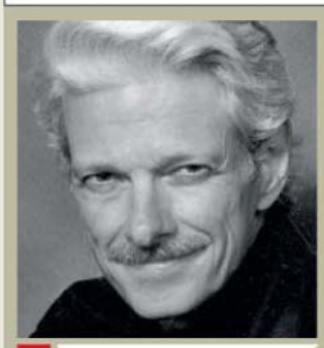

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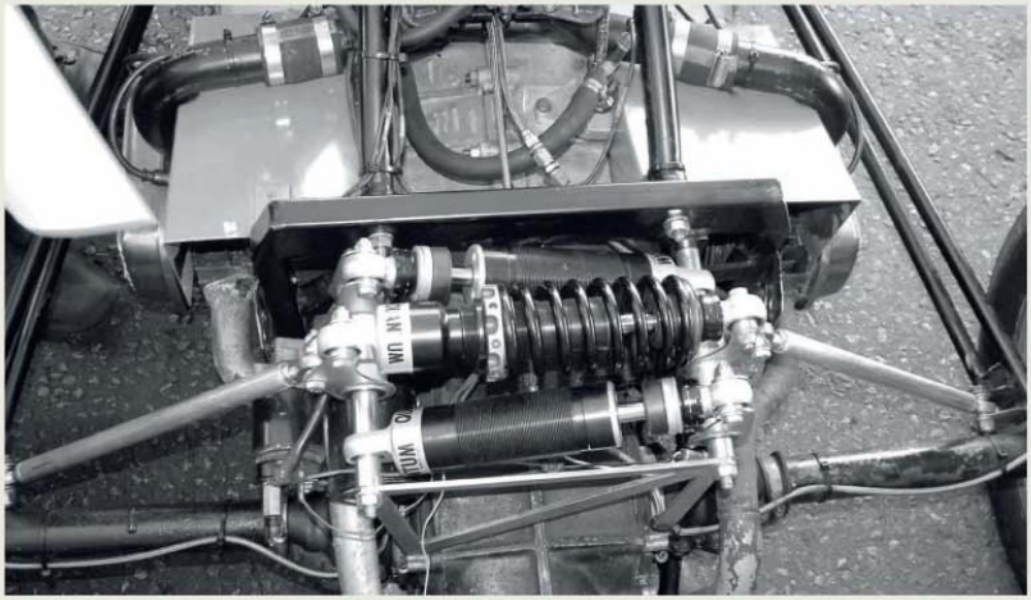

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Rising rates

THIS MONTH:
Q Monoshocks, Z-bars and bump rubbers - how do they work?
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Q Part 1 Monoshock suspensions
I have seen some of the alternate springing methods used on racecars these days, including monoshocks and third springs, but could you explain how they work and what their advantages might be over coilovers?

Part 2 Z-bars
Given a situation where you need a softer suspension set up, would it be useful to use an S-shaped anti-roll bar instead of a standard, U-shaped bar? I would assume that on a vehicle with a relatively low c of g, like a Formula Ford, trying to load the inner wheel to an extent could yield some additional grip? Do you have any comments on this?

Part 3 Bump rubbers
Now that the NASCAR Car of Tomorrow is allowed to use bump rubbers, do you have any good advice to give on this subject?

A I have grouped these questions together because there is a common thread through all of them - they relate to ways we can get a wheel rate that rises as the suspension compresses.

To understand some important differences between ways of doing this, it is helpful to recognise that a four-wheel suspension system has four modes of movement - roll, pitch, heave and warp - and the elastic resistance to wheel displacement, or rate of elastic loading change with respect to displacement, can be different in all four modes. However, in most suspensions, the wheel rates at a given wheel are very nearly identical in pitch and heave, and in roll and warp. Also, in road racing cars, the right and left wheel rates are identical, or very nearly so. Consequently, for simple and conventional cases, we can break the suspension system down into front and rear systems, each having a wheel rate for ride and another for roll.

> **"in road racing cars, the right and left wheel rates are identical"**

In most suspensions, neither of these rates is truly a constant. When the system has to contend with large variations in load, it becomes desirable to have the suspension get stiffer in ride as it compresses. Before rising-rate suspension became popular in racing, it was widely used in road vehicles, particularly in the rear suspension on trucks and front-wheel drive cars.

If we have a conventional suspension with two individual

springs acting at the wheels, two dampers acting on the two wheels separately and an anti-roll bar, and we arrange for the springs to have a rising rate, then the rate in both ride and roll rises as the suspension compresses in ride. This also applies if we provide packers or bump rubbers on the shocks or elsewhere.

One effect that this will have on car behaviour is that when we set up the aero balance to add more downforce at one end than the other – to make the end with more downforce stick better at high air speeds – the change in roll resistance distribution will change the handling balance oppositely to the change in downforce. This makes the net effect somewhat more difficult to predict, and it may in some cases make the car unresponsive to the adjustment. To get away from this, it is desirable to have a way to add wheel rate in ride that does not add wheel rate in roll. Third springs, Z-bars and monoshock systems are various ways of doing this.

In monoshock applications, the single coilover acts only in ride and there is generally no damping in the roll mode

THIRD SPRINGS

For those not familiar with these concepts, a third spring is most commonly seen in pushrod or pullrod suspensions, with rockers and a T-bar for anti-roll. The T-bar is a torsion bar with the torsional part forming the leg of the T, and push / pull rods extending from the rockers to the ends of the cross of the T. The T-bar can rock backward and forward freely about its lower end, so when the rods move synchronously there is no resistance. When the rods move oppositionally, however, the bar is forced to twist and resistance results.

The third spring attaches to the middle of the top of the T, where the leg meets the cross. It is most often a coilover, but can be a spring on a slider, a dummy shock, a shock or slider with a rubber snubber or a coilover with a snubber. Ordinarily, the third spring is designed to have a pronounced rising rate and the third spring acts only when its attachment point to the T-bar moves, which only happens in ride. As such, the total arrangement provides a steeply rising rate in ride, without a rising rate in roll. Depending on the geometry used, it is theoretically possible to have rising or falling wheel rate in either mode. The nice thing is that we can control the two independently.

MONOSHOCKS

A monoshock suspension generally has a single rocker with a single coilover, actuated by pushrods from both right and left wheels. The coilover acts only in ride, much like a third spring. Roll is usually accommodated by having a laterally sliding shuttle in the rocker. The pushrods anchor to this shuttle bar and when they move synchronously they rock the rocker. Conversely, when the pushrods move oppositionally, they slide the shuttle bar. Roll resistance is commonly provided by stacks of Belleville washers on the bar.

This arrangement offers independent control of roll and ride, much like a third spring, but with reduced weight and cost. Generally, there is no damping in the roll mode, though, which is a disadvantage. Monoshocks are normally only used at the front, in smaller-displacement formula and sports racers.

Z-BARS

A Z-bar is what the second questioner describes – a transverse torsion bar, similar to a normal anti-roll bar, but with one arm pointing back and one forward. It affords a way to spring only the ride mode in a suspension that doesn't have pushrods and rockers. We should note that there is no such thing as a negative-rate spring, though in certain unusual cases, it is possible to mount a spring so that the force generated by the assembly diminishes with increasing displacement, but there is no way to make a spring do that by itself. A Z-bar, at least as we normally encounter it, cannot in itself reduce roll resistance or promote roll. It just adds rate in ride without affecting roll. This means we can use it to get reduced roll resistance with a given ride rate, if we use it in conjunction with soft individual wheel springs or with no wheel springs at all.

> **“there is no such thing as a negative-rate spring”**

We most commonly see this with swing axle rear suspensions. By having a high wheel rate in ride and little or no wheel rate in roll, we can minimise the limit oversteer and upward jacking that a swing axle rear end tends to generate. Even when the Z-bar is the only spring in the system, the suspension still resists roll and creates load transfer. It just does this entirely through its geometry, rather than elastically.

If we were to use Z-bars instead of anti-roll bars at both ends of a modern formula car with low roll centres, we would increase roll, but we would not increase the loading of both inside wheels. Increasing loading of the inside wheels - ie equalising the loading of inside and outside wheels and reducing load transfer is beneficial in all conditions, wet or dry, but there is no way we can do that for both wheel pairs by making changes to the suspension. The suspension only controls how much of the load transfer occurs

SS Collins

Some stock swing-axle Beetles used a rear Z-bar, and variants on the theme are commonly found on Formula Vees. Used in place of anti-roll bars at both ends, though, this set up would increase roll but not inside wheel loading

> "If we soften the [bump] rubbers to get some roll compliance, we give up some aerodynamic control"

at the front, compared to the back. The only way to reduce the total load transfer at both ends combined is to lower the c of g or widen the track.

BUMP RUBBERS

With Stock Car front ends, we have a somewhat similar situation, but with some differences. Generally, in oval track racing a given track's turns are all taken at similar speed, but the car has to pass a ride height check. With a Stock Car, we are trying to get the splitter or valance as close to the track as possible, and keep it there, without destroying it against the track surface, yet still have the car pass the static check. So we run soft springs and a big anti-roll bar, and arrange for something to bottom out when the car reaches the desired ride displacement. Until recently, at least in the upper NASCAR divisions, bump rubbers were prohibited, so people arranged for the springs to reach coil bind. Now bump rubbers are permitted, and teams are learning to work with them.

The bump rubbers are on the shock shafts and unavoidably act in both ride and roll. They can be as soft as we like, but we still face a trade-off between controlling the splitter and having highly non-linear roll resistance at the front of the car. If we try to soften the rubbers to get some roll compliance, we give up some aerodynamic control.

LAT

NASCAR engineers are now having to learn to use bump rubbers on the CoT

On high-speed ovals, aero forces are so significant that reducing front roll resistance can actually cause a push, by costing us front downforce as more air gets under the nose. On short tracks, this is less of a concern, but is still a consideration that is worth thinking about.

The problem with having a steeply increasing wheel rate in roll at just the front of the car is that it becomes increasingly difficult to get good handling balance through the entire turn and as grip level varies. We can increase rear roll resistance easily enough, but giving it a non-linearity that harmonises with the front is not possible.

CONCLUSION

Rules permitting then, there would be a strong case for having a stiff Z-bar at the front of a Stock Car, in addition to the anti-roll bar, and having sliding drop links with bump rubbers on the bar. Another possibility would be to have a third arm in the middle of the anti-roll bar, and a bump rubber acting on that. I'm sure NASCAR would not allow this, but if you are running with a different sanctioning body, or running to track rules, maybe you could get your officials to allow it.

I have heard of one instance of a Z-bar being allowed as an anti-roll bar. This was on the swing axle rear end of a Triumph Spitfire used in SCCA competition. Aftermarket anti-roll bars were legal, and the officials ruled that the bar still qualified, even if one arm pointed the wrong way. To me, it's a bit of a stretch to call a device an anti-roll bar when it doesn't resist roll, but that was their ruling.

In many cases, the ruling comes down to whether the device is reasonably affordable, can be retro-fitted to existing cars, and whether it improves the show. Having a car that is more consistent is definitely desirable from a competitor's standpoint, but from a promoter's standpoint there is a strong case for deliberately making it hard to achieve consistency.

When all the cars are inconsistent, this makes for more lead changes and less predictable race outcomes - in short, it improves the show.

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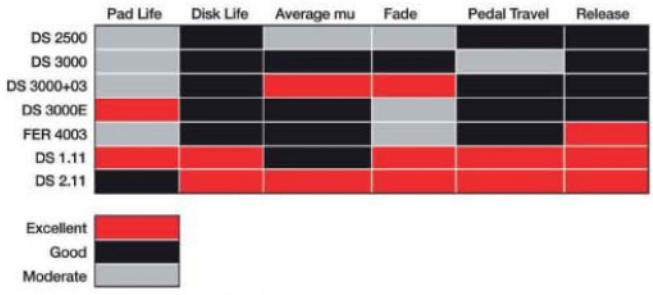

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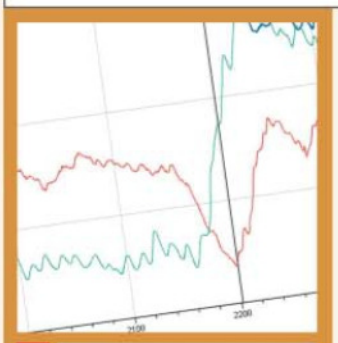


FIRST PRINCIPLES

Databytes gives insights to help you improve your data analysis skills each month as Pi Research's engineers share tips and tweaks learned from years of experience with data systems. Plus we test your skills with a teaser each month.

Understanding bitfields

These handy devices pack data and allow you to transmit more information in less space

Devices that send data to a logger using CAN or serial data streams and sometimes even loggers themselves pack status information into bitfield channels. The most common reason for doing this is to optimise bandwidth in the stream. For example, a CAN packet consists of eight 8-bit values (a binary 8-bit number or byte can represent values from 0-255), if it is sending status information that only takes two values (on or off) it could use one space in the CAN packet to represent each one. This would mean it could send eight channels of status information in one CAN packet. If a bitfield is used, it could transmit all eight messages in one byte, leaving seven bytes free for other information. On a data logger these packed bitfield channels are often given away by their naming, which regularly contain words like status, bits or enumeration. Plotting these channels on a normal time / distance chart will show the values changing, but it is difficult to interpret them as it is the individual bits that are significant rather than the absolute value. Consider the simple bitfield that is sent from an ECU, shown below in table 1.

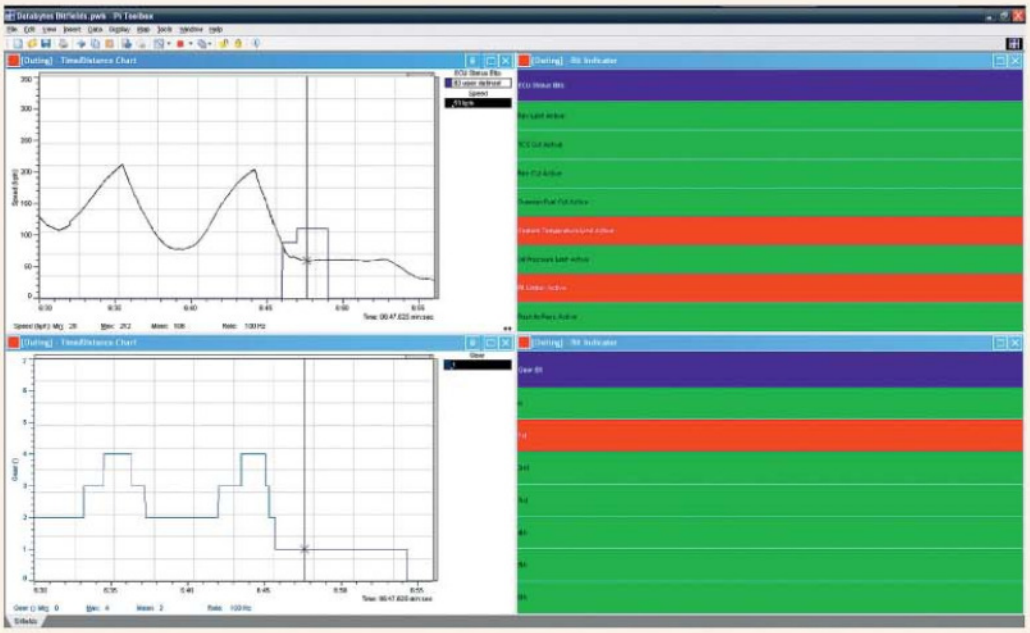
ADDITIONAL CALCULATIONS

It is easy to de-code the meaning of the channel if only one of these bits is active at a time as it will take the value shown in the right most column. However, if two or more of these are happening at once, the channel value will be the sum of the decimal values and some additional calculations to de-code it will need to take place. Let us say that during a pit stop the pit limiter is on and the coolant temperature limit has also activated, the channel would have a value of 16+64=80 – not immediately obvious from the decimal values, though good data analysis packages will have a bit indicator display. This comprises a number of indicators that change

TABLE 1

Example bitfield sent from ECU

Bit position	Reason	Decimal value
0	Rev limit active	1
1	TCS cut active	2
2	Rev cut active	4
3	Overrun fuel cut active	8
4	Coolant temperature limit active	16
5	Oil pressure limit active	32
6	Pit limiter active	64
7	Push to pass active	128



colour when each bit in the bitfield channel changes from off to on. They often have the ability to name the individual bits, making it even easier to de-code them without referring to documentation or a calculator. The screen shot shows the difference between plotting the channel ECU Status Bits on a time / distance chart and in a bit indicator display. It is far easier to instantly interpret the results in the bit indicator.

USING MATHS CHANNELS

The power of bitfields is not just limited to ones generated by attached devices either. You can make your own maths channels that output bitfield. The astute amongst you will have noticed that, in the table above, the decimal value of the channel is 2 raised to the power of the bit position i.e. bit 5 is set by 25=32.

A common bit maths channel is Gear Bit. This simple channel allows the car's gear position to be displayed in a bit indicator. The formula for this maths channel is pow(2, [Gear]) or 2 raised to the power of the value of the Gear channel. You can see that this channel, when plotted in a bit indicator display, gives a very clear signal of the gear the car is in when compared to plotting it on a time / distance chart. This channel is very useful when using real-time telemetry data as the gear lights illuminate as the driver goes through the gears in real time when on track. Bitfield status channels and bit indicator displays are a powerful method of quickly interpreting data from an attached device, and they can be harnessed to make better use of real-time telemetry data.

As you can imagine, there are many other applications that you can start to make use of with this technology, limited only by your imagination.

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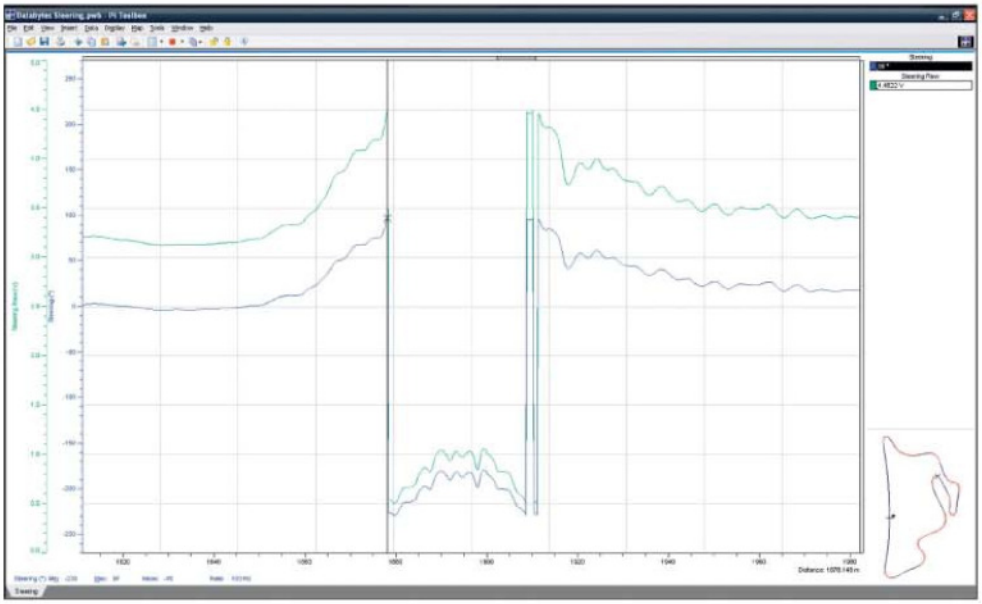
CHALLENGE

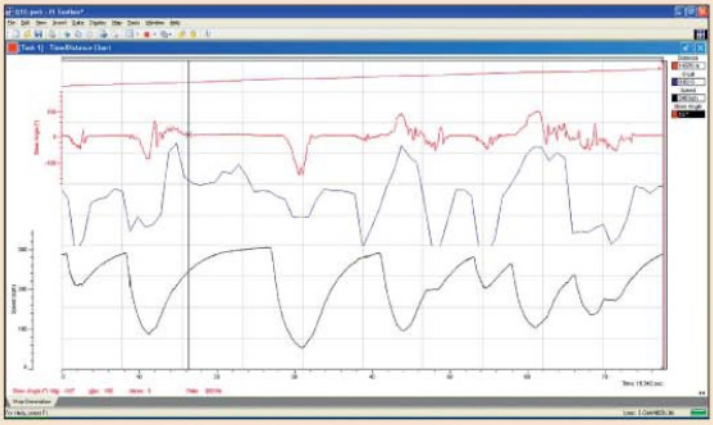
Test your own data analysis skills. The answer will be in next month's *Racecar*



The traces above show calibrated steering rack angle in degrees and raw voltage from the steering sensor of a short section of track in a tight left-hand corner. Calibrated steering angle appears to spike down from around 90 degrees to -230 degrees and back up again in two places. Raw sensor voltage appears to follow. What is the cause of this?

a) The sensor is failing, which causes the reading to drop out
b) The sensor is reading the car's true steering movement
c) The sensor is moving through its maximum electrical travel

In last month's CHALLENGE we asked:
Why is the data engineer struggling to obtain a representative map of the circuit?



The answer is:
c) The rate at which the accelerometer is being logged is insufficient to compute the radius of the corners.

Robin Cull of Pi Research explains:
Map creation relies on lateral acceleration to derive the instantaneous corner radius through which the car is travelling. This is the basic principle behind how a map is drawn. As the sensor is only being logged at 1Hz, the corner radius derivation will be sudden ie it won't see the gradual emergence of a corner and, in the case of a quick corner that has a time of less than a second to complete, the lateral acceleration through that section could be seen to be zero throughout and so the corner will not appear on the map.

A logging rate of 25Hz is sufficient to draw a map, although if a higher rate is used this will result in slightly more accuracy. It should be worth bearing in mind that due to the track map in this case being a representation, a slightly filtered signal can improve the 'flow' of the generated track map.

