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EXCLUSIVE

McLAREN F1 SECRETS

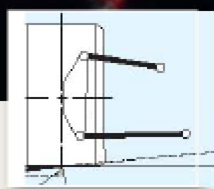
WE DELVE INSIDE THE TEAM'S INNOVATIVE TECHNOLOGIES

Nature's composite

The pros and cons of wood in racecar construction

Bruce Ashmore

Former Lola man on winning design and life in America



Anti effects

Mark Ortiz adds his views to this controversial subject

OFF SALE DATE 11 TH SEPTEMBER

Fiddle brakes. You wouldn't normally think of the simple, mechanical lever system used by the drivers of trials cars to apply braking force to one or other rear wheel independently in order to turn more tightly as having much to do with modern Formula 1 cars. As we reveal in this month's exclusive look at some of McLaren's notable technical innovations of recent years, however, the fiddle brake concept is the same as that behind the brakesteer system used to advantage by the Woking team on its cars in the late 1990s. Also under the 'McLaren Secrets' heading, we bring you inside stories on the use of aluminium beryllium, the team's Mercedes-developed KERS and the creation of the McLaren MP4/23, which carried Lewis Hamilton to the World Drivers' title in 2008. It's not often one is given the opportunity to part the 'technical curtains' at McLaren, and *Racecar Engineering* extends its sincere thanks to the team's design and development director, Neil Oatley, and press officer, Steve Cooper, as well as Wolfgang Schattling and Frank Reichert at Mercedes-Benz Motorsport, for their invaluable assistance. This month's issue isn't solely restricted to Formula 1. It also contains a typically thorough Forbes Aird feature – in this case, on the use of wood as a racecar construction material – plus a response from Mark Ortiz to the views of fellow contributor, Danny Nowlan, on the subject of 'anti' effects. In addition, there is a full report on the enthralling Formula Student event that took place recently at Silverstone, an interview with former Lola designer, Bruce Ashmore, and comment from Peter Wright, Nick Daman and Chris Aylett.

EDITOR
Graham Jones

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FORMULA 1

Stage set for FIA election showdown

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Opening exchanges: Mosley backs Todt, Vatanen wants reform

THE RACE FOR the presidency of the FIA looks set to be contested by two of the sport's most high-profile names, with former World Rally Champion Ari Vatanen going head to head with ex-Ferrari F1 boss Jean Todt.

Vatanen confirmed he was to stand for the post at the German Grand Prix, while Todt made his intentions clear a week later, and the opening exchanges suggest that Vatanen is to stand on a manifesto for change within the FIA and the way it is run, while Todt will represent the old, Max Mosley-led order.

Unsurprisingly, Mosley was quick to lend his support to Todt, stating in a letter to FIA clubs before Todt announced his intention to stand that 'Jean is unquestionably the outstanding motorsport manager of his generation, arguably of any generation... If he agrees to stand, I think he would be the ideal person to continue, but also to extend the work of the past 16 years. He can be relied on in all areas where the FIA is active. I very much hope you will give him your support.'

THE TODT ANGLE

For his part, Todt – who ironically was Vatanen's boss when the Finn drove for Peugeot in the '80s – has made it clear he will carry on with the Mosley agenda, the Frenchman saying: 'It is my intention to continue and expand the outstanding work of president Mosley who, for 16 years, has worked tirelessly to strengthen the FIA's major motorsport championships and to position the FIA as the voice of the motoring public, actively promoting safe, clean and affordable mobility for all.'

THE VATANEN ANGLE

Meanwhile, Vatanen, who until recently has worked as an MP in the European Parliament, warned that Todt is too close to Mosley, and would not in fact represent a real change at the head of the FIA. 'They are very close friends and worked closely together when Jean was at Ferrari and Max at the FIA. But that can also turn out to be a handicap,' the Finn told the *Associated Press*. 'You need a new star, an independent person who represents change. The fact that he [Todt] has FIA support may somewhat distort the situation, but I'm not worried. When the wind starts changing, it does change.'