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74-1000U (1")
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75 Series

75-625U (5/8")
75-700U (7/10")
75-750U (3/4")
75-812U (13/16")
75-875U (7/8")
75-937U (15/16")
75-1000U (1")
75-1125U (1 1/8")

76 Series

76-625 (5/8")
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76-750 (3/4")
76-812 (13/16")
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76-937 (15/16")
76 -1000 (1")

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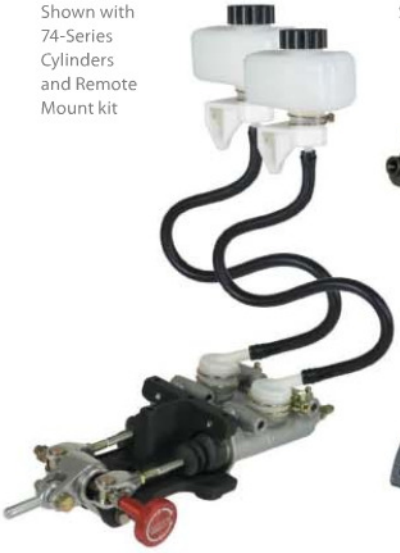

72-610 (Aluminum Remote Mount 90°)
72-650 (Aluminum Remote Mount 60°)

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Shown with 76-Series Cylinders

72-602 (Aluminum Overhung 6.2:1)
72-605 (Aluminum Overhung 5.5:1)
72-606 (Steel Overhung 6.2:1)

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72-601 (Steel Firewall 6.2:1)

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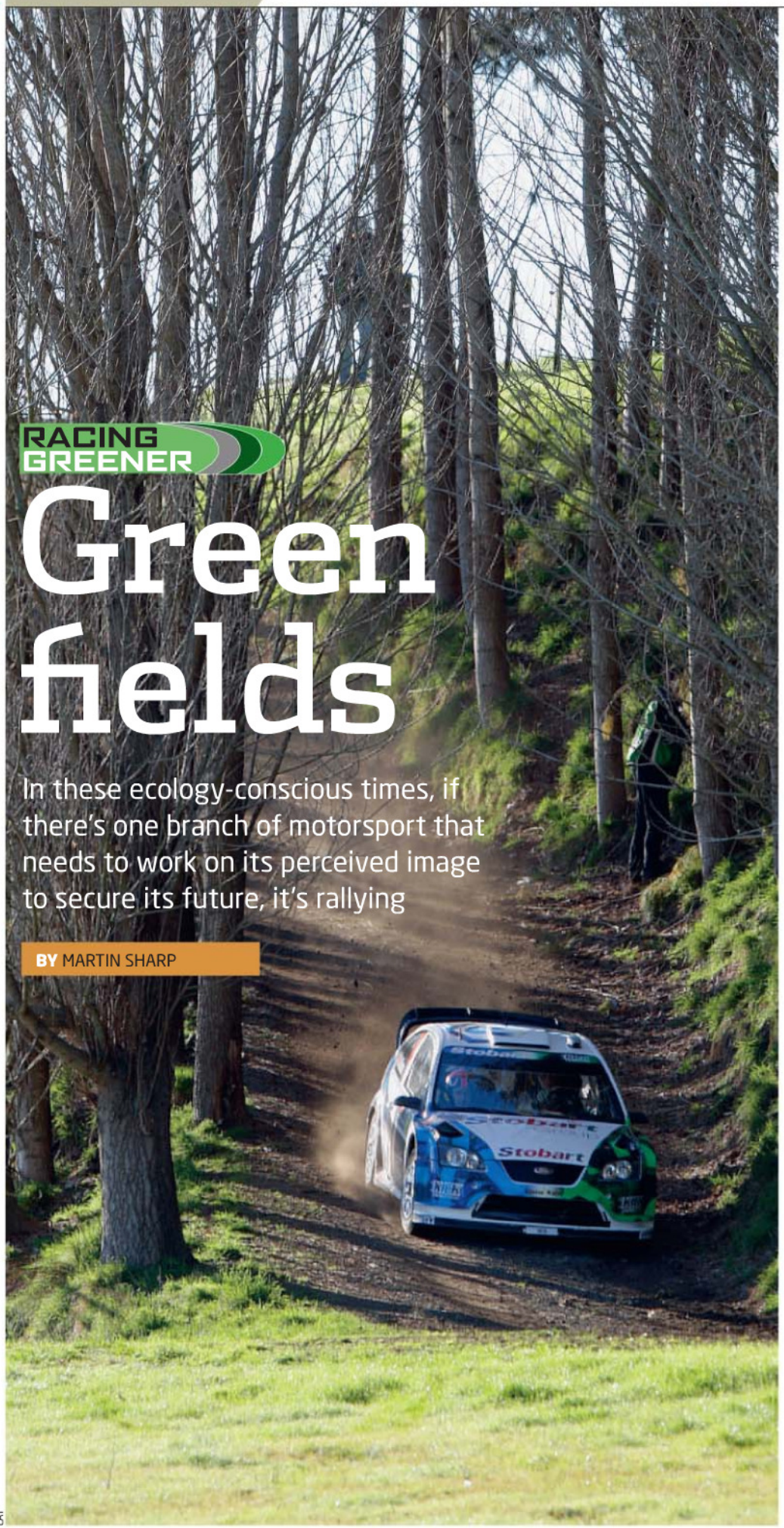

LAT

RACING GREENER

Green fields

In these ecology-conscious times, if there's one branch of motorsport that needs to work on its perceived image to secure its future, it's rallying

BY MARTIN SHARP

When launched, the Toyota Prius hybrid cost more to build than it was sold for. But, over the years, by investing heavily in hybrid technologies and rationalising its production processes Toyota has managed to bring that cost below the retail price of the car, making earning profit with such cars a realistic expectation. As a result, other car manufacturers are joining the hybrid bandwagon.

But what's this got to do with motorsport, you might ask? It's not as if supplies of oil will run out in the foreseeable future. More likely, as it becomes more and more expensive to extract, there will come a break point at which it becomes economically not viable to do so. At that point, oil will effectively be gone for good. And as motorsport currently depends entirely on oil, it stands to reason that the sport must also have a finite future.

The branch of our sport currently perceived to be doing something about dealing with this potential situation is Formula 1. Although KERS may still be in its infancy, the point is that the general public *knows* Formula 1 is doing something about where it gets its energy from, how it is used, and how this can be improved for the future.

CRITICAL ISSUE

No matter how rose-tinted the spectacles are through which the future of motorsport is viewed, energy source is a critical issue which, if ignored, could lead to the death of particular motorsport disciplines. And surely the branch of the sport which is most directly in the firing line is that which is not cocooned in its own purpose-built facility and can be witnessed first hand as its cars blast through small villages and forests – rallying.

Up on the top line of rallying, in the World Rally Championship, is where moves should be seen to be being made in a similar way to Formula 1, not only in a bid to secure its long-term future,

Did you know the FIA has been involved in a programme of tree planting to offset carbon emissions through motorsport for years?

but also to act as an example to lesser rallying categories.

But what is being seen to be done in rallying about energy at the moment? As far as the public is concerned – apart from the fact that World Rally Cars use catalytic converters – zilch, nada, nowt. It is an almost hidden fact that the FIA is planning the use of bio-fuels in world rallying next year and few are aware of the FIA's tree-planting gestures over the past few years. Quite why this information is not generally made available is unclear.

What is certain is that the governing body is currently in the process of putting together what is understood to be a wide-ranging policy document on energy usage and emissions in motorsport, perhaps with the intention of getting a 'good hit' of publicity on these emotive subjects. However, it is not known when the document is going to be released.

LAT

The Germans led the way in 'waste segregation', insisting all service work is done on vinyl sheets to prevent pollution. All other rallies followed suit

POLLUTION RESPONSIBILITIES

Top manufacturer rally teams know they have responsibilities in this area, yet are contesting the World Rally Championship to win, gain publicity and sell more cars. So, as in all forms of the sport, their emphasis is on extracting as much performance from their cars as possible, not necessarily on dealing with their 'pollution responsibilities'. That's not to say they're not acutely aware of them, and the scale of the threat to the future of their sport, as Ford's M-Sport motorsport director, Mark Deans, explains: 'Motorsport always has an impact on the environment, yet the biggest challenge in this area is to rallying – a very visible sport – and we have a responsibility. M-Sport is currently three quarters of the way though an environmental assessment of the whole team: trucks, sea freight, air freight, CO_2 generation, everything involved.

'BP is working with us on this, and part of the strategy is in the segregation of waste. We consider it to be a requirement to view the German regulations in this regard as the minimum – for example, you have to lay a vinyl sheet under the rally cars in service on Rally Deutschland to stop possibilities of oil leaking into the earth. We do that on all rallies now. And all components, even broken ones, have to go back to M-Sport.

> **"Being careful with the sequencing of events will carry benefits"**

'Being careful with the sequencing of the calendar of events so that less carbon is used will also carry benefits in minimising CO_2 emissions. Although it needs thinking through, I believe there will be some benefits in using remote services to keep road section distances down.'

Deans feels that the message these sort of activities should be sending out has not got back to the public yet, but that it will: 'Perception is reality,' he says. He also makes the point that the absolute creation of CO_2 by rally cars is relatively small, and that the challenge now is to create the sort of emissions improvements in rally cars that are being made to road cars.

However, he feels it is too early to regulate this through fixed rules because current EU regulations are toward smaller displacement, turbocharged petrol engines, though he believes this will result in WRC2 cars having smaller engines in two to three years time.

Interestingly, because in principle a WRC2 car will be cheaper than a World Rally Car, Deans sees the possibility for teams to have a *bigger* fleet of rally cars, meaning it might be feasible to have a cache of rally cars in the Antipodes, for example, thereby saving cost and emissions on transport. In this way, it would actually be possible to make a WRC season cheaper: 'You've got to look at the total cost, not the initial costs,' he says.

FORWARD PLANNING

In preparation for next year's bio-fuel plan, Ford has already been testing engines on the dyno, and only there because it was not possible to fit the 'bio' equipment in the current rally cars. On this subject Ford's chief engineer, Christian Loriaux, points out that while the planned bio-fuel has a reasonably low 'e' number, it is second generation fuel, so is twice as important as first generation.

Loriaux is also, it seems, very interested by the KERs technology being trialled in F1, but sees cost as the biggest issue: 'When you try to make rallying cheaper, you can't then go to KERS. There's debate on bio-fuel as well, on whether it's really the best thing or not. Personally, I think there are some very serious problems,' he says.

'Look at it in the long term. I mean, the best would be more properly managed nuclear power

LAT

Ford's M-Sport concern showed this bio-fuel Fiesta rally car at the Autosport show held in the UK earlier this year

The cars may be getting greener, but this view of all the support vehicles together in the service area shows the problem is bigger than just the cars themselves...

LAT

stations, because that's the greenest energy you can get – provided it's managed and safe. Like the ecologists, I used to hate it, but nuclear is the cleanest thing, and from that you get electricity, and from that you charge car batteries – and battery technology is moving pretty quick now. So this is the way to go.'

The M-Sport engineer believes there won't be an infrastructure for hydrogen for a long while, and sees political issues on the subject causing problems. 'There are a lot of people who believe in electricity... I think what will change is that all the engines will become more efficient – you can see that happening very quickly. Everybody is coming back down to smaller engines, and I think soon the biggest engines will be 1.8 turbos. That seems to be coming along a lot quicker than we ever expected. I'm surprised myself. There's no doubt the whole of the industry is on the move now, and it's becoming a proper issue.'

Another who thinks along similar lines is Citroën Sport's chief engineer, Xavier Mestelan-Pinon, who is also of the opinion that world rallying has to be seen to be doing something about its emissions (see p37), and agrees that more WRC2 cars could be built than today, and that caches of WRC2 cars in long-haul destinations are entirely possible.

DIFFERING ROLES

Over in the Subaru camp, chief engineer David Lapworth makes an interesting point about the differing roles world rallying and Formula 1 play: 'Formula 1 is a demonstration of technology, so it is easy to see that it needs to be a long way ahead, and needs to be sending out the right messages and so on. The role of rallying, traditionally – though I can't say it's always going to be that way – is to promote the cars we sell today. It's the old thing about win on Sunday, sell on Monday, so we've got to be connected to the cars you can buy today, and right now they don't have KERS...

'You may want to buy a [Subaru] STi or WRX on Monday, so we're not promoting the cars that may be available five years from now. There's a balance in there somewhere, but we've got to keep the connection to cars that you can buy today. Our regulations have always been based around homologation, minimum production and real technology and I don't think you want to lose that completely. But you could cherry pick certain bits and say you can demonstrate that "you have 50Kw of energy recovery", or similar.'

With the current escalation in supercapacitor capabilities, it will soon be possible to make energy storage more compact and Lapworth confirms that such a system could be made to work in a rally car, but points out that there is a body of thought fixed firmly on *actual* cost reduction in rally cars. 'We come at it from the opposite side, which is, "No, what we need to do is to increase the value." And, if that [KERS] added value to the World Rally Championship there would be less complaining about the budgets and people might be more attracted, but it's not as easy as you think to do. If it adds £10,000 ($17,800) to the cost of the cars there will be some people who will say, "That's crazy, they're already more expensive." Then we would argue, "No, we're adding value to the tune of more than £10,000. We're bringing in green technology, we're thinking about the future."'

> **Everybody is coming back down to smaller engines**

ENERGY DENSITY

'In terms of energy storage, though, the big problem is energy density, and petrol takes a lot of beating. Storing energy chemically is very efficient and you've got the advantage that you only carry half the fuel, because the other half is provided for free. As you drive round, you scoop it in through the restrictor and you burn it in the car. That's how it works.

'And when you go to power density, when you actually talk about delivering power to the wheels, an internal combustion engine again takes some beating... electric motors of, say, 300kw are big electric motors, at the moment. But for power and energy density, flywheels look very good, that's why some of the Formula 1 teams are pursuing that route. Some are pursuing electrical technology because they've got it, but the ones that started with a completely clean sheet of paper, I think a lot of them are looking at flywheels.'

In principle then, Lapworth agrees that with the imminent WRC2 regulations it is a good time to implement 'green' rules for rally cars. Practically though, he sees difficulties, pointing out that it has already taken three years to get an agreement on the basic technical regulations, and these are still not yet finalised. 'There are some complicated compromises in there. One half of the championship, or at least half of those involved in the politics, are pushing all the time for cost reduction and, I reckon, are anti-technology. They don't really care about the manufacturers' reasons for being in [the WRC] and the manufacturers come at it from the opposite direction, saying "We want to promote our cars and our technology and our brands." Then it completely falls apart.

'A logical thing to do would be to reduce the capacity, reduce restrictor size and add backing with some form of energy recovery, but you can't imagine how complicated it is to get something like that done.'

Lapworth confirms, however, there is no reason technically why any of the changes mooted for Formula 1 would not work in a rally car: 'It's easy, if you want to go that way, to write rules without the costs going crazy... but, as always, there will be some cost – you know what they say, you don't get owt fer nowt.'

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RACING GREENER

Pointing the way

Citroën's brand new WRC concept car introduces KERS to rallying. Is this the future?

As *Racecar Engineering* was closing for press, Citroën took the covers off a hybrid concept car at the Paris Motor Show that it believes could point the way to a more environmentally acceptable future for the World Rally Championship.

The Citroën C4 WRC Hymotion4 is based on this season's winning C4 model, but in addition to the standard car's turbocharged, four cylinder petrol engine, the Hymotion4 is fitted with a 125kW/300Nm electric motor/generator connected to the rear differential and linked to an array of 990-cell batteries.

The kinetic energy recovery system (KERS) retains the energy generated during braking and then delivers it back on demand, either to be used in bursts to augment the petrol engine on stages or to run the car on electric power only while on road sections or in service areas.

Confirming the view of Citroën Sport's chief engineer, Xavier Mestelan-Pinon in the main story, the French company, in common with other competing manufacturers, expects upcoming WRC regulations to be more reflective of current environmental concerns.

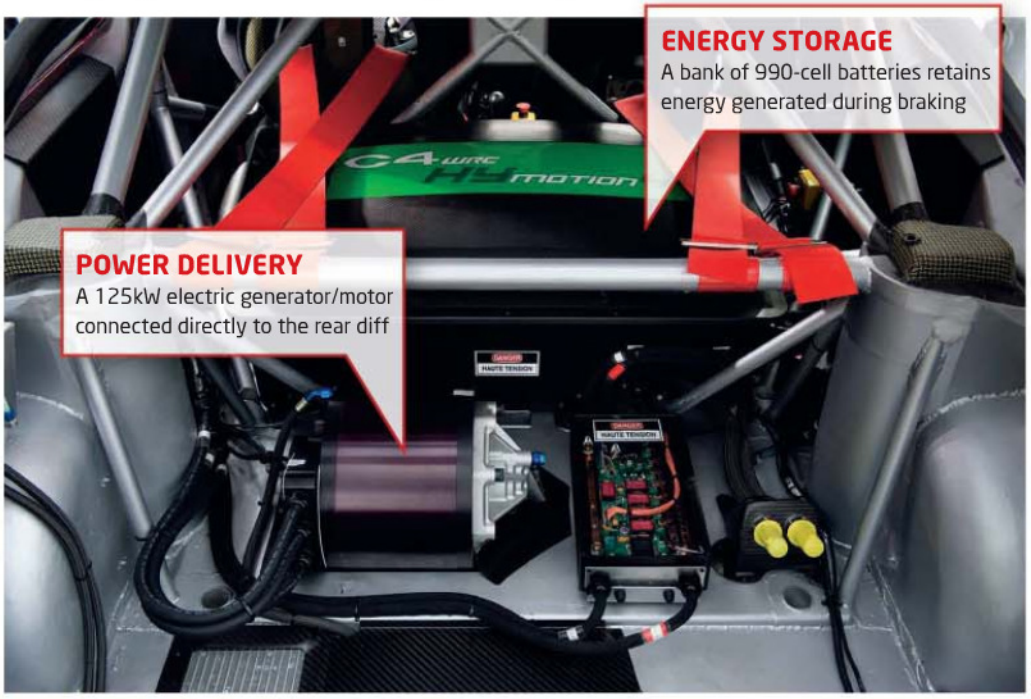
A statement released at the time of the unveiling said, 'The C4 WRC Hymotion4 fits perfectly with Citroën's long-term commitment to motorsport and its consequential environmental policy. This concept underpins the brand's policy to conceive very high performance cars that respect the environment and is the first step prior to other developments that will be guided by future evolutions to the FIA regulations.'

The C4 WRC Hymotion4 has already run at Citroën's Satory test facility, which is a creditable effort as the project was only embarked on in June of this year. Development work continues, with a view to refining the characteristics of the energy recovery system for the rallying environment and, in particular, adapting it for the rigours of non-tarmac events (there are only two tarmac rounds on the 2009 WRC schedule).

It is understood that, in due course, Citroën Sport hopes to present the system to FIA officials with a view to it forming the basis for a standardised WRC energy recovery system.

Citroën

Citroën's green performance cocktail mixes one part turbocharged four cylinder engine with one part electric motor



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After two largely disappointing seasons Subaru Tecnica International/Prodrive looks to have sorted its World Rally Car problems with the all-new S14 WRC

1ST SIGHT

Fighting back

BY MARTIN SHARP

Subaru's recent lacklustre world rally fortunes have largely been due to the spasmodic performance of the three-box Impreza WRC2006 and WRC2007, which meant any effort to turn those fortunes around required a thorough re-think. And it looks like that might just have happened, in the shape of the new five-door hatchback version of the latest Impreza WRC2008, which made its debut on this year's Acropolis Rally in Greece. The revised dimensions of the latest Impreza's two-box bodyshell enabled Subaru Tecnica International and Prodrive to thoroughly revamp its World Rally Car.

The old three-box car, known internally by the S12 and S12B codings (S13 was considered potentially unlucky), was used up to Rally d'Italia in Sardinia this year, but they never really shone and the works drivers - Petter Solberg in particular - were critical of the car's frustratingly frequent handling inconsistencies. These derived from a multitude of detail difficulties, which many different engineers had worked on overcoming. One of these was excessive under-bonnet heat 'cooking' the inner front wishbone spherical joints during a stage. There was also speculation over the consistency of the performance of the French-made Bos dampers, questions over front-end rigidity and much more...

While the team struggled on, attempting to improve the S12s, rally engineer Christophe Chapelain returned to the Prodrive fold in August 2006 after a spell as technical director with the Nissan Rally Raid team. Chapelain's brief was to ensure that the S12's successor was, quite simply, a better World Rally Car. He looked briefly into the difficulties being experienced with the S12s, but concentrated on his task, the new S14.

> "The only area of close similarity is in the engine"

The new bodyshell dimensions brought with them the need to make the gearbox more compact and Chapelain was handed the opportunity to design a new World Rally Car from front to rear – a prospect not available to Prodrive/STI for many years.

Further assisting the development process was the fact that by the time the new car was just about ready to rally, Prodrive chief David Richards and his engineering boss David Lapworth had ceased their pursuit of Formula 1 efforts, and began concentrating on the underperforming Subaru World Rally Team instead. In a sense, the core of the 'old team' was back, steering an effort in which they have a great deal of experience and understanding.

In Greece this year, Lapworth explained the philosophy behind

TECH SPEC

IMPREZA WRC2008

Engine: H-4, flat four cylinder, 16 valve, turbocharged

Capacity 1994cc

Bore: 92mm

Stroke: 75mm

Engine management: Subaru programmable electronic EMS

Power: 300bhp at 5500rpm

Torque: 650Nm at 3000rpm

Transmission: six speed electro-hydraulic

Differentials: electro-hydraulically controlled centre, mechanical front and rear

Drive system: Subaru Symmetrical All Wheel Drive

Suspension: MacPherson strut front and rear

Shock absorbers: Bos, fully adjustable

Brakes: AP Racing 310mm ventilated discs and six-pot calipers front and rear (on asphalt front discs are 378mm)

Exhaust: Inconnel with Subaru anti-lag system, catalytic converters

Steering: power-assisted rack and pinion

Dimensions:
Length: 4415mm

Width: 1800mm

Height: 1475mm

Wheelbase: 2635mm

Weight: 1230kg (WRC regulation minimum)

Data system: single integrated electronic system controlling engine, transmission and data logging

In-car display: LCD colour monitor with eight selectable data screens

Tyres: Pirelli (control tyre)

Radio equipment: Kenwood

Turbocharger: IHI, with WRC regulation 34mm restrictor and Subaru anti-lag system

Spark plugs: Denso

Wheels: BBS – 15in diameter for gravel, 18in for tarmac

Fuel tank capacity: 80 litres

Design: CFD for entire car

the S14: 'This is the first time in a long time we've gone through the car without constraint. The only area of close similarity is in the engine, which is an evolution. Everything else I can say almost without exception is new. There are one or two nuts and bolts that worked perfectly well on the old car that we've carried over, but really we were able to look at every part and not worry about carry over at all.

'It's a night and day difference. In the philosophy behind the design of the car, the layout of the car, the suspension geometry and so on. We've combined it with a lot of stuff we've learned from all kinds of projects, both racecar and road car, we've involved our boffins and Fuji Heavy Industry's boffins in trying to establish some measures in handling and steering, to ensure that we designed the car from the beginning to be easier to drive.'