The election will take place in October and is decided on the votes of FIA general assembly members, of which there are 200. Mosley will not be standing for re-election.

THE CONTENDERS

Todt: favoured by Mosley

LAT

JEAN TODT

Background: former World Rally co-driver and boss of Peugeot Talbot Sport, masterminding championships in World Rally and World Sportscars, plus two Le Mans wins. Joined Ferrari in mid-'90s and oversaw record breaking Schumacher years.

FOR: one of the most successful motorsport managers in the business.

AGAINST: not popular with many in F1, which might make negotiations difficult.

Vatanen: for change

LAT

ARI VATANEN

Background: Spectacular rally driver with 1981 World Rally Championship to his name. Survived near-fatal crash in 1985 and went on to compete regularly in Paris-Dakar. Elected to European Parliament in 1999 and 2004, but not re-elected in 2009.

FOR: Popular 'racer' with agenda for reform. Experienced politician.

AGAINST: the voting system already in place could favour Todt.

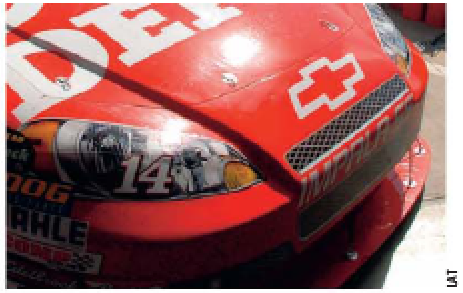
SEEN WINGING IT

LAT

ART ran its cars without the top element of the rear wings at the Norisring round of the F3 Euro Series. The move was protested by a rival, but was deemed to be within the regulations, which state that the rear wing end plates must be big enough for the official numbers. The team simply folded the sticker around the edge of the end plate... ARTful, eh?

NASCAR

Old names out, new names in?



General Motors is cutting back heavily on its racing budget

LAT

GENERAL MOTORS' RECENT bankruptcy protection and reorganisation will have immediate impact on all three NASCAR series, but it seems the Nationwide and Truck Series teams were hurt more than the Sprint Cup, as Chevrolet-backed teams were notified they would be losing all financial backing from the manufacturer. The major teams affected include Kevin Harvick Inc, Rusty Wallace Inc, ThorSport and JR Motorsports, though it is understood engineering help will continue to be given to some of the teams, including wind tunnel time.

The Sprint Cup teams of Hendrick Motorsports, Richard Childress Racing, Earnhardt Ganassi Racing and Stewart Haas Motorsports have all had their sponsorship cut back, but team sources remain tight lipped as to how far the cuts went.

The move follows the news recently that the two remaining Cup Series Dodge teams – Penske Racing and Richard Petty Motorsports – have not been receiving their scheduled sponsorship payments from the manufacturer, who also recently filed for bankruptcy protection. From that RPM laid off 11 members of staff and cut employees' wages. A possible reduction from four to three teams could also be on the horizon.

Dodge cut its backing totally in the Nationwide and Truck Series at the end of last season and Ford followed suit with the Truck Series over the winter. Kevin Harvick Inc also laid off a handful of employees after the GM cuts were made known.

Other manufacturer changes that have been floating around the garage area include Red Bull Racing – whose contract with Toyota is up at season's end – and who will be switching to Chevrolet and leasing engines from Hendrick Motorsports. Earnhardt Ganassi Racing (EGR) could lose its backing from Chevrolet, resulting in either a disbanding of the team or a switch to Toyota likely at the end of the season. There are also rumours that with the departure of Martin Truex jr from EGR, should Ganassi have a team remaining for Juan Pablo Montoya, Ganassi will move it to his Indianapolis facility with his Indy Car and Grand Am teams.