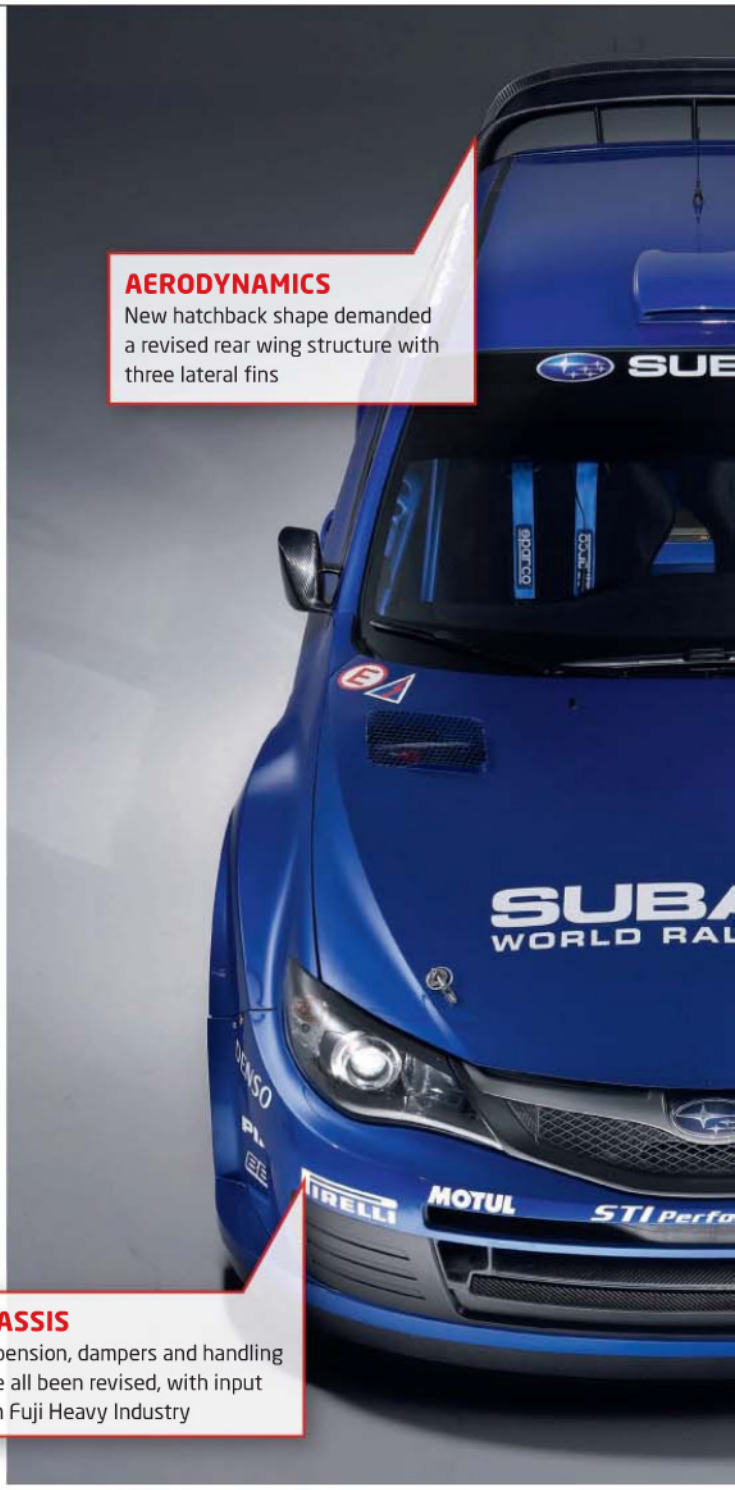
Prodrive in Banbury, England and Subaru engineers in Japan worked together on the entire project. Most of the detail design is done in Banbury, while engine design and development and aerodynamic work has been very much a collaboration between the two countries.

IN CFD WE TRUST

So strong was the team's faith in computational fluid dynamics that the new car rallied in Greece without ever having been in a wind tunnel, although a wind tunnel verification visit was scheduled after the Acropolis Rally. Using CFD on the new car is understandable, considering the different rear aerodynamic requirements of a hatchback, compared with the previous three-box shape.

However, as Lapworth explains: 'The layout for us is better. It's given us a bit more freedom, especially for things like getting spare wheels into the car. It's a good place to start from. The wheelbase, the distribution of the main masses around the car, the chassis stiffness... It's an easier place to start to build a World Rally Car from. The only disadvantage you get compared with the old days is the trend for cars to get heavier, but in the current regulations there's enough scope to overcome that. Really there's no disadvantage at all, everything is positive.'

The team's confidence was evident because, despite the original plan being to launch the S14 at this year's Rally Finland (some two months after the Acropolis Rally), the car made its debut earlier, as Lapworth explains: 'Everybody's been flat out for the last few months to try and get ready for this [Acropolis] date because we want to get back to winning as soon as possible, and the sooner we start competing the sooner we start winning again.'



AERODYNAMICS
New hatchback shape demanded a revised rear wing structure with three lateral fins

CHASSIS
Suspension, dampers and handling have all been revised, with input from Fuji Heavy Industry

TESTING

Although much development had been undertaken pre-Acropolis, the team managed 3000km of 'proper' dirt road testing, predominantly with Markko Märtin at the wheel. The priority here conformed with Lapworth's career-long philosophy of ensuring the suspension set-up and transmission tuning approach are aimed primarily at building a car that's easy to drive, then exploring directions to follow in later development.

It's a logical strategy not to compromise driveability at the

SUSPENSION
Rear suspension is no longer multi-link, but is now MacPherson strut like the front. Bos dampers are retained but have been completely re-designed

ENGINE
300bhp, 1994cc, turbocharged H4 boxer motor is an evolution from the previous S12B WRC. Six-speed gearbox is all new

IMPREZA ANCESTRY

The production Subaru Impreza first appeared in 1993, with the Group A Impreza 555 rally car arriving shortly after that in the same year. Although the two cars were dimensionally different, much of the first Impreza rally car's underpinnings were based on the Group A Legacy, which was born in 1990. An adjustable hydraulic front diff appeared for the Impreza in 1994.

Then, one year later, the FIA brought the 34mm inlet restrictor in, but revised camshafts, a higher compression ratio and detailed engine management work saw similar maximum grunt produced by the further restricted Subaru engine to that of the previous 38mm restricted unit. And Colin McRae became World Rally Champion in it.

In 1996 Group A cars gained 30kg (1230kg minimum). Then the World Rally Car regulations came in a year later. Subaru's contender became the Impreza WC97. Based heavily on the previous Group A car, it was the first WRC ever to be launched.

The Impreza WRC98 was the only newly homologated car in 1998 and now had fully active differentials. The following WRC99 heralded the arrival of the semi-auto H-pattern gearbox and fly-by-wire throttles.

Then came Christian Loriaux's [now chief engineer at Ford World Rally] breakthrough Impreza WRC2000. The entire car had been investigated. It was stiffer and had a great deal of its weight much lower in the car. And it set the scene for World Rally Car engineering in the noughties.

In 2001 the Impreza WRC reverted to a four-door platform. A year later, a revised turbo housing, flywheel, exhaust manifold and water injection gave the car a considerable increase in maximum torque.

The 'bug-eye'-shaped body appeared in 2003 and the team experimented with aerodynamics to a greater degree than previously. The '04 car remained little changed and 2005 was the last year of the 'bug eyes' before the re-styled 2006 car, which also took account of changes in regulations aimed at improving crew safety. The '07 version was again an interim car before the much changed new WRC2008 arrived this year.

The S12B was the last incarnation of the old WRC Impreza prior to its fundamental re-design

LAT

outset yet, engineering-wise, the Subaru's longitudinally arranged boxer engine layout dictates packaging compromises in the routing of the steering mechanism – something that was revised for Greece. However, the drivers didn't like the way it felt so further revisions were made for Rally Turkey.

Lapworth considers that the suspension geometry and weight distribution compromise chosen currently for the car probably suits difficult, fast events best: 'We'd like to think events like Finland and New Zealand will be strengths of the car but [we] generally go on the basis that if the drivers are confident and the car is easier to drive it probably helps everywhere.'

10 days after the Greek rally, an evolved S14 took to its first tarmac development test with revised uprights and brakes, but the same geometry and weight distribution. Again, Märtin drove, and is scheduled to continue with research and development work.

'He [Märtin] will filter out all our wacky ideas and try them all and make sure everything works, so what Chris [Atkinson] and Petter [Solberg] get to try are ideas that are already proven,' explains Lapworth. 'If they like them, [they'll] only need fine tuning to their [driving] style.

> **It's an easier place to start to build a World Rally Car from**

'The target is to try and find a middle ground where he [Märtin] understands what it is they're looking for and they trust him to filter out from the development those that work for them.

'Clearly, all three of them have different styles and Markko would make no attempt to recommend to Petter a roll bar balance front to rear, for example, or a ride height, but I think he understands enough about the way Petter drives to say, "Try this, I think you might like it",' reasons Lapworth.

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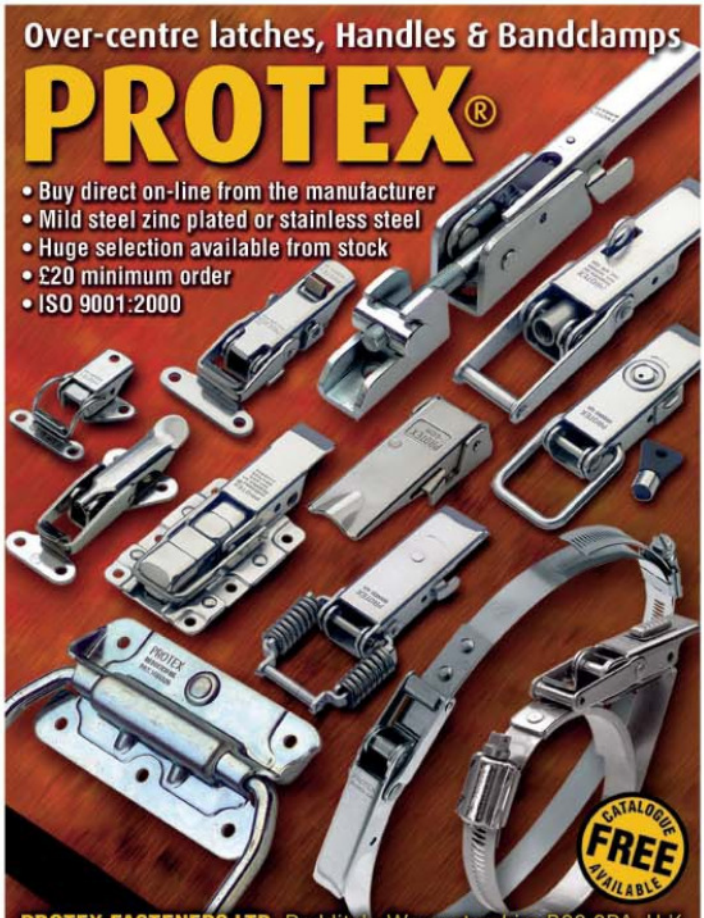

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TEAM EFFORT

While the Subaru World Rally Team (SWRT) was running the lacklustre S12, Prodrive chief David Richards pulled back on investing in on-event hospitality and staff, but it was always his intention to bring back the motorhomes and a bigger team when the S14 arrived, as it did for the first time in Greece this year, effectively two months earlier than some team gurus would have preferred.

In 20 years with SWRT, operations director and team manager Paul Howarth has never witnessed such a strong effort from everyone in the team to get the S14 cars built and in Athens with all the kit on time: 'If you think what the team has been through during the last couple of years, the motivation from shop floor upwards to get this new car out, looking like it does, is a mega example of a brilliant team event.'

Howarth consistently emphasises the resilience of the individuals in the team: 'Eighty per cent, or even more, were never with us when we were winning. If you come from an environment where you were winning five or six rallies a year, that became almost, "Oh, we've won a rally." I'm now looking forward to the day these boys experience winning because you've got to know how to win.

Design-speak

Bar the engine and a few 'nuts and bolts' everything on the S14 is new. Here are some of the major design changes

Chief designer Christophe Chapelain underlines the point that, compared with the previous S12s, the S14 is a new animal.

GEARBOX

'The gearbox is completely different. The old gearbox was 15 years old, the centre bearing distance was old fashioned and, with the new standard of gears, we can now make stronger ones.

'We decided to change because everybody knows we've got the engine in front of the gearbox, and the new gearbox is much better in decreasing the driveshaft angles [in plan view]. We also tried to place all the main gearbox components lower for the centre of gravity.'

Although it remains an H-pattern change, further revisions to the electro-hydraulic, semi-automatic gearshift system have also smoothed and speeded gear changes. 'We kept the H-pattern because we know the system and, for us, the barrel system [sequential dog] would be new and not under control. Also the shifting with the H-pattern is faster than the barrel.'

COOLING

The Group N STI version of the latest Impreza features a bonnet scoop for engine intake air, but the World Rally Car version does not. The reason is the Group N car is a 1000-off homologation car, while the WRC must be based on a 25,000-off family car. And besides, Prodrive/Subaru is satisfied with the intake air filtration and cooling solutions found for the previous S12 and S12B WRC. Chapelain: 'We were happy to keep the filter the way it was last year, and to ensure we have enough cooling capacity. If you start to make the filter and the air intake in different places on the car, you don't have enough space for the intercooler and the radiator. We were quite happy with last year's intercooler and radiator layout and, as we started in the high temperatures of Greece, we didn't want to take any risks with the cooling on the new car. We will have some different ducts on different events depending on the speed of the event.'

Despite its shorter bodyshell, the new car has a longer

"The objective was to provide more grip and more stability"

CHRISTOPHE CHAPELAIN

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wheelbase than the previous Impreza WRC, which should improve stability and mid-corner grip in fast corners. Plus, a better car weight/inertia to wheelbase ratio helps optimise the handling in corners.

SUSPENSION

The S12's multi-link rear end has now morphed into a more conventional MacPherson strut design, while the strut front end remains MacPherson, as per last year, though with new, lighter uprights, which the team claims are as strong as the old units.

After some delicate negotiation, it was possible to retain French manufacturer Bos to supply dampers, although these are thoroughly revised compared to those used on the S12s – completely new roller bearing designs with different strokes. These have been progressively developed from a base design in January using new parts and new technology.

'Every time it was a big step forward,' explains Chapelain of the dampers. 'The objective was to provide more grip and more stability. We are not 100 per cent happy yet and we are still working on them. We had a compromise for Greece but it was only a small compromise because we are very close to what we want to achieve.'

AERODYNAMICS

The new car's hatchback shape alters the aerodynamics at the rear, requiring a revised, double-plane rear wing with three lateral fins between the planes. Chapelain considers it likely that the increased three-quarter-rear side surface area will provide more aerodynamic side force, which can help contribute to improved stability.

The new car's bodyshell is heavier than its predecessor and is now equipped with side impact, pedestrian impact protection and meets current road car crash regulations. Naturally, the team has striven to reduce weight in other areas and to bring the bodyshell weight down to the minimum FIA figure.

With all this work done, the rally cars left Banbury at midday on the Saturday before the Greek event, arriving in Athens on Tuesday night. Most of the team were already there to begin the set up, not just of the cars, but also of the masses of service equipment for the cars and the hospitality service area. The remainder of the team arrived on the same night as the cars.

With the Acropolis event and the following Rally Turkey, held just one week later, among the roughest rallies in the World Championship and generally requiring the biggest parts usage of the year, getting the service side of the operation right was crucial, too. Operations director and team manager Paul Howarth: 'We have to have the spares. You've got to consider at what point in the stage are they going to get a puncture, because they are going to be more fatigued due to the ambient temperature. Petter and Phil were quick in Sardinia [the WRC rally previous to Acropolis] but they're fit lads. Although the spare wheels are out a lot quicker [in the new car] they can sit in the boot or the middle of the car – you can just lift the tailgate up and, bang, it's out. But the problem in a rally such as Greece is where to stop to change it. Some of the stages are so narrow, you get one wrong jacking point and all your practice goes out of the window.'

Before Acropolis, though, Howarth was pragmatic: 'As soon as the numbers go on those doors we're going to be playing a different game completely. This year the stages are phenomenally tough, the toughest I've seen, so you don't know what you're going to expect. You can have anything from a clean run to a run where you need two new bodyshells because they've had two crashes (but hopefully not). You're in control but you've got to expect the unexpected...'

H4 engine remains essentially the same as in the S12B, with the same cooling and filtration systems. The big changes are in the gearbox that attaches to it, which has been completely re-designed for increased strength, smaller dimensions and a lower centre of gravity

Rear suspension is now MacPherson strut with new Bos dampers all round

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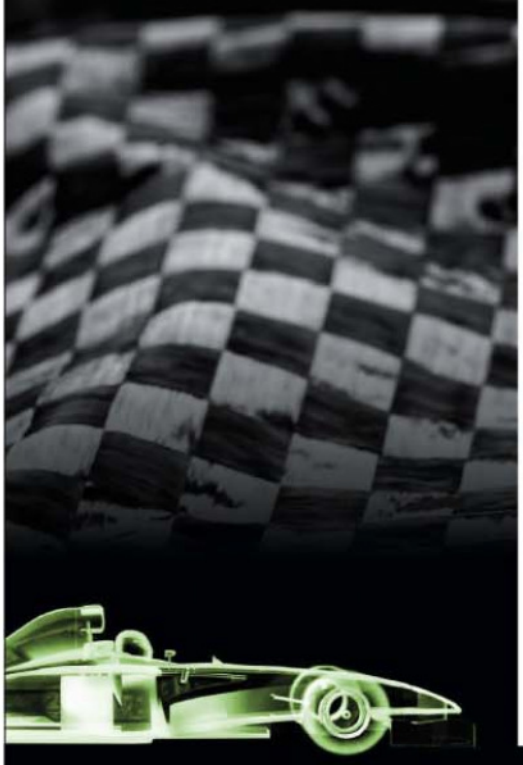

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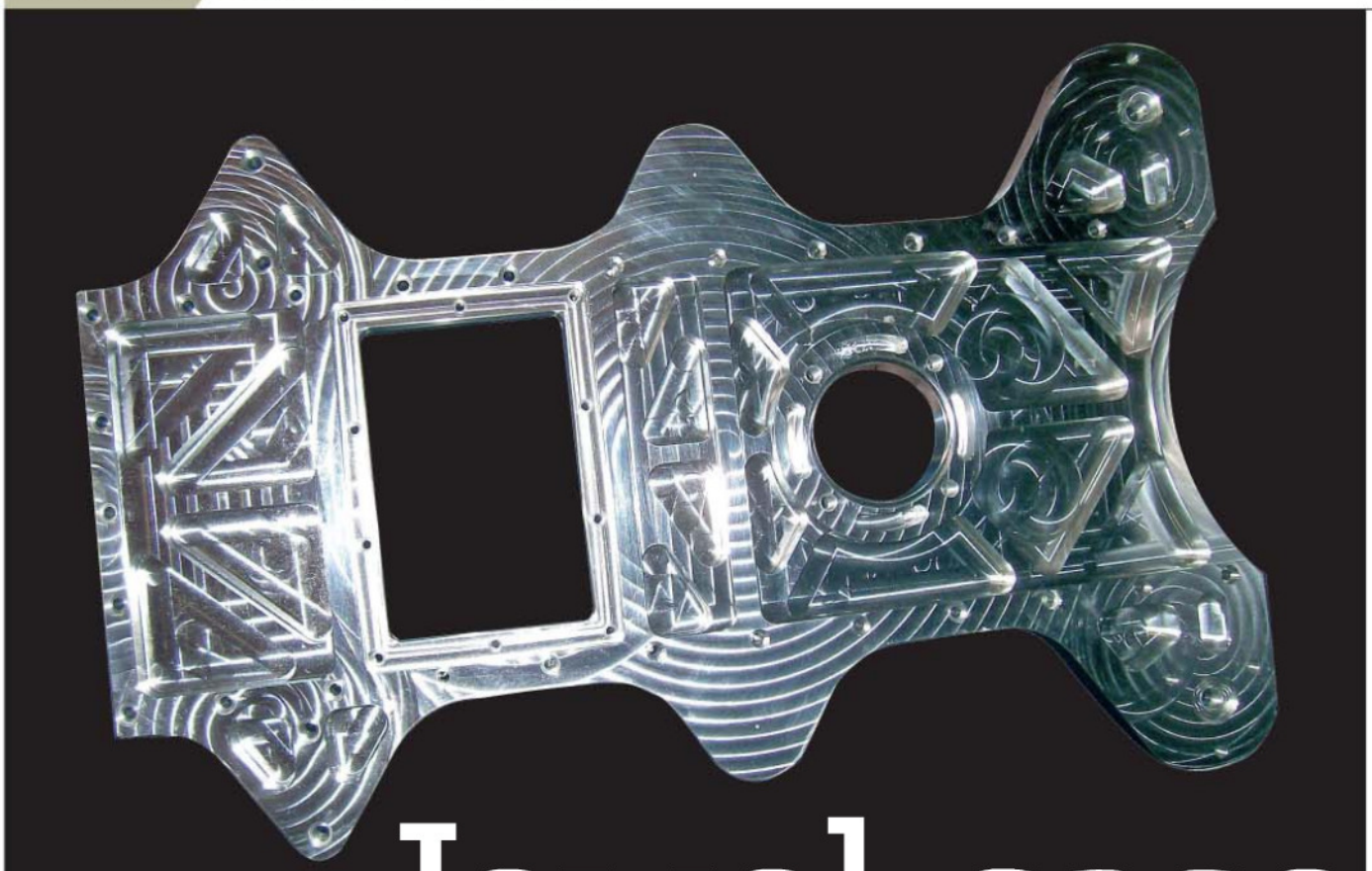

Jewel case

A neat, transaxle-style rear end to mate up to a motorcycle engine and gearbox unit has been produced by one of *Racecar's* Australian readers

Above: the top plate fresh off the CNC machining centre in April 2008

One of the major design challenges facing anyone aiming to install a motorcycle engine into a racecar is how to take the drive to the rear axle. There are three principal options – chain, gear or shaft drive – and, as most of the designs retain the transverse alignment of the common donor motorcycle, most similarly utilise chain drive. In these circumstances designers must find a means of supporting the final drive assembly,

BY SIMON MCBEATH

comprising rear sprocket, differential and associated bearings and output shafts, as well as engineer a reverse drive mechanism (at least where this is applicable). Around this the rear suspension also needs to be packaged.

As a result, neat, integrated solutions are not easy to achieve, but Australian Mark Cotterell, with the help of a couple of clever associates, has done just that, designing and producing a rear casing that does all the aforementioned jobs and also has the benefit of carrying the chain internally. Unsurprisingly, Cotterell believes his design offers a number of advantages over those already available.

The well-proportioned Cotterell MP301 taking shape in Mark Cotterell's Sunshine Coast workshop, Queensland, Australia

THE COMPETITION

The majority of existing solutions consist of fabricated tubular or machined transverse bulkheads connected by sturdy longitudinal members that carry the fore and aft loads from the final drive to the chassis, with more or less neatly integrated suspension mounting points built in and around this structure. In comparison with a transaxle unit, it's hard to resist unkind references to a Victorian threshing machine when viewing many of these designs. Functional they may be, elegant, clean and tidy they rarely are.