Meanwhile, NASCAR chairman Brian France jr hinted that the organisation is willing to look at foreign manufacturers entering the sport. 'We have been talking to people off and on for a long time,' he said. 'These are decisions in terms of a new manufacturer joining the sport that would take a long time to evaluate and actually enter. It's not something where we just flip a switch and it would just happen. Clearly, there are some companies that are going to look at opportunities that have not been there in the past. It is under a very clear set of circumstances that manufacturers come to NASCAR to compete and that will not change.'

Since Toyota – who could now be seen as the strongest among the manufacturers involved – joined the sport in 2004 there have been rumours of Nissan jumping into the NASCAR circle, but earlier in the year a source close to the manufacturer's racing division said the idea had been shelved.

One would have to surmise though that for other manufacturers to become involved NASCAR would have to do some tweaking of the current car to make it more identifiable to those seen in showrooms. But maybe, just maybe, that might be around the corner...

BRIEFLY...BRIEFLY...BR

FORMULA 3 TO FOUR

The chassis life of Formula 3 cars is set to be extended to four years, after a decade in which the chassis homologation has gone in three-year cycles. The cycle of the current cars that were introduced in 2008 was due to cease at the end of 2010, but this will now end in 2011, with new designs hitting the track for the 2012 season. Conveniently, this also fits in well with the FIA's desire to launch a global race engine across a variety of series that year.

JOBSEEKERS UP 50 PER CENT

Motorsport recruitment specialists in the UK are reporting seeing an increase of around 50 per cent in the number of skilled people looking for work since the downturn in the economy kicked in a year ago. For the full story, see Race People p88.

GP3 HITS TRACK

The car for the all-new feeder series for GP2 – predictably enough called GP3 – has successfully completed its first tests. The Dallara-built spec car, powered by a 280bhp Renault engine, was shaken down by current GP2 ace Romain Grosjean. Meanwhile, series organiser Bruno Michel has claimed there are 41 teams interested in the 10 available entries (each for three-car teams). Michel has also said he plans to keep the budget beneath the cost of Euro F3.

GOODRIDGE EXTENDS

Goodridge celebrated its 40th year in business on Monday 13 July, with the opening by Sir Stirling Moss, of the new £500,000 extension to its headquarters near Exeter Airport. Sir Stirling also opened the original factory, on the same site, 20 years ago

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Electric FSAE camber car from Cal Poly
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CAUGHT!

Carl Long, independent Sprint Cup car owner and driver, and his crew chief, Charles Swing, have been a fined a NASCAR record of $200,000 (£121,400), suspended for 12 races, and penalised 200 points when the primary engine for the non-points Sprint Showdown at Lowe's Motor Speedway during May was found to be oversized. Swing was also admitted to hospital with a heart condition during the same week. 'We purchased an ex-Ganassi engine from Ernie Elliott at the beginning of the season,' explained Long, who appealed the decision to the National Stock Car Commission, but only had his suspension limited to the Cup Series so he can continue to work in the Nationwide and Truck Series. 'We overheated the engine in practice and had to change it. We had the option to withdraw and go home before submitting it to inspection, but trusting that our blown engine wouldn't have any problems passing NASCAR tech, we submitted it and put our other motor in the car to get ready for the Showdown.

> "The .17 is as wrong as if it would have been 400 cubic inches"

'The rules are 358 cubic inches (350 with an eight cubic inch tolerance) and ours is 358.17 cubic inches. The .17 is as wrong as if it would have been 400 cubic inches. This engine is 50 horsepower less than top teams, but it was all that could be afforded. I would have never knowingly gone to the race track with a big engine! This suspension has not only stopped me from racing, it has also hurt me with my every day job (car chief and spotter at Front Row Motorsports). I don't consider myself a cheater. I am addicted to the worst drug ever… racing!

'Every dime we have been able to scrape up we use to race because we love the sport. It takes about a half million in equipment to be able to build an engine, so I have to rely on other people and this time it bit me.'

Adding insult to injury, Long detonated his secondary engine during the Sprint Showdown when a mechanic installed the in-line oil filter in the wrong direction, starving the engine of oil. The fine should be paid by Swing by the end of the year, if not it falls to the car owner, but neither will get a 2010 licence until the fine is paid in full.

FINE: US$200,000 (£121,400)
PENALTY: 200 POINTS, 12-RACE SUSPENSION

REGULATION

WRC tech regs get thumbs up

Revised regulations for rallying's top category receive positive reception

THE FIA WMSC response to economic and environmental concerns has resulted in numerous rule changes in the World Rally Championship.

The restriction to one tyre type remains, but a choice of compounds will be considered. Additionally, a single fuel supplier is to be considered. The proposed introduction of the turbocharged 1600cc engine has now been brought forward to 2011, while the plan for naturally aspirated 2.0-litre Super 2000 cars to run as WRCs has now been canned. Instead, a 'WRC Cup' for Super 2000 cars will be introduced for 2010.

The regulation blueprint for these new World Rally Cars is based on the philosophy of the existing Super 2000 formula, with restricted electronic sensors and controls and a four-wheel drive system using exclusively passive limited slip differentials. Externally, the new cars will use a re-designed rear aerodynamic device.

BP Ford team boss Malcolm Wilson is positive about the changes: 'There's still a lot of detail to come, but in principle we're happy. The turbocharged 1600cc engine ticks all the boxes. Environmentally, smaller engines with forced induction are the way all manufacturers are going.'

The new formula is welcomed broadly by top team engineers, with the proviso that the WMSC's edict is 'in principle' and that pertinent details of the new regulations are yet to be decided.

Ford's chief engineer, Christian Loriaux, explained he can see 'no real point' in thinking deeply about the new 1600 turbo engine rules until the actual detail is known. While praising the initiative behind the capacity change, Loriaux is adamant that the engine should be based on a production unit, going on to suggest minimum weights for internal components.

'Manufacturers want to show the ruggedness and design expertise in their products and this is the best way to do it. While there is no turbo 1600 planned for the Fiesta (Ford's proposed new WRC car), there is a suitable 1.6-litre base engine, which we would be able to turbocharge in a similar way to the 2.0-litre World Rally Car,' he explained.

However, while such a 'follow-on' option is generally assumed, it is not yet detailed in the new regulations. Nor is the method of controlling power outputs. Current WRC engine output is controlled by a physical restriction in the inlet tract, and Loriaux points out that by forcing intake air speed to become supersonic above a certain rate this way, thereby rendering it unusable and potentially damaging, this 'naturally' restrains the engine output and rpm: 'I hope this is the way we have to go,' he says.

The Ford engineer went on to say how he felt teams should be able to alter the material specifications for the crankcase and head castings, and that he is concerned over the recent trend to increase the minimum weight of the 2.0-litre S2000 cars, in a bid to rescue parity with Group N.

Ford/M-Sport has already built a 2.0-litre, normally aspirated, S2000-specification Fiesta, which Loriaux says 'goes well but is down on overall power, particularly torque at lower engine speeds… The 1600 turbo would be quicker than a Super 2000 – and that's the idea. Make the rally engine more relevant to the trends in the motor industry, while it provides cheap, well-controlled grunt.'

World champion, Citroën Racing's Sébastien Loeb, also approves of the new engine regs: 'Obviously, there is still a lot of detail to come, like the power of the car. But for me it was important to keep the turbo engine. Without the turbo was not the best way.'

Of the turbo 1600 rules, Citroën's chief engineer, Xavier Mestelan-Pinon, had this to say: 'I'm an engineer. I'd prefer a bigger engine, of course, but the most important thing is the spectators, the people who buy our cars. Look at NASCAR, the cars are not up to much, but spectators love the racing and the cars.'

INDY CAR

Honda urges IRL to speed up rules debate

Japanese manufacturer is keen to get Indy rules finalised

HONDA'S PRESIDENT OF performance development, Erik Berkman, has called on the Indy Racing League to decide on its future chassis and engine rules by the end of this year.