There do exist encased gear-driven variations, such as those

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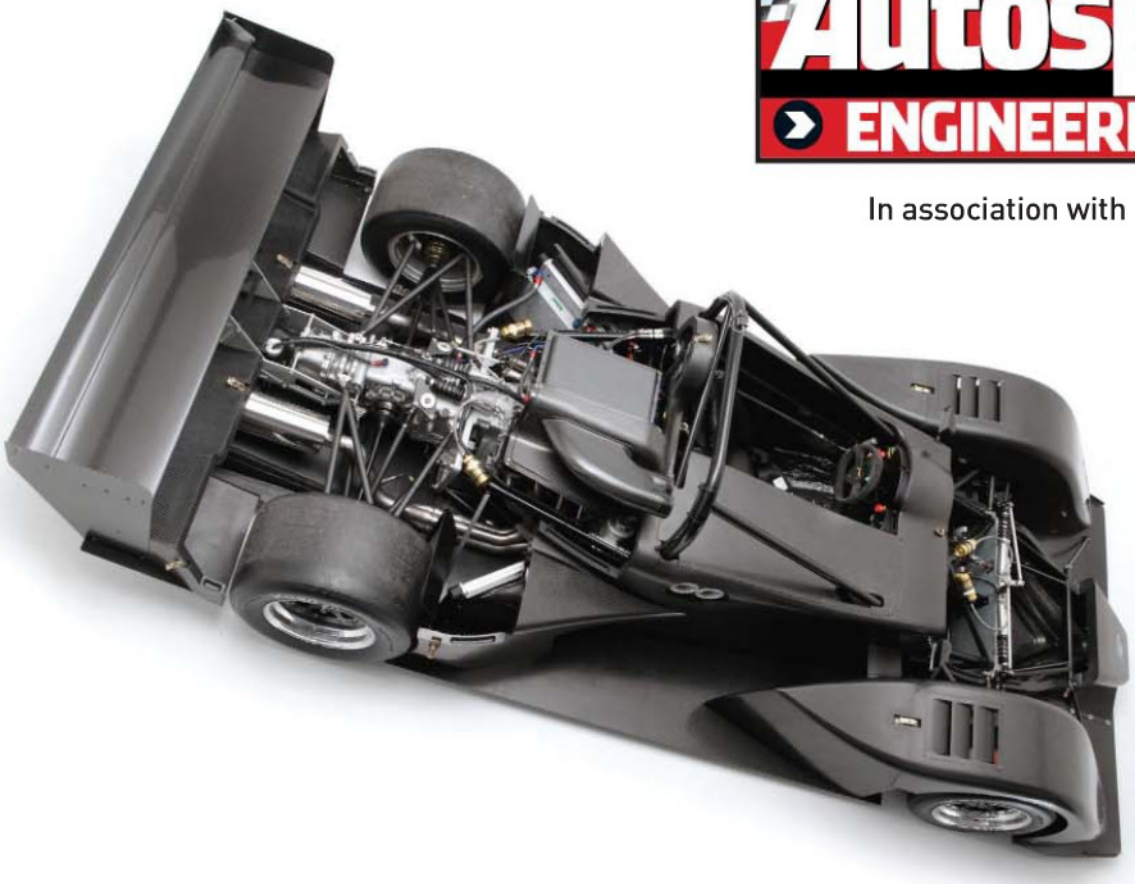

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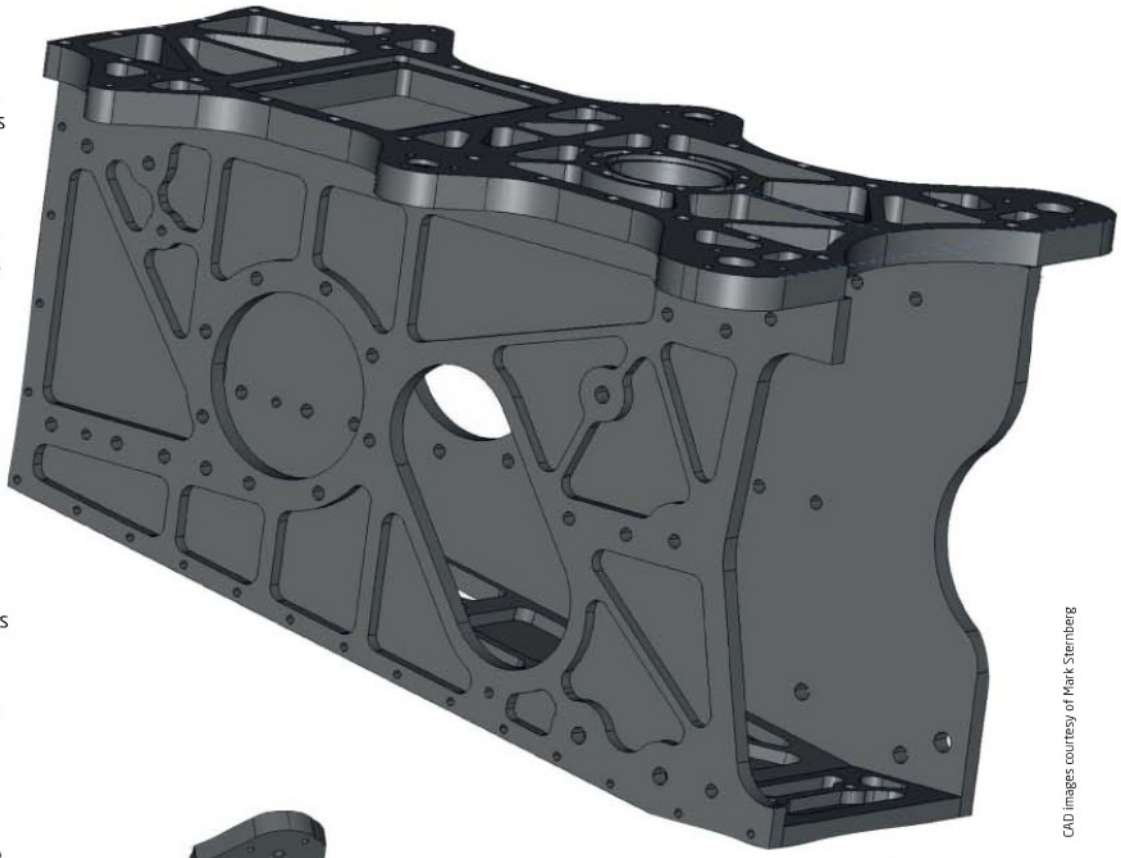
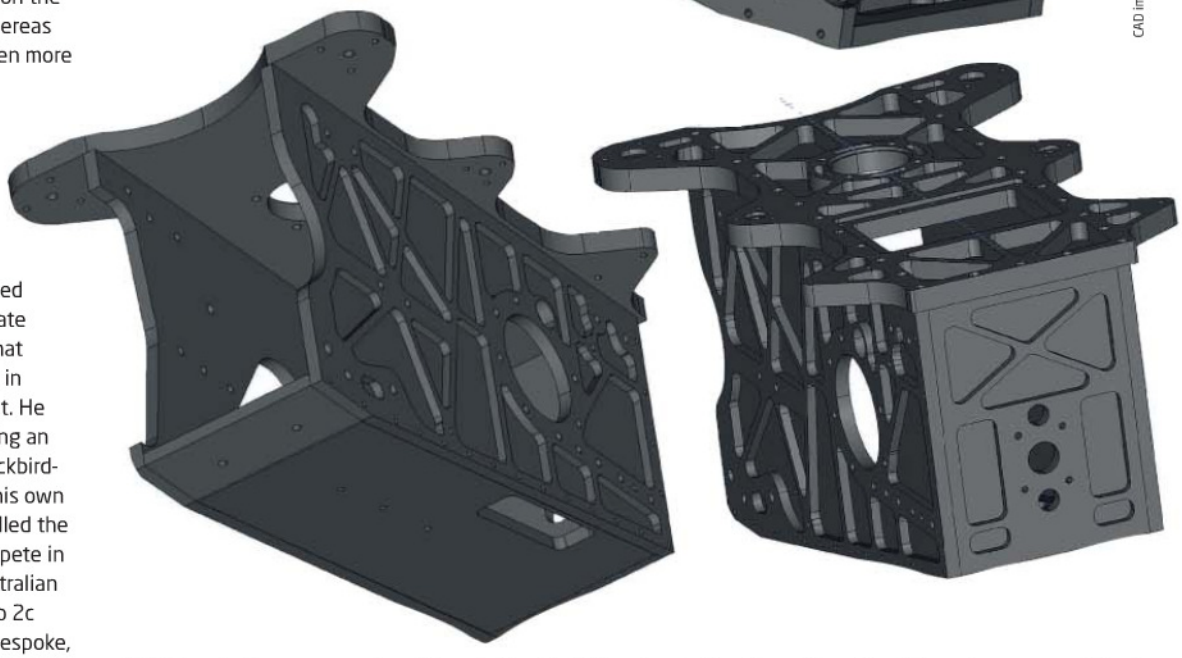
made by UK-based DJ Racecars and the Powertec/Quaife-designed unit used, for example, on the Radical SR3. The former is for the Suzuki Hayabusa engine and gearbox, the latter aimed at 'most superbike engines'. But these are not cheap, nor do they offer any design flexibility in the distance between front and rear sprockets, so reduce the options for the placement of two of the major masses and achieving a particular weight distribution. And the suspension and other 'peripheral' components still need separate attachments.

Progress towards a more integrated chain drive rear end was made by the likes of Stohr and West in their 'D' and 'C' sports racers in the USA, when they produced machined rear casings that not only supported the final drive assembly, but also carried the suspension. However, they still carry the chain drive on the outside of the casing, whereas Cotterell has taken an even more integrated approach.



CAD images courtesy of Mark Sternberg



3D CAD renderings were produced from Cotterell's 2D drawings before the main parts of the casing were machined

DETAIL IN DESIGN

A high-end jeweller/designer by profession, Queensland-based Cotterell is a self-confessed perfectionist, and his innate eye for fine detail and what looks right has stood him in good stead on this project. He is in the process of building an 1100cc Honda Super Blackbird-powered sports racer to his own design – eponymously called the Cotterell MP301 – to compete in the Confederation of Australian Motor Sport (CAMS) Group 2c 'Supersports' class. The bespoke, lightweight, spaceframe chassis and up-to-the-minute body will sit on a donor Formula Ford Van Diemen RF92's suspension, the dimensions of which were suitable and spares for which are easily obtained.

But given the amount of work he'd already committed to, designing and manufacturing virtually the entire car, what made Cotterell decide to do his own thing with the rear end? 'There were a number of reasons for going my own way,' he replied. 'One was engine choice and another was trying to be as involved as possible in the direction the car took as an end product. And much of this was to try and control the budget. Off-the-shelf parts are great, but they come at a price, in more ways than one. The engine choice was actually friend, fellow racer and technical adviser Stuart Hooper's suggestion for a bike-engined car in the Supersports class and I have a lot of faith in Stuart's ability and knowledge. But the Honda is not as popular a choice as some of the other bike engines, hence rear-end assemblies and many other parts are not available for it. So I was on my own in that respect from the start. But the basic idea of a bolt-together assembly at the rear was Stuart's, and I developed it from there.'

DESIGN CONCEPTS

Conceptually, Cotterell's rear casing set out to achieve a number of targets: 'I wanted the rear end to be extremely clean under the bodywork, for aerodynamic reasons, for appearance's sake, and so there's no chain off-cast over everything! Also, the damage a chain can do if it breaks is considerable, and I didn't want it ripping the suspension to shreds, and quite possibly causing an accident if that happened. Besides all that, it's just neater.

'There are really only a couple of disadvantages – the cost in time and funds to design and build the first one, of course, and internal access is a little more limited, so the selection of gearing [if it needs changing for a different track] requires a little bit of forethought.'

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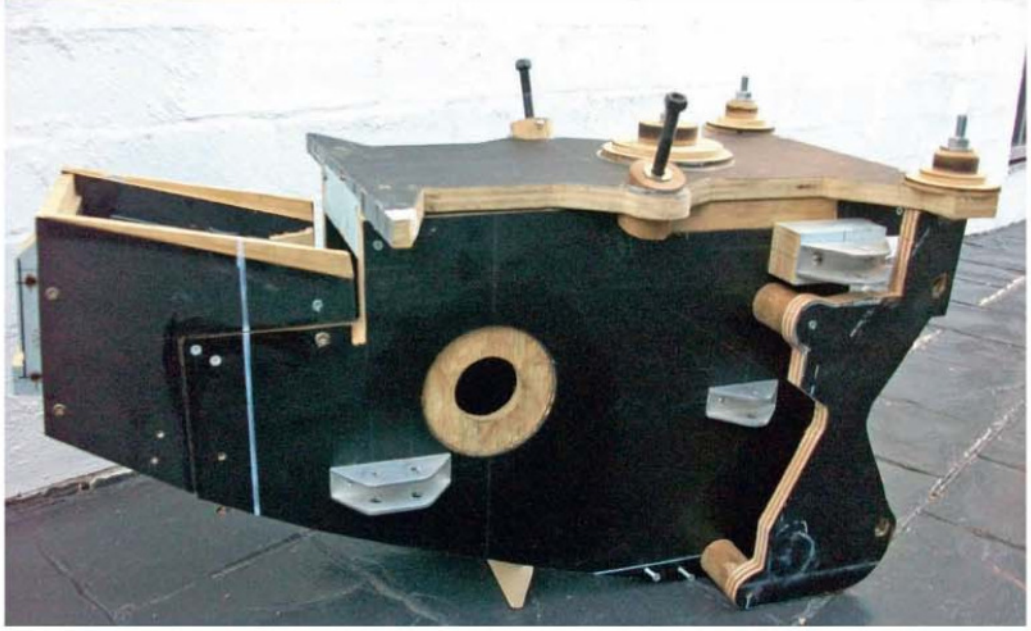
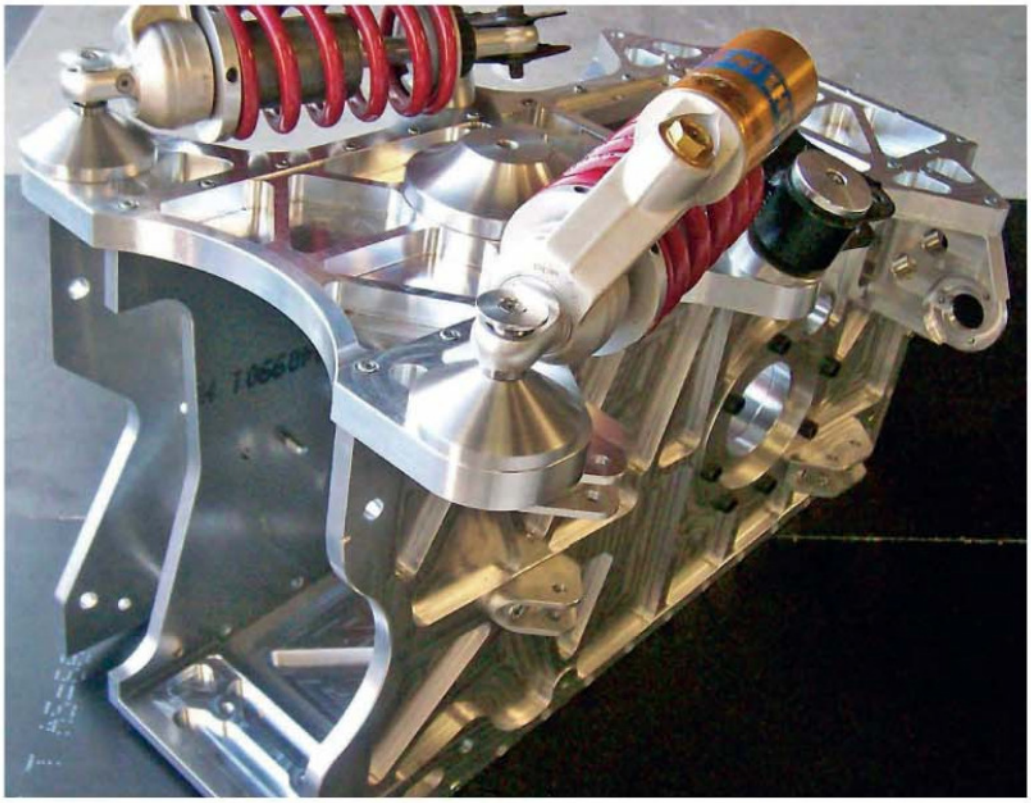


The original plywood mock-up Cotterell made to test his idea, preliminary work taking three and a half months



From all this came the 17 finished 6061 aluminium alloy components from the machine shop that make up the case

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WHERE?

Races are mainly in New South Wales and Queensland

History

Started with the Lotus 7 and copies thereof

1970s

Known as 'Clubmans' in the 1970s then 'Sports 1300'

2003

Became 'SuperSports' in 2003, with rear-mounted bike engines to 1100cc and front-mounted car engines to 1300cc and 1600cc

Regulations

Ferrous spaceframe chassis, non-ferrous stressed panels permitted

Composite bodywork permitted

Flat bottom between front wheel axle line and front of rear wheels, otherwise aerodynamics very free

No weight limits
Stringent safety requirements

After three and a half months drawing his designs in 2D at half-scale on a drawing board and creating a plywood mock-up, Cotterell took his designs to Mark Sternberg of CNC Precision Machining in nearby Kuluin. Sternberg generated the requisite 3D CAD and carried out the CNC machining of the 17 aluminium 6061 alloy pieces, machined down to just 3mm thick in the pocketed areas, that comprise the whole assembly. On the machining company's work, Cotterell is candid: 'Mark's grasp of what I was trying to achieve was brilliant, and his machining capabilities made many things possible that I didn't believe I could hope for.'

The main case is essentially made up of the top plate, three side plates, two base plates and a back plate, which are dowelled and bolted together. Internally is a substantial bracket that, as well as cross-bracing the structure, carries a Toyota Camry starter motor that operates the mandatory reverse gear mechanism. 'All the suspension and mechanicals are housed in or on the main plates,' explains Cotterell, 'while the underside is inclined up to the rear at 10 degrees and allows for a diffuser to be bolted directly to the casing. The sway bar bolts directly to the back plate, and rear wing mount provision is also catered for, the mounting plates for which feature a jacking point'. The chosen differential is the Quaife ATB torque-biasing unit.

Careful detailing and positioning of the engine, which is very slightly offset in the chassis to the right, and the final drive mechanicals has allowed the chain to be carried internally, yet the casing remains relatively narrow. The design also allows equal length driveshafts, but Cotterell is slightly reticent about some of the internal details that enable this, not surprising given the amount of time it took to work it all out. He also states that he'll probably offer replicas for sale now it's all on CAD, having had in mind all along that it would be adaptable to other popular motorcycle engines.

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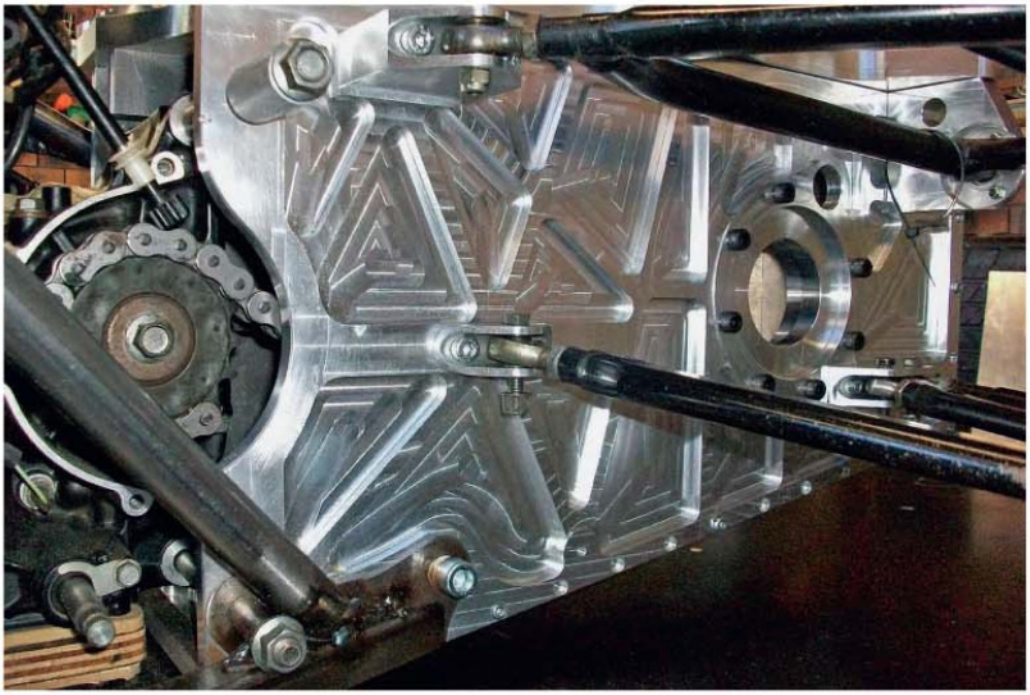
EASE OF SERVICE

While admitting to slightly reduced access for servicing and gearing changes compared with a tube frame rear end, Cotterell reckons he has made it possible to change the gearing if needed. 'Changing front sprockets should be pretty simple and quick, and with a six-speed gearbox this generally allows you the option of going one gear higher or lower, which covers things in most cases. Changing rear sprockets is a little trickier, though should be possible between races. The rear sprocket is a two-piece unit, which makes changes quite simple, and I've designed in a service hole for tooling directly opposite the sprocket bolts to assist access. There is also a removable service hatch in the top, and you can remove one whole side, complete with the suspension, or drop out the base plate. Most importantly, the whole rear end, including the engine, can be unbolted quickly and wheeled away.'



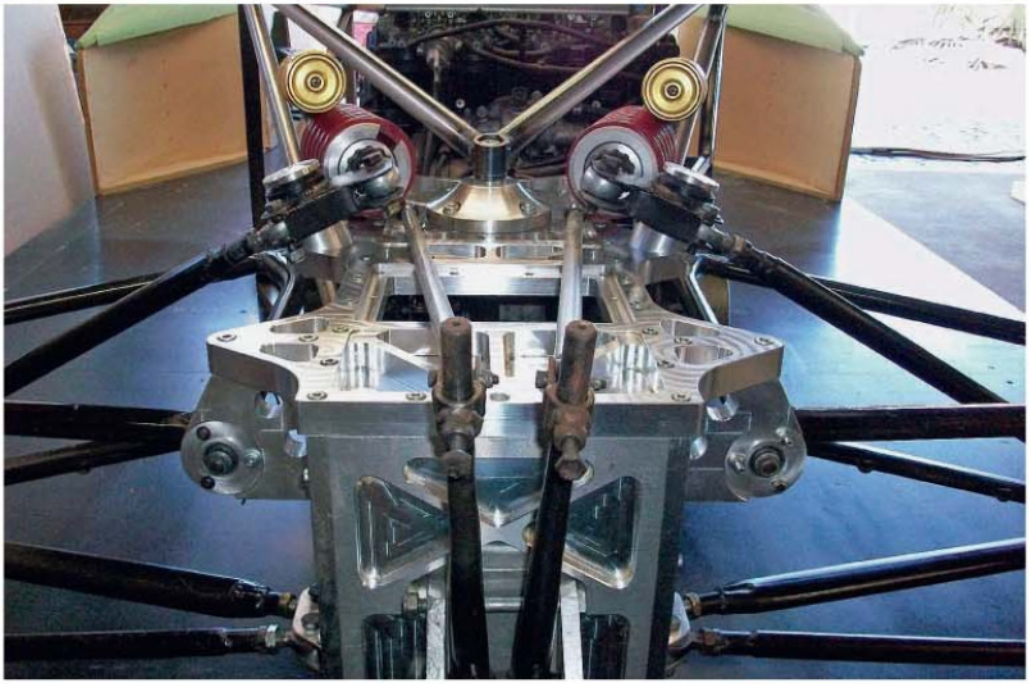
The chain drive runs from the front sprocket, shown left, to the main sprocket, with 7mm clearance to the case side

CHAIN THEORY

The front and rear sprocket centres are a little over 350mm apart, something on which Mark Cotterell has firm views: 'Most of the cars I know that have run short chains have had major driveline problems, with the chains burning out. Short chains create amazing amounts of friction, and it's not as if they're running in oil. So I felt that a reasonably long chain length was a must. Chain tension will be maintained with an adjustable idler sprocket mounted inside the casing, off where the front lower wishbone leg attaches, which is right in the middle of the chain.'

The suspension mounts do not feature any geometry options on this first unit, Cotterell commenting that, 'I decided I already had enough unknown quantities and, anyway, I knew the suspension worked. However, if I was to make further units we could alter the CAD prior to machining to accommodate different geometries and mounting options, if required.'