Talks on the future of the series have been ongoing (see V19N8), but Berkman has said future plans need to be finalised this year if all those involved are to have cars and engines ready for the changes by 2012.

'If we get into the first quarter of next year and it continues to draw out,' Berkman said, 'we won't be able to do it for 2012. We need to know by Christmas so we can put plans in place and budget for it accordingly.'

The main stumbling block remains the question of what engine configuration to use, with Honda keen on a six cylinder and other manufacturers wanting four, but Berkman says Honda would be willing to discuss an equivalency formula of some sort.

Meanwhile, the IRL has announced changes to its aerodynamic rules in an effort to spice up the racing at its oval events. The tweaks, which come in the wake of some lacklustre encounters recently – particularly the Richmond race, where the top two finishers apologised to the crowd for the lack of race action – include tyre ramps and sidepod extensions.

IRL competition president, Brian Barnhart, said it was vital that the series restored its reputation for close racing. 'We have always prided ourselves on doing our best to create the most entertaining and compelling on-track product in motorsports, and I think in the last several years – especially with this version of the racecar – we've been very successful in achieving that.'

CAUGHT!

NASCAR Sprint Cup team Earnhardt Ganassi Racing has been fined and penalised for rule violations that came to light during the post-race inspection at the Chicagoland race. The no 1 Chevrolet, driven by Martin Truex jr, finished 16th in the race, but NASCAR found that the car's right rear quarter panel was too high. As a result, crew chief Kevin Manion was fined $25,000 and placed on probation until the end of the year, while car owner Teresa Earnhardt was docked 25 owner points and Truex 25 driver points.

FINE: $25,000 (£15,150)
PENALTY: 25 DRIVER AND OWNER POINTS

Randy Hood, crew chief for the no 1 Chevrolet driven by Danny O'Quinn jr in the NASCAR Nationwide Series, has been fined for rule violations discovered at Daytona. Hood was fined $2500 after the transmission assembly in the Chevy was found to be under the minimum weight of 80lb.

FINE: US$2500 (£1,500)

Marco Sorensen was stripped of his Hungaroring Formula Renault Europcup win after his Motopark Academy car was found to be running with parts that did not conform to the regulations. The team is to appeal the decision.

PENALTY: DISQUALIFICATION

Four Audi A4s were excluded from the Zandvoort round of the DTM for weight-related infringements. The cars of Alex Premat and Timo Scheider did not get to the scales on time, while Markus Winkelhock did not have the mandatory 1kg of fuel in the tank and Christian Bakkerud did not weigh in at all.

PENALTIES: DISQUALIFICATION

INDUSTRY

Select Committee announced

MIA assists with submissions to influential enquiry into UK motorsport

FOLLOWING THE MIA'S successful Motorsport Industry in Parliament day in July, the organisation has been invited to assist with the submission of evidence to a House of Commons Select Committee enquiry into the motorsport industry. Specifically, the MIA will help companies present their written views.

'I welcome this excellent news, as it is the first time the motorsport industry has been privileged to present to a Select Committee,' says MIA CEO, Chris Aylett. 'This is a vitally important time, as new policies are being formed that will set the direction of government support for the future. We have worked hard to explain to Parliament the real, and successful, UK business that supports motorsport and to address their incorrect perception that we only supply Formula 1! I encourage all interested parties to contact us at www.the-mia.com for help with submitting evidence.'

The House of Commons Business and Enterprise Committee will carry out the enquiry, looking at the role of the sector in the wider economy, assessing the effects of the recession and the effectiveness of current government policies. The enquiry will also study the role universities and academic research play in supporting motorsport, examine how engineering excellence can be maintained and review the role of motorsport SMEs. Where barriers exist to innovation, it will see what can be done to overcome them.