The whole rear end assembly, including the casing, differential, starter motor for reverse drive, chain and fittings, rockers, springs and dampers has come in slightly over target weight, currently sitting at about 35kg. 'I was hoping it would be a little lighter, but I know where the excess is and Mark [Sternberg] will machine a bit more material out before the car runs. That should shed the odd kilo or so.' Though essentially pretty narrow, the Cotterell rear casing is clearly wider and taller than the aforementioned Stohr and West casings, given that it encloses the chain. Cotterell: 'The Stohr rear end doesn't include a reverse gear, which is one of the reasons it is quite low and small, although I think it's a pretty neat little unit. But I believe my unit will offer better torsional rigidity because of its larger size.'



Rear view of the casing in place in Cottrell's car shows the suspension and chassis pick-ups and slight engine offset

Intriguingly, Cotterell has also pondered the possibility of producing a version of this rear end in carbon composite: 'You could easily do this in carbon and, although our CAMS Supersports rules don't allow for it, I may well think about a carbon unit later. However, that'll wait until I've run this first unit, until I know it works and that it's right.'

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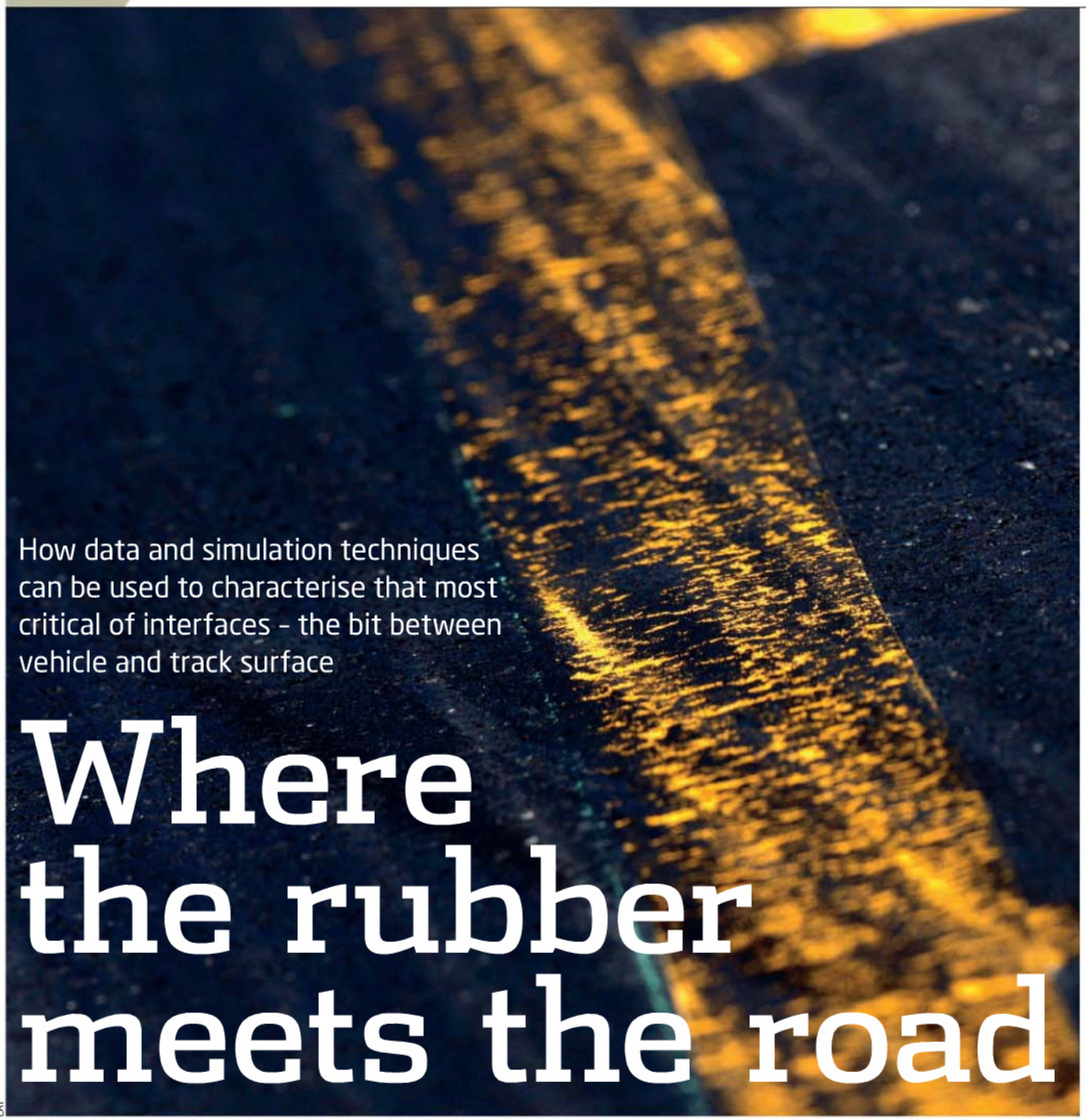


LAT

How data and simulation techniques can be used to characterise that most critical of interfaces – the bit between vehicle and track surface

Where the rubber meets the road

BY DANNY NOWLAN

One of the best racing quotes I have ever heard is that the footprints of your tyres are all that separate you from St Peter. That quote from Mark Donohue summed up so succinctly what our business is all about. It's about what happens at the four contact patches and how they respond to the loads and inputs applied to them. If we can nail down what the tyres are up to, then we are three quarters of the way toward understanding what makes the car work.

This article deals with techniques to quantify how tyres respond to the loads applied to them. We'll discuss the various tyre models that are out there and, ultimately, come up with a model that is both straightforward and quite robust. Then, by using a combination of actual and simulated data, we'll discuss how we can gain some useful insights into what the tyres are doing.

Before we begin, however, a word of warning: this is not the first or the last word on modelling the racing tyre. The racing tyre is highly complex and the model we've evolved has gone through at least three iterations and is currently on its fourth. In terms of engineering analysis, this is perfectly acceptable, as the history of science and engineering is littered with multiple attempts to classify phenomena. Does this mean all of the preceding attempts were irrelevant? Absolutely not. Think of it as like filling in a big jigsaw puzzle. Every time you make a step you fill in a bit more of the picture and learn more. Here we will be doing the same thing.

First, let's discuss the most common tyre model out there, which is the Pacjeka model. The heart of the Pacjeka is that for a given load, if we know our maximum forces longitudinally and laterally, we can characterise the slip angle and slip ratio properties into a perfect curve. Let's consider the lateral case. First, we have to normalise slip angle and the tyre force by the load, initial cornering slope (Fy vs slip angle) and maximum lateral coefficient of friction. This is shown below:

$$\alpha_n = \frac{C \cdot \sin(\alpha)}{\eta_y \cdot Z}$$

$$F_n = \frac{F_y}{\eta_y \cdot Z}$$

THE PACJEKA TYRE MODEL

For interested readers who are going to work through the maths, use slip angles in radians and not degrees. When we plot this, you wind up with a curve that looks like that shown alongside in figure 1.

The good news is that we can distil this down to a curve fit of four parameters. This can be plotted as a function of tyre load or other relevant variables. Also, if we plot η_y and C as a function of load, we can build a complete picture of how the tyre responds.

The bad news is the function for these parameters is far from intuitive and, unless you have maths analysis packages at your disposal, you'll be hard pressed putting it together. The reason for this is shown in equation 2, while the four parameters we're looking at are defined by vector D, as shown below:

```
thi = (1 - D(4))*alpha + (D(4)/
D(1))*atan(D(1)*alpha);
theta = D(2)*atan(D(1)*thi);
val = D(3)*sin(theta);
```

From a mathematical standpoint, this equation is messy. All the inverse tans combined with the sin means you will be challenged to find a curve fit unless your maths is very strong. The strength of Pacjeka is that it is very comprehensive. Its weakness is that is not particularly intuitive.

To get us out of this predicament, let's consider the ChassisSim tyre model, which can be thought of as a simplified Pacjeka model. This tyre model has been applied to vehicles in categories as diverse as V8 Supercars, F3 and A1GP, to name but a few, and we've always been pleasantly surprised by how it's stood up. The heart of the ChassisSim tyre model is the representation shown below.

$$F_y = fn_y(\delta_{CAMB}) * fn(\alpha) * F_\max(TL)$$
$$F_x = fn_x(\delta_{CAMB}) * fn(SR) * F_\max(TL)$$

The first term, fn, that is a function of α (slip angle) for Fy and SR (slip ratio), for Fx is a function that is normalised between +1 and -1. Observant readers will note the strong similarities between this representation and the Pacjeka co-efficients. The only difference is that the slip angles and slip ratios are not normalised. The purists might ask, doesn't this vary with load? Well no, it actually doesn't. If you need to convince yourself, ask for some tyre results and have a play. If you non-dimensionalise by the maximum possible tyre force for the relevant loads, the curve shape is almost load invariant.

An example of a useful approximation of this function is shown in figure 2 above.

As can be seen in the graph, the horizontal axis is shown in degrees. While in numerical modelling we will use radians, I've shown degrees because I think it offers the reader a more intuitive feel of where the numbers are going. You can see the slope at low slip angles rises quite steeply but, as the slip angle increases, it drops off quite markedly. Figure 2 will be a good reference when we come to quantify tyre loads.

F_max(TL) represents the maximum possible force that the tyre can apply, both longitudinally and laterally. In more traditional terms, it is the radius of the traction circle/ellipse. To readers familiar with the Pacjeka representation, the cornering stiffness and η_y are all bundled in when you multiply out all the terms.

F_max(TL), which represents the radius of the traction circle, is the beating heart of the ChassisSim tyre model. Since it is completely user-definable, in reality it can take any shape the user wants. But working out what this curve looks like will be the major focus of the data and simulation analysis covered in this article.

Lastly, $fn_y(\delta_{CAMB})$ and $fn_x(\delta_{CAMB})$ dial in the traction ellipse and camber sensitivity parameters.

While this model isn't perfect, the big advantage is that the reader can see what leads to what. This representation also lends itself to data analysis – maths is the language of the physical sciences, but there's no point in pursuing it if you can't understand it. The plan of attack is to use this tyre model, some data and simulation analysis to get a better understanding of what the tyres are doing. With this in mind, the check list for our analysis will be as follows:

- Good calibrated race data – in particular we'll be looking at steer, vehicle accelerations, throttle and, if we have them, strain gauges.
- A car model of the set up in a racecar simulation package of your choice.
- A modicum of common sense...

Figure 1
Plot of normalised Pacjeka tyre parameters

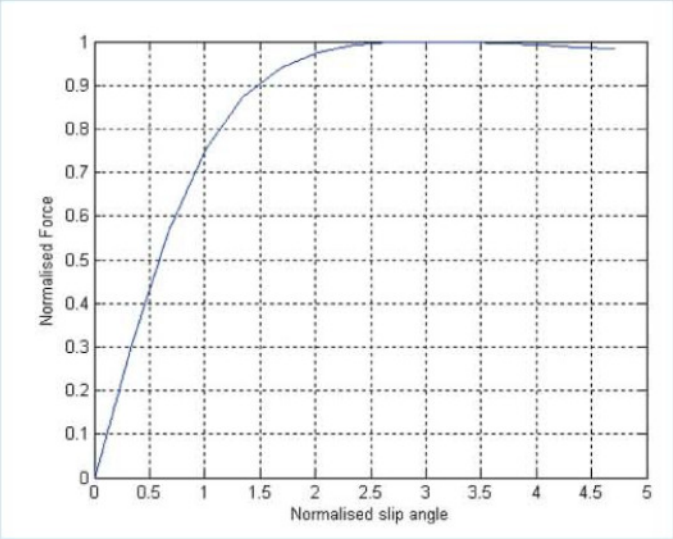
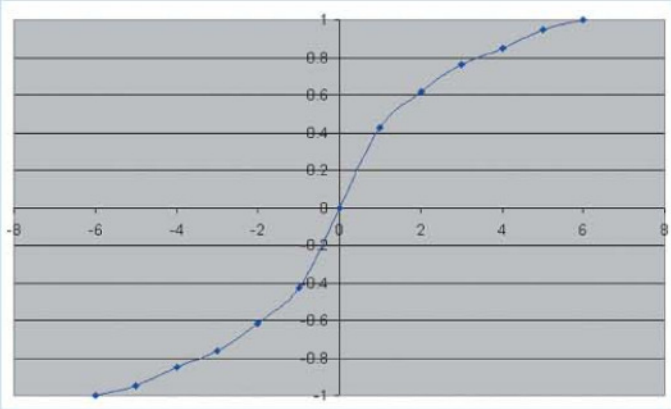


Figure 2
Normalised slip angle function - horizontal axis degrees



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THE ANALYSIS

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The first thing in our analysis that we need to look at is steering and, in particular, steering calibrated at the tyre, as opposed to at the steering wheel. Looking at the article in race car stability terms, it can be shown as such:

$$\alpha_f - \alpha_r = \delta_{steer} - \delta_{N.S}$$

The best way of looking at this is simply to overlay steering and neutral steer, as illustrated in figure 2. Any steering trace over the neutral steer line is understeer, anything below it is oversteer. This is going to form a critical component in working out which end of the racecar is operating at its traction limit.

To help visualise what is going on with the tyre forces, if we examine the tyre forces at peak lateral *g* we can deduce the following relationships. At the point of max lateral grip we have:

$$m_t \cdot a_y = F_{y1} + F_{y2} + F_{y3} + F_{y4}$$

Note, we are assuming both rdot and Vydot are negligible. If we define,

$$\Delta\delta = \left|\delta_{steer} - \delta_{N.S}\right|$$

and assume the camber functions as unity for the time being, and there isn't a big variation in slip angle from side to side, we can deduce the following relationships:

For understeer:

$$m_t \cdot a_y = fn(\alpha_f)\left(F_{y1} + F_{y2}\right) + fn(\alpha_r - \Delta\delta)\left(F_{y3} + F_{y4}\right)$$

For neutral steer:

$$m_t \cdot a_y = fn(\alpha_f)\left(F_{y1} + F_{y2}\right) + fn(\alpha_r)\left(F_{y3} + F_{y4}\right) \qquad (4)$$

For oversteer:

$$m_t \cdot a_y = fn(\alpha_f - \Delta\delta)\left(F_{y1} + F_{y2}\right) + fn(\alpha_r)\left(F_{y3} + F_{y4}\right)$$

Remembering, of course, that,

$$\alpha_f = \delta_{steer} - \frac{a \cdot r - V_y}{V_x}$$

$$\alpha_r = \frac{b \cdot r - V_y}{V_x}$$

The values of fn for various slip angles can be deduced from figure 2, shown on page 62.

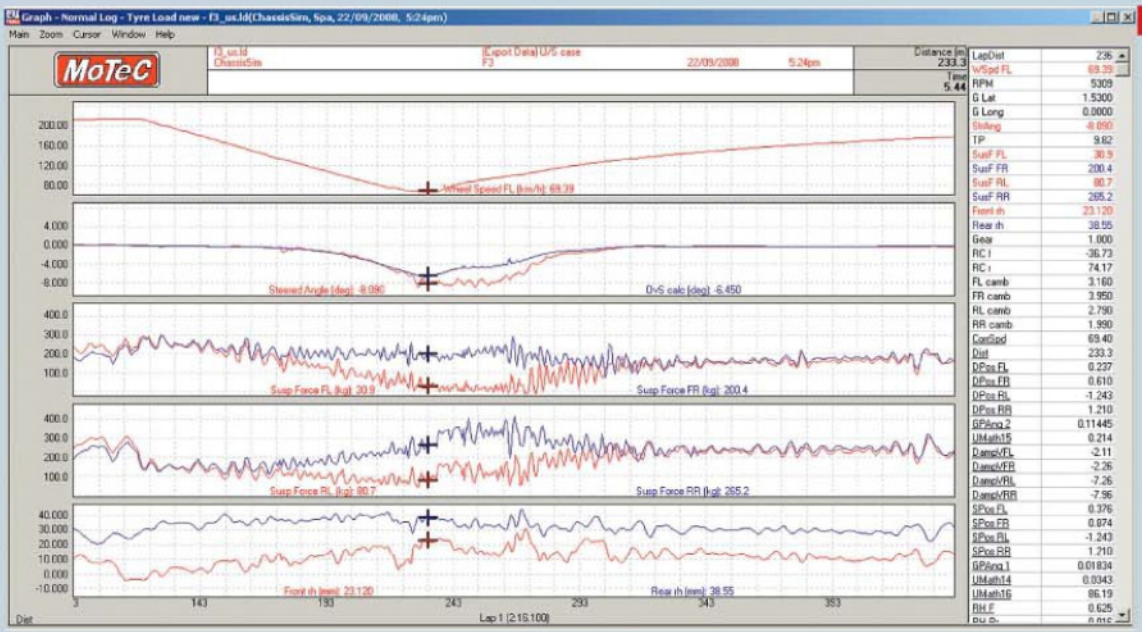

Figure 3

An F3 car understeering

RECALL FOR OUR NOMENCLATURE

wdf = weight distribution at the front
wb = wheelbase of the car
a = (1 - wdf)*wb
b = wdf*wb
Vx = forward velocity of the car
Vy = sideways velocity of the car
r = yaw rate of the car
δsteer = steered angle of the car at the tyre
αf = front slip angle
αr = rear slip angle

Equation (4) gives us a very powerful tool for visualising what the forces are doing and how we can quantify them. Assuming we are at maximum slip angles when we are at the limit we can produce a further simplification. Then fn becomes unity and we only need to evaluate fn for the end that is not at the limit.

We can illustrate these techniques with an example, here an F3 car understeering, as shown in figure 3. From there we have the following conditions that are summarised in table 1 below. From equation (4) the case we are dealing with here is understeer. This means Fy1 and Fy2 are giving their full contribution. We can also make things easier on ourselves

TABLE 1

Values derived from figure 3 data

Parameter	Value
Vx	69.4km/h
Ay	1.53g
Susp Force FL	30.9kgf
Susp Force FR	200.4 kgf
Susp Force RL	80.7 kgf
Susp Force RR	265.2 kgf
Steer	-8.1 deg
Neutral Steer	-6.45 deg

here by enforcing another condition. Due to the car's weight distribution and the fact we are at mid-corner we have,

$$wdf \cdot a_y m_t = F_{y1} + F_{y2}$$

Working through the numbers for the front, a useful approximation we can come up with is that given the load on the front left is almost negligible, then it can be written as such:

$$wdf \cdot a_y m_t = 0.41 \cdot 1.53 \cdot 9.8 \cdot 550 \approx F_{y2} @ 200.4kg$$

$$F_{y2} @ 200.4kg \approx 3381N$$

While this is something of a trivial example, it nonetheless illustrates that by using a few simply placed approximations we can start quantifying what is going on with the race tyre.

LAT

A true mathematical picture of your tyres will quantify your intuition

LAT

Understand your tyres and you're a long way toward dialling in your racecar

The power of these approximations is that, while they are not perfect, they do give us a very quick way of describing the race tyre and building a picture of what it is doing so we can quantify our intuition. A very wise man once observed that all the qualitative analysis in the world counts for nothing unless you can put some numbers to it.

There are a number of ways we can extend equation (4) out. If we find approximately equivalent load points, say for four equivalent load conditions, then the astute mathematician will realise we have four equations in four variables. This can be readily solved. Another way of tackling the problem is that if we know what the load values are, then we can come up with an arbitrary function for the tyre load curve. To illustrate with an example function:

$$Fm = \sum_{i=1}^{4} a_i \cdot L^i$$

In this case, L is the load applied to the tyre and ai represents the load coefficients for a particular tyre. We can then put all the mid-corner points together and, if we know the loads, then we can readily formulate a least-squares method to come up with our approximation. What we are doing is minimising the error between the measured lateral acceleration and the acceleration produced by our guesstimate.

In cases where we don't have tyre load sensors, simulation can come to our aid. We come up with a very rough model and then run the simulations to replicate the tyre loads. If the cornering speeds are within reasonable agreement (say, within 3-4kmh), provided we have matched the set up from the data with that used with the simulation, then we can use the simulated tyre loads to substitute for actual tyre loads. While this isn't perfect, sometimes in data engineering you have to make do with what you have, and this is another useful application of simulation.

Once we have the estimated tyre curve, racecar simulation is a valuable tool to refine the tyre load curve, and the procedure is quite easy:

- Run the simulation for a given set up and match this to the data.
- Focus on the discrepancies in speed and tyre loads. This will provide very strong indications on where you need to go. For example, if your speed through high-speed corners is too high, what the data is telling you is to reduce the cornering force in the high-load section of the tyre.
- Do this from run to run and you will get progressively closer. The ChassisSim tyre force modelling toolbox will do this autonomously.

In conclusion, the techniques discussed here provide some powerful tools to construct and visualise what the tyre is doing. Is this the first and last word on tyre modelling? No, but it will allow you to quantify simply and quickly how tyres respond to the forces and loads applied to them. Furthermore, the use of vehicle simulation is an invaluable tool for refining the tyre model. It provides the equivalent of a tyre dyno and will produce valuable insights in to where to go with the set up of a car.

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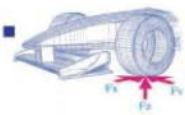

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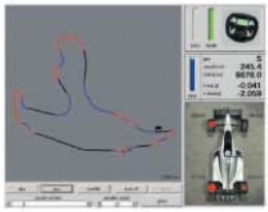

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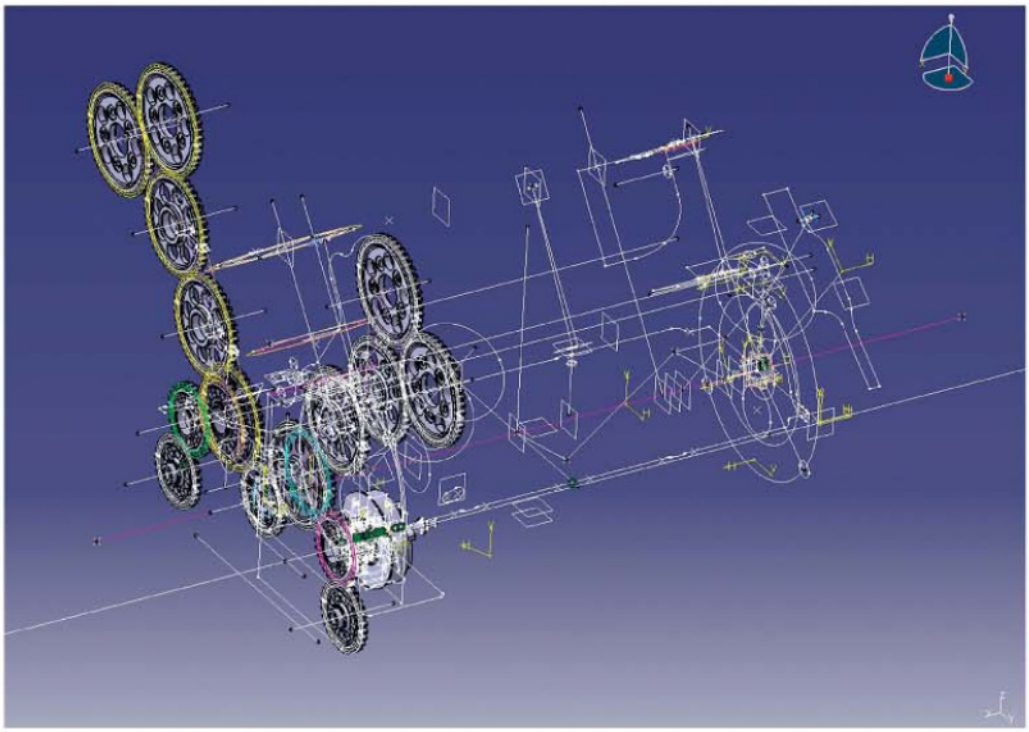
How does an engine from a small, private manufacturer challenge the works-developed power units? We talked to AER to find out

BY CHARLES ARMSTRONG-WILSON

A brand new, ground-up racing engine emerging is an increasingly rare event these days, and even rarer outside the seemingly unlimited budget, manufacturer-backed operations. The standards required to be competitive in the 21st century have pushed development costs out of reach of most smaller engine builders, yet still engines emerge against the odds, and from time to time, the smaller firms manage to take on the big players on even terms. But how can they compete without the huge budgets? We talked to one such company to find out.

Oliver Allan is the technical director at Advanced Engine Research and has been responsible for the company's turbocharged V8, used in Sportscars, and all subsequent engine projects from the company. He joined from Ilmor where he admits he learned his trade under the masters, Mario Illien and the late Paul Morgan. Allan agrees that this was a rare privilege, but is quick to point out that the AER V8 is not a clone of an Ilmor Formula 1 engine. 'I was determined that we wouldn't be creating an Ilmor/Mercedes LMP1 engine,' he says. 'I wanted to do something that was what I considered original.' Not least, he was working with a smaller design team and a smaller budget. Yet the product he was drafting still had to be competitive against heavily funded, works-developed engines. So with these not inconsiderable constraints, how did he tackle the project?

'I think you start at the beginning, which is the concept,'



CATIA wire frame models were used to create the architecture of the engine while keeping the main dimensions fluid

he says. 'I'm a great believer that right first time is the cheapest. So we spend an awful lot of time thinking about the problem first before we commit to anything.' What are the considerations at this stage that start to dictate the design, we asked. The first, as Allan points out, is what fuel the engine will be running on, and whether it will be normally aspirated or turbocharged. 'That will be the first port of call for me when you are going to decide bore and stroke and valve angles. You can achieve power in two ways – either through more revs or forced induction. But that means the fundamental balance of the mechanical system alters too, because in a turbocharged engine very little breaks because of revs. With these you are always operating at low rpm, whereas in a high speed, rev-dependent engine, bore and stroke are compromised to achieve the required reliability at high engine speeds.

'You are really considering your goals, like what rpm is it going to run at, and what loads are going to go through it. There are an enormous number of key dimensions of an engine beyond bore and stroke. Things like the v angle, bank stagger, main bearing size, big end bearing size, the list just goes on and on. And all of those decisions are made from science-based fact. You want the smallest bearings you can have in an engine for the friction, but you don't want to have big end bearing failures. The sums can be done for all that sort of thing.

'I think that's really where our approach is very scientific. We will look very carefully at all those numbers. So the effect of a v angle on the torsional behaviour of an engine or packaging vs centre of gravity - every part of the engine is a compromise, and it's about understanding the compromises.'

> **"doing the engine right first time in a short timescale is the biggest way to save costs"**

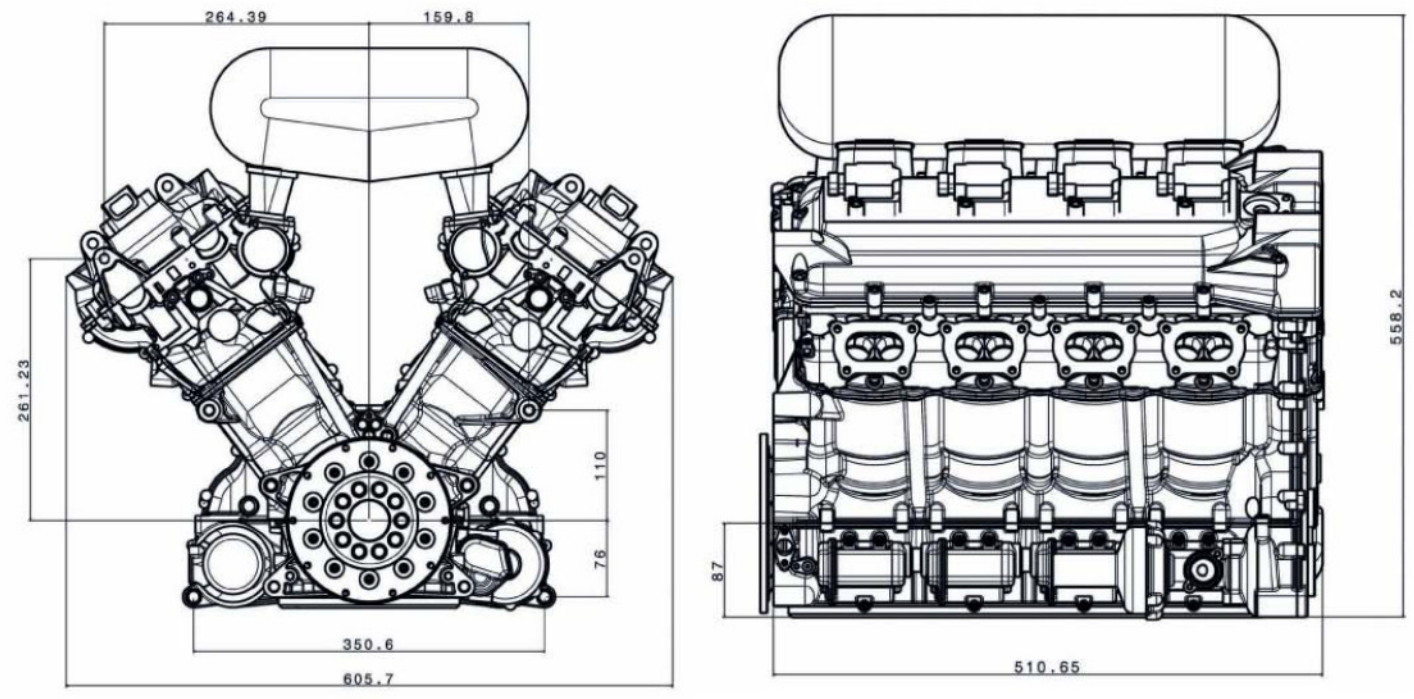
However, at some point, the architecture of the engine has to be laid down in a tangible form, so where do they start? 'It's a building-up process,' says Allan, 'and this is where CATIA lends itself to my approach. Within CATIA, there is the option to use wire frames, like skeletons. You can have a wire frame for a crankshaft, for instance, and it will allow you to type in two numbers, like bore and stroke, then it will alter the geometry of the crankshaft to suit. So I retain an enormous amount of flexibility in the early part of the design process.'

Allowing for a change in v angle during development is considered critical by AER's engineers to obtaining an optimum configuration for an engine

UNDERSTANDING V ANGLES

This is the key to AER's approach and allows the design to progress without having to backtrack too far at great expense should an area of the design later prove to be less than optimum. Allan drums this into his designers from the moment they start to create components in CAD. For instance, he wanted to avoid fixing the v angle of the engine until very late in the process. 'We just said for all the models, the v angle will change, it is not fixed at the moment. Everything has to be based on the fact it will survive a v angle change.' Provided this consideration is built into the models at an early stage, CATIA can allow such fundamental changes to be made very late in the design process.

The reason the v angle is so tricky to arrive at is, apart from the structural and dimensional needs of a racing engine, subtle changes in the firing order create different vibration signatures



Every aspect of the engine was modelled during the design process, from bank stagger to bore spacing, but combustion chamber work was done by 'feel'

> **you tune the torsional behaviour of the crankshaft, the camshaft and the gear train**

within the engine. 'You are looking for reinforcing orders, so whatever order is strongest, you are looking at what that is going to excite. Changing the v angle you just effectively change the magnitude of the orders. You are trying to avoid all those situations, so essentially you just make sure you tune the torsional behaviour of the crankshaft, the camshaft and the gear train. I'm pleased to say that we have never had a torsional-related failure on the engine. I'm therefore comfortable we did the right sums and made the right decisions during development.

'The core of the model is the engine wire frame. It will cover bore and stroke, v angle, bank stagger, all those things, and they will be fed into every other part of the engine. So the cylinder head model will be based on having a bore spacing that is flexible. The cylinder head, however, is one place where you're likely to have problems if you go outside the bounds. The gear train was driven by a spreadsheet, where you feed in gear pinion centres, so if the cam spacing or the cylinder head changed, they would alter, too.'

One of the biggest growth areas in engine design during recent years has been computer modelling. Big, manufacturer-backed racing efforts have access to time on supercomputers to run complex CFD on combustion, but is this available to AER? 'We don't do complicated CFD in the combustion chamber or anything like that,' admits Allan. 'We would like to, but don't do it. We are working on experience and feel.' However, the company does use simpler, one-dimensional modelling. 'We use Optimum Powertrain and GT Power as well,' and Allan has strong views on such techniques: 'I have a general philosophy with simulation that it is only as good as the boundary conditions you put in. With these software codes, you very rarely get to know what assumptions have been made behind the scenes. As a result, I tend to use those systems in an advisory role rather than a defining role.

AER's technical director Oliver Allan was responsible for the V8 Sportscar engine project

> **simulation is only as good as the boundary conditions you put in**

'For instance, looking at inlet tracts and those sorts of things, that kind of stuff the software packages are very good at doing. There are fairly straightforward phenomena that govern them in terms of wave dynamics and so forth. I'm not worried about producing accurate predictions of horsepower because they make all kinds of assumptions about friction that don't apply to our engines. You can go back and change [the assumptions], but in many ways, it's almost not worth the effort. As long as it is not wildly out of bed so your engine characteristic is massively

Life Racing's PDU32 was one of the first power distribution units produced for racecars

altered, we are just trying to get it so it is sensible. You are looking for more general trends and it is a sensitivity analysis.

DRAG MANAGEMENT

Allan is particularly keen on minimising drag in his engines with bearing sizes and the management of lubrication. 'The oil flow of the V8 engine is very low and I won't say more than that. But considering what engine it is, it is very low and that's where we come back to the concept. One of the things was we wanted to reduce friction. How do you reduce friction? Well, it's everywhere in the engine. It's not just about having small bearings. It's about how much oil you've got in the engine, because the more oil you've got the more you have to pump round. Putting all the oil in exactly the right place is key, and the oil flow to the V8 engine is lower than the [AER] P07 I4 four-cylinder engine, for instance. And that's with a doubling up of camshafts. It's actually lower than that, which highlights the philosophy of this engine. So I think we do some very nice things there and our crankcase pressures are very low. Those sorts of areas are optimised. The conceptual part of the process is key to me in terms of being efficient and doing it for sensible cost.'

This neat and functional oil union demonstrates Allan's thinking of keeping the machining in two dimensions to reduce time and cost

DETAIL ENGINEERING

Finally, with the concept laid down and the main dimensions fixed, what is the next priority?

'Engines are about details,' asserts Allan. 'That is a fundamental truth about engine design in my opinion, and somewhere it is easy to come unstuck. At that point, you are just making sure all the details are absolutely correct. And you are also thinking about things like how you build the engine. It is very important to me that the engine is an easy engine to build, that it's modular and that it allows you to do things in differing orders, depending on what is appropriate at the time.

'Easy to manufacture as well, and I think it is quite easy to understand where that came from. At Ilmor you were intimately involved in manufacturing, and Paul [Morgan] was a manufacturing engineer, that's what he enjoyed doing. As a result, he was always drumming into us, how do we make this easy? A lot of it again is just the details – boring stuff like putting an undercut in the right place, don't grind something if you can turn it to the tolerance, why does it need to be that tolerance? It's that level of detail that's important. I don't really allow people to do 3D machined parts here, I think that is kind of lazy. So we will have parts of the engine that are all 2D cutter paths and can be produced easily and effectively. A good example is an oil inlet fitting on the engine. The guy who designed it actually did two versions. He did a 3D version, which I wasn't happy with, and a 2D version, and it was the 2D version that won.'

> **"Putting all the oil in exactly the right place is key"**

So that is the secret? As Allan puts it, 'Fundamentally, doing the engine right first time in a short timescale is the biggest way to save costs. And secondly, don't spend money on things that aren't appropriate.' Good advice from a man who knows.

Even in twin turbo form it is obvious how compact the AER V8 is when seen in situ in the back of an LMP1 Sportscar

DEVELOPMENT OF AER

Mike Lancaster founded AER as an offshoot of his engine electronics company Pectel

Advanced Engine Research is probably unique among engine manufacturers in that it was born out of an electronics company. Mike Lancaster, working with a business partner, founded an electronics company to make control systems for engines, its customers including Toyota, Nissan and Ford

Interestingly, neither founder came from an engine background, with Lancaster's previous work being in film and video, but their early efforts in engine control systems were successful. With that knowledge, Lancaster felt that engines were not being designed with enough consideration for the potential of the electronics, so Advanced Engine Research was born in 1998. Shortly after the formation of AER, Lancaster started Life Racing as an in-house division to serve the company's electronics requirements and to provide a bespoke service to the automotive industry.

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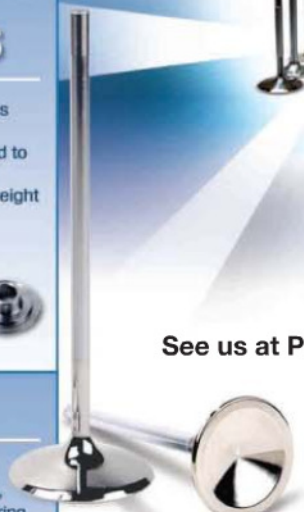

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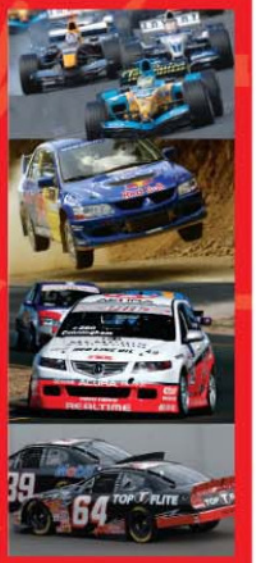

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A twist in the tail

There were surprises aplenty at Formula Student Germany '08, but the best came in the final moments of the last day

BY ALLAN STANIFORTH

The most impressive aspect of Formula Student Germany '08, at the Hockenheim GP circuit for its third year, might lightheartedly be described as 'airy fairy', despite being of ever-growing importance on the planning and build lists of every team at the top end of the results for the past 10 or 15 years.

Among the data required from entering teams, there is to be found an 'invisible target'. It carries no award, or penalty, though it is listed among the criteria design judges will later study, and is a strong pointer to skilled design in the small projectiles now being created across the world by engineering student teams for annual competition. That target is weight, and the design implications in the use of a free, readily available fluid, otherwise known as thin air – the fluid that is now often seen to be replacing light alloys, honeycomb panelling, even carbon composites.

As recently as 10 years ago, before the American originators and creators of the competition had a 'foreign' competitor from outside their shores, the 100 or so universities that were involved in Formula Student had been steadily paring weights down, from over 300kg (660lb) to the mid and then low 230s. That invisible target became an unofficial 200kg (440lb) – something that is perhaps impossible under the current rules structure. Or perhaps not? Founder of Lotus, Colin Chapman, generated more amusement than respect from rivals when he once put his car on the grid unpainted in a ruthless search for lightness, yet the principle was valid. After all, you can't get lighter than removing something completely. But how about the chassis?

> "you can't get lighter than removing something completely"

Over the horizon came a pioneering entry from the UK, where Leeds University had not only raised most of the necessary finance to cross the Atlantic, but also decided to invest an appreciable part of it in the relatively strange new world of the composite tub, with a calculated saving of 18kg (40lb). They didn't win, but they did put in a very respectable performance for first timers, returning the following year to get into the top 10 in design.

THE SCALES DON'T LIE

However, a set of experimental official weighing scales introduced by the organisers began to reveal that the figures provided on teams' entry forms were not only guesses, but also often extremely optimistic ones. To give judges some more reliable guidance, it was decided to weigh each car at scrutineering and record the figure on a sticky label. Plenty of teams looked astonished (or embarrassed), but not as surprised as officials when the entry from Delft in Holland read 199.7kg (439.3lb).

Shock and disbelief all round, with the late Carroll Smith, then head judge and a lifetime veteran of the racing scene as driver, builder, designer and skilled interpreter of rulebooks, ordering a re-weigh, adding cheerfully, 'They've probably filled the tanks with hydrogen.' They hadn't, and the scales stayed obstinately inside 200kg. Delft began a new era, with their own entries joined by many others as, year by year, those scales sank through 190, 180 and 170, and they arrived in Germany this year to be labelled at 162.7kg (357.9lb). Still ahead of everyone? Well, no, actually. Not after the University of Quebec recorded a shattering 159.7kg (351.4 lb).

There were, of course, dozens of different weight reduction secrets in both cars, but they shared at least one – and it was difficult to hide. It was the decision to abandon the popular, 600cc Honda CBR four-cylinder engine in favour of the single-cylinder Yamaha 450 WR. Both felt the loss of 25 per cent of the permitted swept volume was more than compensated for by a similar percentage loss in structure, including three

All photos: FSG 08

From the UK came the Oxford Brookes entry, squeezing a potentially record breaking 93bhp out of its engine, but...

...at the expense of its silencer

After a strong showing throughout, Delft (with a car weight of just 162.7kg) held off Stuttgart in the final stages of the Enduro to clinch the overall win

cylinders, pistons, rods, plugs, valve gear and inlet and exhaust manifolds. Paddock prowling therefore took on a curious new dimension, of looking for things no longer there, a number of components having been replaced by thin air.

Among eight UK entries this year, that from Hatfield (University of Hertfordshire), despite weighing in at 219.4kg, came a highly meritorious fifth overall from 78 entries, of which only nine made it under the magic 200kg mark.

Hatfield listed among its innovations discarding carbon fibre in favour of a new polypropylene material dubbed 'PURE' that cut their carbon bill in half, a tyre compound specially created by Dunlop for their car, an in-house vehicle simulator to lighten their testing load and a 'smaller carbon footprint'.

FINAL ELIMINATIONS

Oxford Brookes, after a highly impressive third in design, had a brand new, off-the-shelf silencer shell melt into a massive hole when the flame from their possibly record-breaking 93bhp engine hit it and eliminated them from the final Enduro section (22km, flat-out, twisty circuit with a mandatory driver change and speed weighted against fuel consumption in a special equation). Just to finish in this part of the competition is essential for any sort of competitive result.

Late on the final day, only two teams – Delft and past victors, Stuttgart – were seriously in the running for overall victory. Each competitor is released in random order after a time gap to the car ahead and, by coincidence, Stuttgart followed Delft past the start flag. They would not have to overtake their rivals, only record a better time to win. As their driver entered his last lap, it was as clear to Delft, who had already finished, as it was to the 3000 spectators and other teams watching the big electronic timing clocks, that the gap was slowly but definitely closing. He *might* do it, everyone thought... But then came the misfire, the coughs of an engine dying, being caught by over-run re-starts, the zig zags of a driver seeking every last teaspoon of fuel in the tank. Eventually, it died, rolling slowly to a stop. It appeared the chain had broken, perhaps the result of the final brutal moments inflicted by a despairing driver. The non-finish dropped Stuttgart from possible victory to a lowly 23rd place.

The driver climbed out to stand alone on the empty track beside his dead car, silhouetted against a setting sun. Any film maker would have been accused of overplaying the final act, but this was played out for real. And Delft had won outright.

"paddock prowling took on a curious new dimension – looking for things no longer there"

Car weights keep falling, with Quebec this year coming in at a lowly 159.7kg

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X-Bow marks the spot

A lightweight, road-going racecar built as a collaboration between a motorcycle manufacturer and a racecar manufacturer. Is this the best of both worlds?

BY IAN WAGSTAFF

'We've done everything we can to make the X-Bow as light as possible, and then had to add an extra 80kg to make it eligible for GT4!' said KTM's Toni Stöcklmeier prior to the carbon-fibre monocoque car's debut at Silverstone earlier this year. In road-going form, the first four-wheeler from the Austrian motorcycle manufacturer weighs just 700kg, but then this is more of a racecar built for the road, rather than vice versa. Indeed, the product of Gerald Kiska's design studio looks more like a prototype than a conventional GT and is to be found in the Sport Light category, where production numbers do not have to be as high as for other GT4s.

The two cars that finished seventh and 10th on their debut were, in fact, pre-production prototypes with safety modifications made to include steel rollover hoops to replace the aluminium production versions, a Sparco integrated head restraint, extended wheel covers with added protection between front and rear wheels and zylon fibre layers to protect against debris. The race was in April with full-scale production not due to start until June, with 500 units planned for this year. At the time of the Silverstone GT meeting, 300 of these had already been sold.

The two chassis that have so far raced were not strictly factory entries but were run by Reiter Engineering, which is based near the Germany/Austria border and is best known for

TECH SPEC

KTM X-BOW

Engine: Audi in-line DOHC four with direct fuel injection system (FSI), turbocharger and intercooler

Displacement: 1984cc

Max power: 162kW (220bhp) at 5900rpm

Max torque: 300Nm at 2200-4000rpm

Valves: four per cylinder

Bore and stroke: 82.5 × 92.8mm

Gearbox: VW six-speed manual

Kerb weight: 700kg (+80kg ballast for GT4 Sport Light)

Weight distribution front/rear: 37/63 per cent

Overall length/width/height: 3670 × 1870 × 1160mm

Wheelbase: 2430mm

Centre of gravity: 400mm

Track front/rear: 1644/1624mm

Fuel tank capacity: 35-litres

Brake system: Brembo, four-piston front caliper/two-piston rear

Brake disc diameter: Brembo, 305mm front/262mm rear

Aerodynamic downforce: at 100kph 48kg/at 200kph 193kg

At 700kg and with upwards of 220bhp and wind tunnel development by Dallara, KTM's X-Bow looks to be a strong contender in the GT Sport Light category

Carbon fibre monocoque has front and rear crash structures, with integral aerodynamic and access structures built into the sides of the tub

Aerodynamic development, along with much of the chassis design work, was done at Dallara, the world's biggest racecar manufacturer

the Lamborghinis that it runs in other forms of GT racing, including Gallardos in GT3 and the IPB Spartak Murciélago in GT1. At the time of writing, testing had already been carried out at Misano, Adria and Monza.

DALLARA INVOLVEMENT

Under the watchful eye of chief designer Luca Pignacca, Dallara has been heavily involved in the development of the X-Bow (pronounced 'ex-bow' by the way, not 'cross-bow', to appease Chrysler says Stöcklmeier) from the beginning, much work having been carried out in the company's older wind tunnel in Varano de'Melegari. While many car manufacturers choose to hide the parentage of their vehicles, KTM is proud to have Dallara logos prominent on the X-Bow and Pignacca is very enthusiastic about the project, which has been a major undertaking for the company.

> "claimed downforce of 200kg at 200km/h"

Underlying the racecar nature of the X-Bow is its claimed downforce of around 200kg at 200km/h and transversal acceleration of 1.23*g*, a figure significantly higher than any other homologated road car. This has largely been achieved by means of an underbody equipped with a prominent diffuser. To make this work effectively, the linking points for the rear suspension have been set as high as physically possible and the car's c of g kept to just 400mm. To achieve the required aerodynamic profile, air is channeled into inlets in the sides behind the driver.

Suspended on double triangular wishbone axles, the wheels feature suspension and damping elements by WP Suspension, with a pushrod arrangement up front.

From a safety perspective, the solid, carbon-fibre monocoque is supplemented by a crash box in the nose and another at the back, which cleverly doubles as the silencer, to absorb the force of an impact to the rear of the car. The radiator is also located at the rear and airflow to this is accomplished by using special air baffles, which are fitted horizontally on the sides of the car so that they can also be used as boarding aids.

POWERTRAIN

The engine for the KTM X-Bow is Audi's 1984cc, in-line, four-cylinder FSI unit with turbocharger and intercooler, giving a claimed 220bhp and 300Nm torque peaks at a level between 2200 and 4000rpm. A 300bhp version is already in the pipeline. Use is made of a VW manual six-speed transmission.

The new-for-2008 GT4 European Cup's Sport Light category is for cars weighing less than 1000kg, and while the two X-Bows were the only starters in class at the opening round, it looks to have an interesting future. A pair of Ginetta G50s were to have been entered by KS Motorsports, but series organiser SRO's insistence that cars in the Light class run on grooved tyres led to their being withdrawn. There is also talk of Gillet Vertigo and Funke and Will's Yes! roadster joining the grid in the near future. Either way, these cars will be in stark contrast to the Aston Martin N24s, Ford Mustang FR500Cs, BMW Z4s and the Corvette C6 that currently make up the conventional GT4 grid.

Detailed aero work is evident in the prominent diffuser and rear tunnels. C of g has been kept at a lowly 400mm

Driving impressions

BY SAM COLLINS

Some racecars are beautiful, almost works of art – the Porsche 917 or the Aston Martin Vantage, for example – others are perhaps a little less good looking, but nothing quite prepares you for just how startlingly ugly the KTM X-Bow really is, especially in its GT4 Supersport guise. But looks are not everything, and it is kind of enticing. Its lineage is pretty good too, the concept coming from the Austrian KTM company (notably part of the same group which owns Pankl), and the engineering development by Dallara. And as the world's biggest racecar manufacturer seems to be quite proud of what they have turned out, the chances are it must be pretty good. So *Racecar* went to Varano in Italy to find out.

Just down the road from the Dallara factory lies the twisty confines of the tiny Italian circuit, which are perfectly suited to a high-downforce racer like the X-Bow.

The instant you clamber into its frankly massive cockpit you realise what the GT4-spec car is really built for – wealthy gentlemen racers who want to go out and have a good time. As a result, everything is simply laid out and largely idiot proof.

Out on track the car is lively enough to hold your attention but not so much as to be alarming. The handling allows even a very average driver to get up to a reasonable speed quite quickly. Compared to the Aston Martin N24 GT4, the lightweight KTM is a lot faster in the twisty bits, but feels lacking on the straights – potentially no bad thing for an amateur racer. Having been at the wheel of two very different GT4 racers now the KTM is certainly the easier to drive and round a track like Varano is much faster, but on bigger tracks like Silverstone or Monza the Aston would be a much better drive. You can position the KTM exactly where you want it, in my case just bouncing it over kerbs, and it took it without any complaint. After a few laps I was grinning from ear to ear and felt ready to race, which is rather the point of the car. The whole thing is designed and engineered around gentlemen racers who just want to go out and enjoy racing.

> **Everything is simply laid out and largely idiot proof**

The works support package is geared up for that, too. For €100,000 ($132,000) you can have a full season's support that covers everything from preparation to engineering staff. The only further expenses are tyres, fuel and any costs incurred through crash damage. In addition to this, a series for X-Bows will start in Europe next year, which will piggy back on other existing championships such as GT4 and the Dutch Supercar Challenge. It is hoped that this will fulfill KTM's three main customer aims, which are:

- use of available infrastructure
- racing series within a manageable radius (less than 800km)
- overall cost reduction and efficiency

There is not yet any word on when the X-Bow will be available in North America, but it could be a huge success there when it is. I reckon the look of this car would fit right into the California racing scene, its looks being more akin to something you might find in *Speed Racer* or *Terminator 2*. Oh, and if 200+bhp is not enough, the new 400bhp Formula 2 engine would be a straight swap for the 2.0-litre Audi powerplant. The X-Bow could be the new face of club racing.

***Racecar's* Sam Collins gets a driver briefing before taking to the track in the GT4-spec KTM X-Bow**

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Ultra rapid casting

CRP Technology rolls out the development of a new casting process

The high quality of this un-machined motorcycle cylinder casting is evident

Over the last 20 years, there have been numerous inventions and innovations in motorsport manufacturing. One of the most notable developments has been the uptake of rapid prototyping, and one of the leading suppliers in this area is the Italian firm CRP Technology. Recently, the company revealed the development of ultra rapid casting.

The application for this new process has involved the engine on the CRP Racing Honda 125cc racing motorcycle. The Honda's single cylinder always runs at high temperatures, in some places peaking at as much as 600degC, and has to withstand 14,000 ignitions each minute. By way of a comparison, a cylinder in a current specification Formula 1 engine running at its 19,000rpm limit will only have to withstand 9,500 ignitions per minute.

Performance gains in a two-stroke engine are mainly found by modifying the intake and exhaust ports that are integral parts of the cylinder. Their geometry therefore becomes the main focus for power development in engine design. However, it is often not possible to CNC machine them as the complex shape of the last portion of the exhaust port, often with deep undercuts, means an unreachable tool path. As a result, very high-quality castings are absolutely critical in this area.

The standard manufacturing procedure for such parts is sand casting and it is possible to obtain very good results with the right equipment. The trouble is this equipment is beyond the means of most of the motorsport industry. Tools are expensive and the process requires a lengthy manufacturing time. However, using its new ultra rapid casting technology, CRP's in-house race team was able to test and validate seven different drawings and castings in only 10 months, an output almost unthinkable with sand casting.

PERFECTLY ISOTROPIC

The real novelty of the new process is that, being a low-pressure casting, the melted alloy flows in the mould very smoothly and there are no bubbles or casting porosity issues when finished. The structure is therefore perfectly isotropic and there is almost no need for any weld repair. Finally, the component is machined and fully inspected. As a consequence, this new technology has all the positive elements of rapid casting, but it's much quicker

EVOLUTIONARY PROCESS

The ultra rapid casting is an evolution of the rapid casting process that was developed by CRP Technology (details of which can be found on www.racecar-engineering.com)

The procedure

STEP 1
A disposable pattern is made using Windform PS

STEP 2
The pattern undergoes wax infiltrations (immersion and capillarity) to increase its strength and avoid potential handling breaks

STEP 3
The pattern is immersed in a plaster-like bath

STEP 4
The lost pattern is evacuated by de-waxing inside an oven

STEP 5
The alloy casting is made in a low-pressure environment

STEP 6
Pouring, cooling, reduction of the mould, and gate cutting when needed, as well as shot peening and heat treatments as necessary

CRP Racing's Honda 125 race bike uses an ultra rapid cylinder casting

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SHOW PREVIEW

PRIde of place

It's big, it's in Orlando, it's PRI. The world's biggest motorsport trade show returns for perhaps its most impressive event yet

The Performance Racing Industry (PRI) Show has become an essential part of the motorsport industry's calendar of networking events. This year it runs from 11-13 December.

CUTTING EDGE

Approximately 170 racing companies will be exhibiting this year at the 21st Performance Racing Industry Trade Show that did not exhibit in 2007, almost all of them for the first time ever. 'From sprint car suppliers to international racing brand names to new kart companies, innovation is the driving force of the PRI Trade Show, and these new companies represent that cutting edge that makes the show a must-attend event,' says John Kilroy, editor of *Performance Racing Industry* magazine. 'With 1400 companies exhibiting the latest advances in racing products, technology, engineering and machining, you can't afford to miss a single day shopping the show!'

The Orange County Convention Center, home to the 2008 edition of PRI

Notable among the new exhibitors is JRI Development Group, which will be exhibiting its controlled active shocks, as featured recently in *Racecar Engineering's* sister publication, *Stockcar Engineering* (issue 2).

GRAND OPENING BREAKFAST

Dale Inman, one of the most successful crew chiefs in NASCAR history, will be the guest of honour at the annual Grand Opening Breakfast. Inman will share his favourite racing stories from the early

GETTING THERE

PERFORMANCE RACING INDUSTRY TRADE SHOW

Being a tourist location, Orlando has a wide range of hotels to choose from. There are 25 on the PRI recommended list alone, several of which are within easy walking distance of the Convention Center, but it should be pointed out that some of these have already sold out. Reservations can be made through the PRI by emailing either michelleg@performanceracing.com or tammyk@performanceracing.com

For those travelling to the show from Europe, PRI has once again appointed the experienced TD Sport and Travel of Leeds as its official travel supplier. TD Sport and Travel can assist with a whole package, from flights there to entertainment, and should be contacted via sport@tdtravelgroup.com

Meanwhile, visitors from Australia are catered for by Auto Racing Tours (see info@autoracingtours.com.au).

Orlando International Airport is just over 12 miles or 19 minutes drive from the Convention Center.

Performance Racing Industry Trade Show, 11–13 December 2008, Orange County Convention Center, Orlando, Florida, USA

CONFERENCE PREVIEW

PRI

AETC TO DISCUSS LSX

The 19th annual Advanced Engineering Technology Conference (AETC) will examine Advanced LSX Performance.

Topics planned for the 2008 conference include: high performance LSX engine building; new LSX technology; optimising LSX engine airflow; an in-depth review of LSX forced induction; big cube and tall deck LSX building; dyno and race proven LSX product reviews; racing the LSX; ultimate LSX engine control; LSX in Le Mans, NASCAR, NHRA, SCORE and more; the future of the LSX platform, OEM and beyond and OEM insider LSX information.

Also participating in the AETC, the UK's Motorsport Industry Association (MIA) will be on hand to host an informative round table during the event. The AETC is presented by SuperFlow Technologies Group, in association with PRI and the MIA.

Space for the AETC is limited to 350 attendees, so early registration is highly recommended. To secure a spot at the conference, make reservations online at www.aetconline.com or call +1 866/893 2382.

Advanced Engineering Technology Conference, 8–10 December 2008, South Building, Orange County Convention Center www.aetconline.com

Brutal-looking SuperModifieds will be among the range of racecars on show

Visitors will be able to take their pick from an array of racing simulators, too

NASCAR days, as well as offering some great insight into working with Lee and Richard Petty.

As Petty's pit boss for nearly three decades, Inman and Petty won seven Winston Cup championships. Soon after winning the 1981 Daytona 500, Inman left Petty Enterprises, going on to capture another championship in 1984, and several more wins with Terry Labonte. He retired from racing at the end of the 1998 season. He then added his assistance to starting the Victory Junction Gang Camp, which was founded by Kyle and Pattie Petty, in honour of their son Adam.

The breakfast takes place on Thursday, 11 December, at 7am.

INTERNATIONAL LOUNGE

A warm 'welcome' in several languages awaits international visitors to the PRI Trade Show in the International Lounge. Translation services are available here, as well as email access.

With international buyer attendance increasing every year, the organisers are dedicated to making it as easy as possible to conduct business at the world's largest racing trade show. Stop by for an espresso or a quick check of your business email, and check out the special meeting rooms available for your private business conferences.

VISIT RACECAR ENGINEERING

As usual, *Racecar Engineering* will be exhibiting at PRI. A number of our staff will be on hand, including new editor, Graham Jones, who will be on hand to discuss feature ideas and editorial content. Issue 3 of *Stockcar Engineering* will also be available, so why not come and visit us on stand 1937?

Racecar engineering

'Meet me at the PRI show on stand 1937'

Graham Jones, editor

'Visit me at the Racecar stand at the PRI show'

Tony Tobias, head of business development

'Pick up the latest issues on our stand'

***Sam Collins, editor,* Stockcar Engineering**

Stockcar engineering

Capricorn rises to the challenge

Racing technology specialist chooses Autosport Engineering to showcase its recent launches and expanding business

Capricorn Automotive will present its latest development, a NASCAR Sprint Cup connecting rod, at Autosport Engineering 2009. Launched this September, the rod's fundamental design incorporates core characteristics of materials and features to meet the needs of this application. Customisation of the design and package means it can meet any specific requirements from the teams in North America's most popular race series.

At the show, the company will also be informing its customers and other interested parties about changes to its corporate structure. Now with sales representatives in the important Italian and United States markets, Capricorn has the opportunity to respond faster to customer demands and to build closer relationships.

Capricorn is an enthusiastic supporter of Autosport Engineering and has attended on many previous occasions. Its representative, Martin Keswick, says of the show: 'Autosport International contains one of the biggest motorsport engineering shows in Europe. For a manufacturer of cutting edge, high-performance products and services in the racing and OE segment, exhibitions like Autosport Engineering are a good opportunity to communicate our company's capabilities to a wide spectrum of professionals.'

This year, Capricorn Automotive will be situated in hall 9 on stand E226, and will exhibit examples of its bespoke products for formulae such as Formula 1, NASCAR, NHRA drag racing, MotoGP, DTM, WRC and GT1, as well as numerous OEMs.

New for 2008 is Capricorn Automotive's high-performance NASCAR con rod

CROSSOVER TECHNOLOGY

Autosport International may be Europe's largest, most important motorsport show, but there are also technologies on display that will attract the attention of businesses outside of the automotive industry.

Manbat Ltd is a UK-based specialist with over 50 years experience supplying batteries for a diverse range of products, including watches, wheelchairs, medical equipment, back-up power systems and boats. The company also supplies car batteries to automotive retailers throughout the UK.

Another exhibitor, Powervamp, specialises in the design and manufacture of high-performance portable power packs for the 'instant' starting of all types of turbine and piston engines. A separate division, with its own brand identity, markets batteries and accessories to the racing industry where Powervamp's specialist knowledge is sought out by some of the world's top race and rally car builders.

Autosport International's exhibitors are often much more than suppliers to the motorsport industry.

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Autosport INTERNATIONAL ENGINEERING SHOW
8-9 January 2009 NEC, Birmingham, UK

NEWS

Uddeholm High Performance Steels, the world's leading supplier of tool steel and related services, has confirmed it will exhibit at the 2009 show with a 35m² stand. The innovative tool steel producer from Sweden has helped customers stay ahead of the game for 340 years, since it began in 1668.

Another company with a long history of exhibiting at the Autosport Engineering show is Guhring. Founded in 1898, it is one of the world's leading suppliers of rotary cutting tools and related products. The international distributor will be displaying some of its current range, which includes more than 1620 different tool types and in excess of 44,000 products.

UK firm The Awning Company will be showing its latest shelter solutions to Autosport International visitors. Over the past two decades, this motorsport, equine and exhibition industry supplier has grown to become the country's single largest specialist awning manufacturer.

Vargus Tooling UK Ltd will be displaying its range of world-leading, high-quality cutting and deburring tools for the metal and plastics industry at Autosport Engineering. Originating from Nagariya, Israel, Vargus Tooling is one of Europe's largest privately owned manufacturers and distributors of stainless steel products and metal cutting tools.

Talk to TT: Are you thinking of exhibiting at the show? Talk to *Racecar's* Tony Tobias. Email: expo@tonytobias.com, or call direct on 07768 244 880

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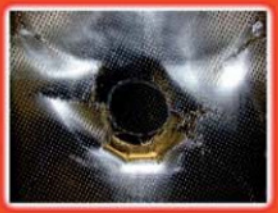

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Held each year as the epitome of Autosport International's sponsored events, the MIA Business Excellence Awards Dinner is not to be missed; the event has taken place since 1995 and brings together 500 leading representatives from the motorsport industry for a unique networking occasion.

Next held on Thursday 8 January 2009 at the NEC, Birmingham, the evening honours the industry's figureheads with the prestigious MIA Awards, given out in seven categories: Service to the Industry, Rally Business of the Year, Export Achievement, Technology and Innovation, Teamwork, Small Business of the Year and Business of the Year. To book tickets, place nominations or find out about fantastic sponsorship opportunities please contact Nicola Edwards at The MIA,

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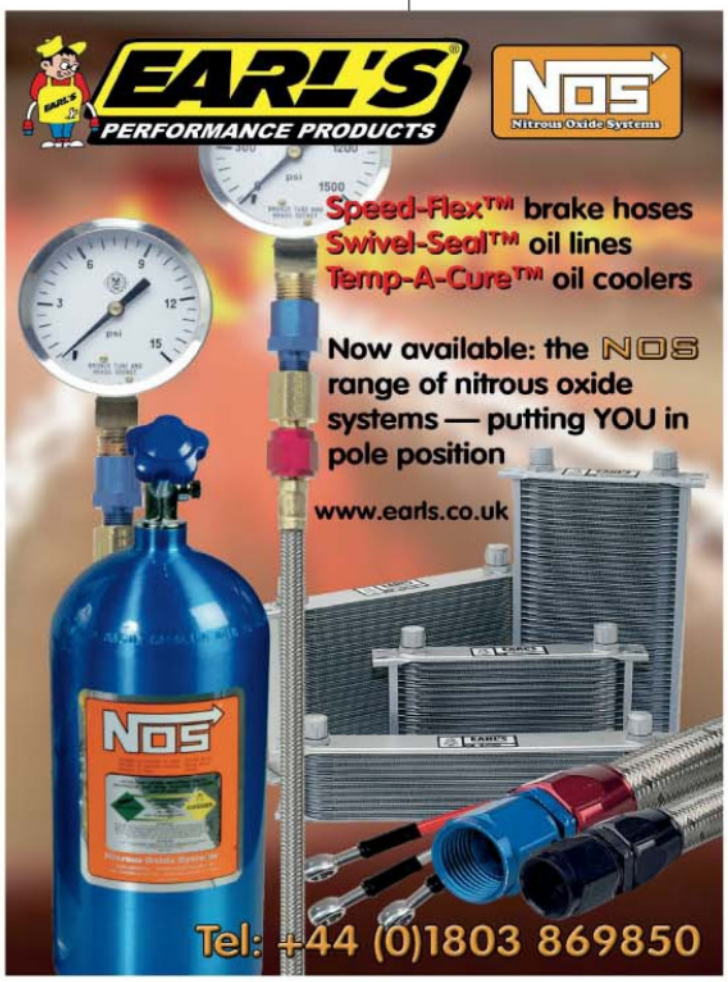

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To find out how your company can be listed in this section contact the Advertising Sales Department on +44 (0)20 8 726 8328

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TOTAL SEAL
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WISECO PISTON
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ACCRALITE PISTONS
T: 0121 525 6450
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Midlands, B66 1QJ, England
F: 0121 553 5951
website: www.accralite.com
email:pistons@accralite.com

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T: USA (+1) 805 298 3785
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T: USA (+1) 801 972 8766

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West Sussex, BN43 5PG,
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www.ricardo.com

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www.swindon-engines.com
sre@swindon-engines.com
F: +44 (0) 1793 528 484

TREVOR MORRIS ENG
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Woodside Farm, Bucknell,
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www.tmeng.co.uk
info@tmeng.co.uk

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DAVE CROSS MOTOR SERVICES
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DBR MOTORSPORT
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DEMON TWEEKS
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75 Ash Road South, Wrexham Ind Est
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T: +44 (0) 1708 229 829
ENGINE DATA ANALYSIS
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GEOFF RICHARDSON ENGINEERING
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T: +44 (0) 1432 354704
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www.ahfabrications.co.uk
alexahf@fairadsl.co.uk.
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VALVE SEATS

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T: +44 (0)208 654 8835

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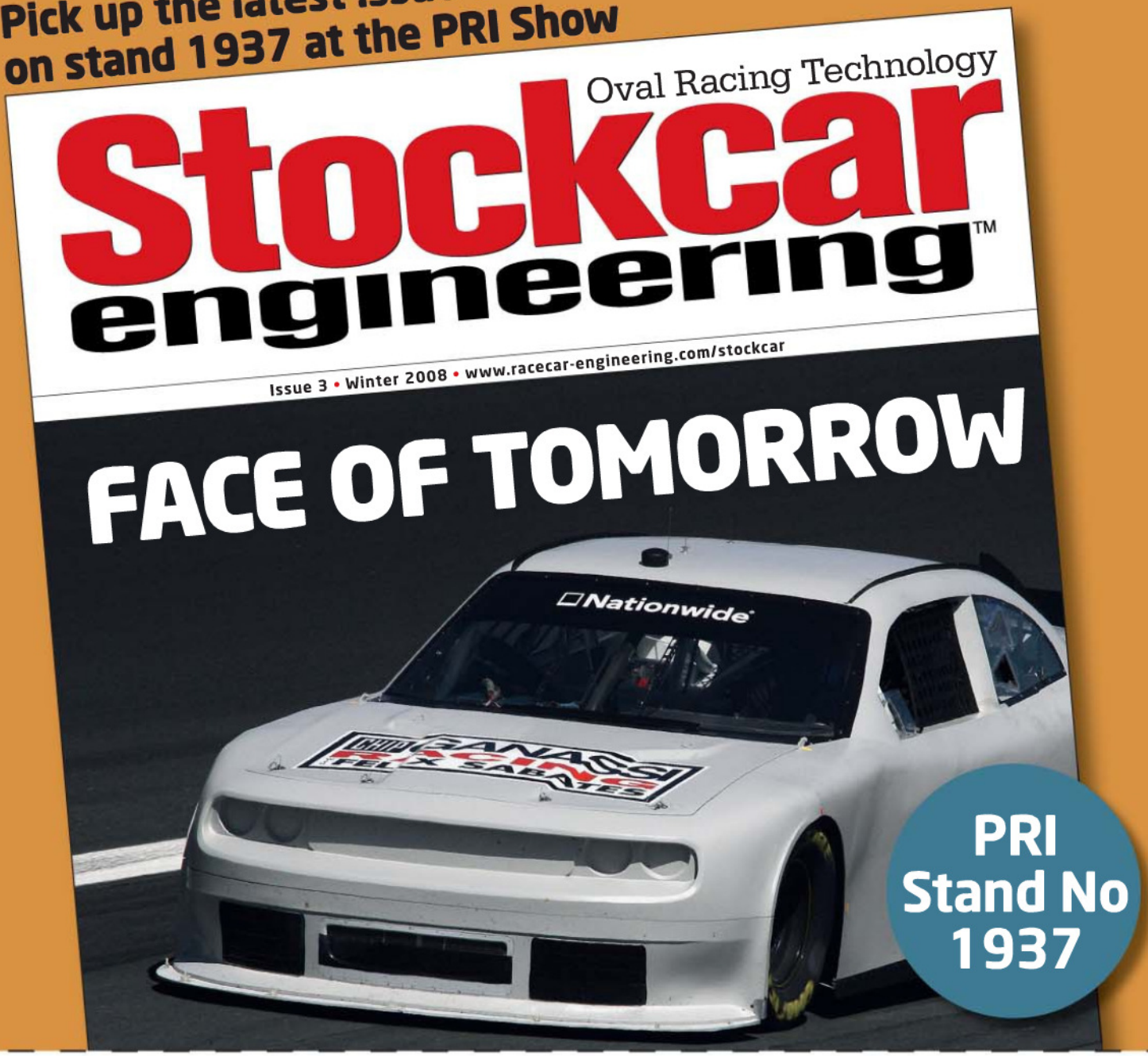

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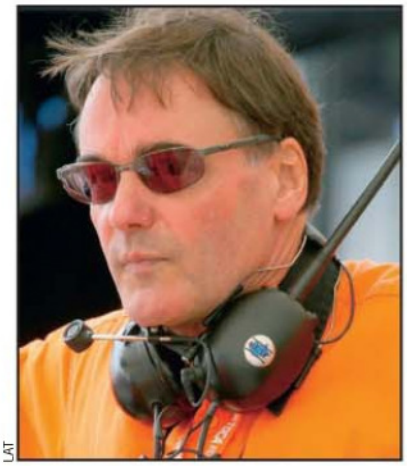
DICK BENNETTS
THE INTERVIEW


LAT

Q What's your view on the announcement that SEAT is to withdraw from the British Touring Car Championship?

I think it's very good, because it was going to be my major debate at our [BTCC] annual meeting – the diesels. Of course, it is sad to see any manufacturer go and two cars off the grid, but the fact is the diesel regulations need modifying as there is no parity at all. They squirt down the straights so quick then they're a bit slow through the corners. That's not racing at all.

The regulations are pretty good as they are but, if diesels are allowed to continue, then there needs to be better parity – maybe a smaller turbo? As I said to Alan Gow [BTCC boss], weight just doesn't hurt the diesels. If you put 30kg on a petrol car it hurts it a little bit, but put 30kg on a diesel and it makes no difference, because it's got so much torque.

Now SEAT has gone, though, I can't see a privateer running the cars. Look what happened with the works team, how unreliable they were, so who would want to run them as a privateer team?

Q You will be going into your third year with the BMW in 2009. How difficult was it to develop?

We initially had a few problems because we've done so many years of front-wheel drive, and then the car's been developed on Yokohamas for World Touring Cars, so we had to re-dial it for Dunlops. But we still got pole at the first ever race!

The first year we ran with a sequential six speed, but this year we've had the H pattern, due to pressure from my engineers, which I'm still not convinced about. There's a 30kg weight saving [with the manual] so if you run a six-speed sequential you have to carry 30kg extra. But the H-pattern can be a problem, as we saw at Brands Hatch when Stephen [Jelley, who was starting from pole] tried to shift too quickly and went from second to fifth. It's too easy to do that, but with a sequential you can't get it wrong. I'd love to go back to the six speed.

Q Is there anything new for West Surrey Racing in 2009?

We've built up a third car and we're looking at running that as well. We're not sure if that will be in the RAC colours yet, though. We're looking at having a co-sponsor, so maybe we will have it orange with the co-sponsor on, or maybe white, or blue, or green, or yellow or whatever – although I would like to have three cars looking the same.

Q WSR spent many years as a Formula 3 team. Would you like to get involved in F3 again?

We were approached by two manufacturers to help them sort their cars out, but they didn't really want to spend the money. I said we've got to have a free hand and we've got to have a good budget, then we'll do a good job, because we go through and analyse things methodically – every part of the car. But when someone is given a design brief they're briefed to make sure it's a cheap car to produce, but that often doesn't work.

As far as running cars goes then, not so much F3, but I would like to look at another single-seater category, and we enjoyed A1GP in the early days.

If we did go back to F3, though, as I joked with someone recently, my two ex-employees – Boyo (Anthony Hieatt) and Trevor Carlin – are both now running F3 teams, so if I try to beat them I might struggle, because they've both worked for me!

Dick Bennetts, managing director, West Surrey Racing
- **1981:** joined new West Surrey Racing F3 team as race engineer from Ron Dennis' Project 4 team, winning title in first year.
- **1992:** took over West Surrey Racing
- **1996:** switched from F3 to BTCC with Ford, then Honda and MG, and BMW since 1997

RACE MOVES

Steve Hallam, McLaren's head of race operations, is to leave the team to take on the role of director of race engineering with **Michael Waltrip's** NASCAR team. Hallam has had a 27-year career in F1, working for Lotus as a race engineer before moving to McLaren in 1990.

LAT
Steve Hallam

The chief engineer for Peugeot's Sportscar programme, **Paolo Catone**, is leaving the team. Catone, a one-time F1 engineer, was the chief designer of the 908 HDi, which finished second in this year's Le Mans 24 Hours, while he was also part of the team that designed the Peugeot 905, which won Le Mans in 1992 and 1993.

LAT
Flavio Briatore

Flavio Briatore is to take on a different role within Renault for 2009, while a team director is to be appointed to help with the day-to-day running of the Formula 1 team. Briatore will, however, still be heavily involved with the Formula 1 operation. At the time of writing there was speculation that **Bruno Michel**, who currently runs the GP2 Series, which is backed by Renault, was in contention for the team director's role.

Cameron Levick is the new chief executive officer of V8 Supercars Australia, replacing **Wayne Cattach** – who has retired – as the head of Australia's premier motorsport series. Levick has an impressive business background, coming to Supercars after a stint as a senior executive with Vodafone, while he has also spent time working with international drinks company Diageo.

LAT
Marc Gene

Ferrari is to keep both its current test drivers for the 2009 season, **Luca Badoer** and **Marc Gene** having had their contracts with the Maranello concern extended. Badoer has been a test driver with Ferrari since 1997, while Gene joined the team at the end of the 2004 season.

Scott R Smith is the new senior communications manager at O'Reilly Raceway Park (ORP), Indianapolis. He has been a part of the

RACE MOVES

NHRA team at ORP since February 2002, and before that was a producer for TV company ESPN.

Dan Brickey, who for 17 years was the NHRA's emergency medical services director, has passed away after a long illness. He was 58.

Richard Cregan, the Toyota F1 team manager who announced he was leaving the team

LAT
Richard Cregan

in September, will be joining Abu Dhabi Motorsports Management – the company behind next year's inaugural Abu Dhabi Grand Prix – as 'team manager'.

Peter Stayner, head of partner management at McLaren, is also taking on a management role at the new Abu Dhabi circuit. Stayner actually started his career in circuit management in the UK, first at Mallory Park, before going on to manage Snetterton and then Brands Hatch. He joined McLaren in 1989 after a stint at the RACMSA.

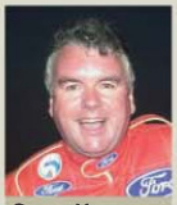
LAT
Gerry Hughes

Design and race engineer **Gerry Hughes** is the new technical director at A1 Team Ireland. Hughes brings a wealth of experience to the role, his cv boasting stints at Lola, Williams Touring Car Engineering, Prodrive, and then Formula 1 – with Jaguar, Jordan Red Bull and Super Aguri – for the past nine years.

Val Thompson has joined Richard Egger Insurance – the specialist motorsport insurance broker – having decided to combine her enthusiasm for the sport with her long-term career in the insurance industry.

Jay Frye has signed a multi-year contract extension with the Red Bull NASCAR team, putting to rest speculation that he was about to join the all-new Stewart Haas outfit. Frye joined Red Bull at the start of the 2008 season in the position of vice president and general manager.

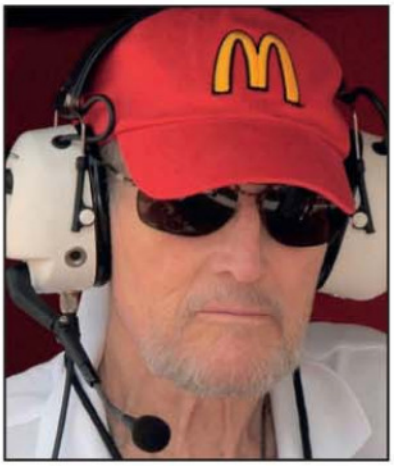
FIA deputy president for sport, **Marco Piccinini**, has announced he is to resign from his position in order to concentrate on 'other professional commitments'. His successor was to be elected in November. **Sean O'Connor** and **Ronan Morgan**, the co-founders of Rally Ireland, the country's round of the World Rally Championship, have stepped down from their posts as consultants to the event.


LAT
Ronan Morgan

Dieter Stappert the former head of BMW Motorsport, has died aged 66 following an illness resulting from a heart attack earlier this year. The Austrian was instrumental in bringing the Munich marque back into Formula 1 in the 1980s and was also involved with motorcycle racing following his departure from BMW in 1986.

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

PAUL NEWMAN OBITUARY


LAT

Paul Newman has died at the age of 83, after a long battle with cancer. While many will mourn the passing of a big screen great, the world of motorsport says goodbye to a team owner who, for over 30 years, has been a part of the very fabric of US racing.

Newman was also successful as a driver, famously finishing second at the 1979 Le Mans 24 Hours with Dick Barbour and Rolf Stommelen in a Porsche 935, 10 years after he was bitten by the racing bug after starring in the film *Winning*. He went on to race in a great many events, even competing in the Daytona 24 Hours in 2000 at the age of 75.

But it was as a team owner that he was to score his biggest racing successes, forming a partnership with Carl Haas to race in CART in 1983 – after he had overseen his own team running Lolas in Can Am (from 1977) prior to that.

Newman-Haas has since gone on to become one of the major teams in US racing, staying loyal to CART/Champ Car – and claiming eight titles – until the merger with Indy Car this year, with Newman taking a hands-on role, headphones in place, in the pits. It might not be as iconic an image as him playing Butch Cassidy, but it's surely the one that will live longest in the memory of those who will remember him for his involvement in American motorsport.

Paul Newman 1925-2008

LAT
Newman began his racing career as a successful competitor in IMSA GT saloon car races in the early '70s

DUNCAN DAYTON
THE INTERVIEW

LAT

Q What was your reaction to being given the Acura LMP1 programme?

We are thrilled with the opportunity. We were originally chosen by Roger Clarke as the lead chassis development team for the LMP2 car. It was a bit of a flyer as people did not know who Highcroft was. I told Acura then, 'We're not here to tell you how to win races, you guys are going to tell us how to do that. What we are here to do is execute your programme with the same attention to detail that you can see in our workshop.'

Over the last two years we believe we have earned the right to run the LMP1 programme. Now we look forward to working with HPD and Wirth Research. There's a great camaraderie and 'English mafia' that has permeated our team.

Q What difference will it make to Highcroft Racing to move up from LMP2 to LMP1?

We will fulfil a slightly different role with the P1 programme. De Ferran Motorsports is going to take on more of the chassis development role but we will still do some of it. From an engineering point of view we will probably take on a couple more people but the team size will stay the same. Obviously, the budget has gone up significantly, as will the testing miles to make sure we are prepared for Sebring on 15 March.

Duncan Dayton, Owner Patron, Highcroft Racing

- Studied architecture at the University of Minnesota, Masters in Design Studies at the Harvard School of Design
- **1989:** Founded Highcroft Racing, initially as vintage racing restoration and prep company
- Professional driver, including victories in ALMS and Formula Ford
- **2008:** winner, Grand Prix Historique de Monaco.

Q What are your feelings about the new ACO rules?

We are waiting to hear what the ALMS and IMSA are going to do as far as the new ACO rules are concerned. Some of the new safety regulations are probably a good idea, though. The problem the ALMS faces, in comparison with the ACO, is that the latter has one race every 12 months. In North America, with a 12-race series and very different circuits to Europe, the rules have a bigger impact. It is appropriate that IMSA reviews the ACO rules and then implements them in a way that benefits the series as a whole.

One of the exciting things happening in the ALMS is the P1/P2 battle. Given the twistier nature of some of the circuits, the P2s can challenge the P1s for overall victory. In my mind, for American racing, the best thing would be to have a two-class race, just prototypes and GTs. I don't believe the fans can tell the difference between the prototypes. In fact, many of the professionals can't. While I understand the concept of P1 being the domain of manufacturers and P2 the privateers, it does not necessarily reflect that way. It looks good in Europe with the larger car counts but here, because of Grand Am, these are smaller.

Likewise in GT, the average punter has been wondering why a Corvette does not race against a Ferrari or an Aston Martin against a Porsche. After all, they are all competing for the same showroom dollars.

It might be different if ALMS and Grand Am were unified as one series with a dozen great teams. However, I don't think it's going to get resolved any time soon and the change of name to NASCAR Sports Cars is not helping. We have more technology in our steering wheel than a NASCAR car has in its entire existence.

I believe in the power of the ALMS series. It has the most open rulebook anywhere in the world, which is why the manufacturers support it. There is nowhere else that you can compete against the great marques of the world in such unabated style.

FORUM

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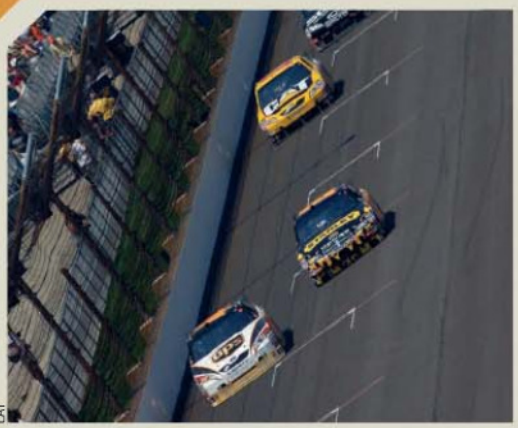


LAT

Revenge of the NASCRABS: are they creating toe in?

CATCHING CRABS

Regarding your engineering article titled Nascrabs in V18 N7, you have things a bit incorrect. They are not creating toe in and toe out. They are shortening the wheelbase on one side and then re-squaring the car. This gives the vehicle the static measurements of not only a different wheelbase on each side but, more importantly, means the rear axle centreline is effectively offset to the right of front axle centreline, when looking from the rear of the chassis. On left-hand corners, this makes the chassis tend to be freer from the centre and off. They have used this for years, but it is more evident now because of the body and chassis rules.

Dirt oval karts in the USA have used this for over 10 years. Many chassis have it built in, but the karts I used had an adjustable hanger for the bearing on the right side, which I used very often. Some tracks needed it more than others.

If you look at Dirt Late Models, under throttle, the left rear tyre is pulled forward to an extreme amount. They are doing the same thing, only dynamically, because of the extreme suspension movement. This is a very purposeful adjustment. I first learned of this technique 20 years ago, when I went to a set-up school held at Mark Richards Racing by an AFCO engineer. This is more prominent on solid rear axle cars, but it can be used on just about anything. You should have someone do a set-up article in the future. It is only one aspect of chassis set up that racers can use in their tool box.

Thanks,

Mike Grady
South Charleston, West Virginia, USA

FORUM CONTINUED

LAT

Dimples - are they cute or simply a load of balls?

INERTER OR NOT?

The inerter does *not* reduce cyclical suspension movement. It has the same effect as adding mass to the sprung elements without an increase in actual weight. It thus lowers the suspension frequency, despite the fact that the high spring rates (needed to control ride height against high levels of downforce) would otherwise produce very high bump frequencies.

Perhaps then it is best to be clear about what the inerter is not. It does not resist linear deflection like a spring. It does not resist linear movement like a damper, but it does resist linear acceleration, so it can be seen as adding what I call 'virtual mass' to the system. The effect will be small, but small gains are just what everyone in F1 is chasing.

For the sake of argument, imagine an F1 car fitted with huge inerters. The suspension would still be very stiff in bump and ride height would reduce only a little, even as downforce tripled the vertical loads on the car. At the same time, the huge inerter would make the vehicle ride over bumps as if it was a 1960s' Cadillac

Peter White
via racecar-engineering.com

NATURE'S DIMPLES

Regarding the article on dimpled aerodynamic surfaces on your website, it's just a question of skin friction drag vs form drag. For bluff bodies, like golf balls, form drag is dominant. For wings below stall, skin friction drag is dominant, so dimples will increase drag. For separation control dimples may work. You can see our explanation here: www.soton.ac.uk/ses/outreach/greenpower/boundarylayers

It's basic fluid mechanics for any engineering student! Shark skin riblets, however, operate differently – they actually affect the boundary layer behaviour close to surface, which is much more complex. Shark skins are also compliant surfaces, so react to the flow. All potentially great gains, but difficult to engineer. Nature is ahead of us yet again.

Dr Kenji Takeda
University of Southampton

GRAVEL TRAP

The real cost of change

SAM COLLINS

It's all a matter of timing. Time something right and it can be fantastic, time it badly and the exact same thing can be an utter disaster. Motorsport is fully aware of this truism, yet often ignores it, continuing on in its own little insular bubble.

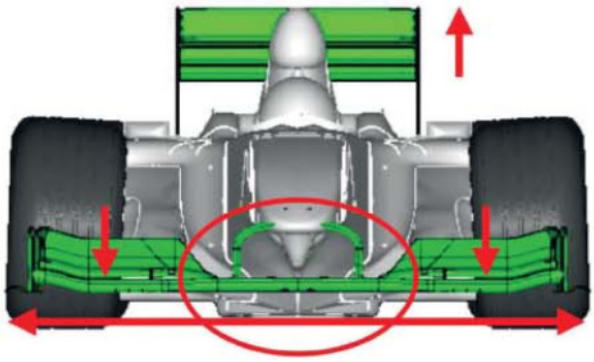
> "the simple fact is, rule changes are expensive"

We are all fed up with hearing about how uncertain the economic future is, which bank has been bailed out today and silly media phrases like 'credit crunch', but the fact of the matter is, money's a bit tight generally at the moment. So introducing cost-cutting measures into motorsport makes sense, doesn't it? Well, at face value, yes. But history shows time after time that when motorsport rule makers have tried to cut costs by introducing new regulations, costs escalate.

An example is the introduction of the incredibly tightly regulated, 2.4-litre V8 engine formula into F1. Or in NASCAR, the arrival of the CoT, which seems to have led to a massive boom in advanced Stock Car technology. The simple fact is, rule changes are expensive - really, really expensive - and not just in professional racing but in club competition, too. The 750 Motor Club-run Formula Vee series in Britain introduced a new 'low cost' class B a short while ago, but what this meant was that everyone in the low-cost class had to spend rather a lot of money to comply with the new rules.

So, with us currently embroiled in what Barack Obama calls 'the worst economic crisis since the great depression', is now really a good time to change regulations? Formula 1, Le Mans, NASCAR Nationwide, WRC and a number of other series are all facing huge upheaval in the next 28 months, so I guess someone thinks this is good timing. But I'm far from convinced, for while a bit of an economic down turn may get rid of the dead wood produced by some totally unnecessary racing series, major upheaval could leave the industry very exposed, with teams facing huge bills for new cars and declining sponsor interest. That is not a great recipe for the sport's long-term future, whereas stability of regulations is.

The law of unintended consequences really is true, and right now I believe motorsport is heading toward a very risky place. Timing, as they say, is everything in this life.



Keep the regulations as they are and save money, or change regulations to cut costs?

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LATE APEX

Of sticks and carrots

Following what almost seems to have become a tradition of launching race weekends on a controversial note, the FIA announced unexpectedly on the Friday afternoon of the Chinese Grand Prix that it was to open the tender process for a standard Formula 1 engine and transmission, to be used from 2010 to 2013.

In the wake of the predictable pandemonium that erupted in the Shanghai paddock and elsewhere, an FIA spokesman issued a clarification: 'The provider will set out a detailed design and will either provide engines in full working order or the designs to allow competitors to build their own standardised engine. 'Where competitors choose to build all, or part, of their standardised engine, the appointed provider will assist the FIA in ensuring all engines and parts have been built in accordance with the appropriate design and (the engine) conforms to a performance output in a prescribed range.'

This would appear to be a more palatable proposition than the original media stories seemed to suggest – that Formula 1 teams would all use exactly the same engines from 2010, and only the names on the cam covers would differentiate them. The fact teams would be able to produce the engines themselves if they chose, but to a tightly prescribed specification, would likely be marginally more acceptable to the manufacturer-backed squads than if they were faced with the prospect of simply bolting a standard engine/transmission package, provided by an FIA-contracted outside supplier, into their chassis.

> **Max Mosley likes to indulge in a degree of theatre when it comes to Formula 1 announcements**

There is no doubt Max Mosley likes to indulge in a degree of theatre when it comes to making Formula 1 announcements, and there was undoubtedly a large element of 'stick' rather than carrot attached to this one as he headed into a significant post-Chinese Grand Prix meeting with FOTA members concerning the thorny issue of cost-cutting in the sport. Even so, the fact that tenders have now been called for the 'standardised' engine and transmission seems to suggest Mosley and the FIA are serious about the strategy and not simply using it as a way to focus team principals' minds in the upcoming discussions.

Much of what has transpired in Formula 1 in the last few weeks seems to have been clearly presaged by the comments of FIA technical consultant Tony Purnell in the exclusive interview published in the November issue of *Racecar Engineering* (V18N11). And at this point, it's worth reminding ourselves of one or two of his more pertinent remarks:

- 'I see Formula 1 steering towards much more restrictive rules so that the areas of technical development are more isolated, but somewhat relevant to society.'
- 'I don't see Formula 1 becoming [a spec series]. I don't think that is on the cards, as some form of technical competition is part of Formula 1's DNA.'
- 'These are crisis times for the automotive industry. [Vehicle sales are down] and they've got to tackle the huge cost of reducing CO2 emissions, so having manufacturers pull out of F1 strikes me as not that improbable. I see the next few months, responding to Max's call to lower costs, as very important. We have to reduce costs for the manufacturers or they'll leave, and we have to reduce costs for the independent teams, or they won't be able to survive.'

As a closing observation in this rapidly evolving story, with the possibility of a single specification Formula 1 engine and gearbox in place from the beginning of the 2010 season, those teams that have succeeded in developing effective KERS packages – unless there is a decision to opt for a standardised system – may find a competitive advantage. So watch out for efforts to be re-doubled in this area over the coming months.

To keep up with the latest developments in this story, and all other F1 technical news, make a point of visiting www.racecar-engineering.com

EDITOR
Graham Jones

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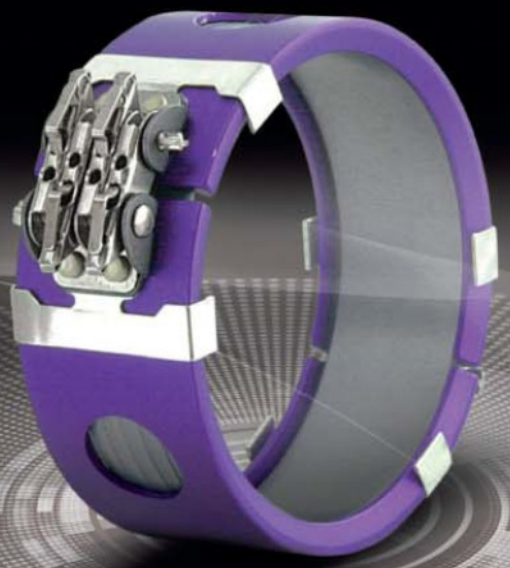

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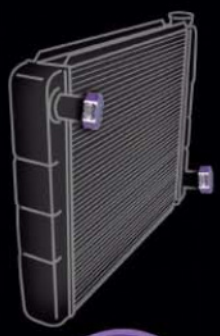

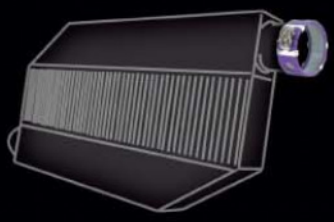

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