House of Lords event has led to MIA involvement with Select Committee enquiry

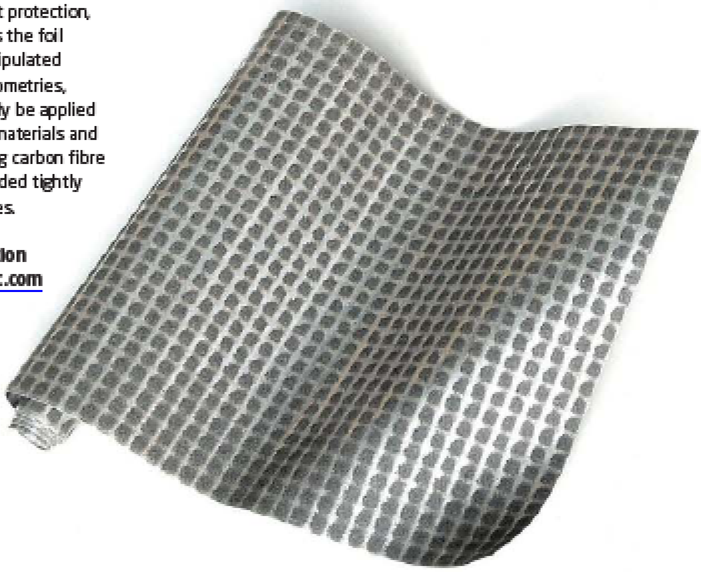
THERMAL BARRIER

ZIRCOTEC ZIRCOFLEX

THERMAL MANAGEMENT SPECIALIST Zircotec has developed what is believed to be the first ever flexible ceramic heat shield material. The new lightweight ZircoFlex product offers a robust solution to the problem of providing thermal protection to vital engine and electronic components.

The ceramic material is sprayed in the form of thousands of individual 'platelets' on the surface of the foil. While they are close packed to provide comprehensive heat protection, the structure allows the foil to be bent and manipulated to suit different geometries, meaning it can easily be applied to a wide range of materials and substrates, including carbon fibre and can even be folded tightly through 180 degrees.

For more information visit www.zircotec.com



SUSPENSION

SPAX TRACK SHOCKS

DRAWING ON 50 years of experience, UK-based suspension specialist SPAX has recently released a new series of steel-bodied dampers to complement its existing alloy-bodied TrakSPAX range. The range of dual adjustable, krypton gas-filled dampers can be specified in a range of configurations and lengths to suit applications from single seaters to Touring Cars.

All the internal components are common to the company's race-proven, aluminium TrakSPAX range, and incorporating both the bump and rebound controls into the 'valve block' has allowed SPAX to produce a very compact damper with an excellent stroke-to-body length ratio. Each unit is dyno tested before it leaves the factory and customers can return the units to SPAX for servicing and calibration.

For more information visit www.spaxperformance.com or call +44 (0) 1869 244771

DATA MANAGEMENT

MOTEC DHB MODULE

VEHICLE ELECTRONICS EXPERT MoTeC has released an innovative new module called a DHB (dual half bridge). It is a high current amplifier that allows low current auxiliary outputs, such as those in ECUs and dash loggers, to drive the high current loads required by motors and solenoids. The DHB contains two high current half-bridge outputs that provide both switched and pulse width modulated (PWM) functionality. These outputs can drive a single motor in two directions, or two motors in a single direction.

The DHB does not require software of its own, instead it works in conjunction with MoTeC's full range of ECUs and dash loggers. The parameters for speed control, direction control or servo control are set up using the respective ECU Manager or Dash Manager software.

For more information visit www.motec.com.au

Small steps

We investigate the iterative design process behind McLaren's 2008 winner

BY SAM COLLINS

It was a showdown in Brazil at the end of an action-packed season, and predictably it was a thriller. The 2008 Formula 1 World Championship was decided with only a few hundred metres to go – Lewis Hamilton took the title in his McLaren-Mercedes MP4/23 after a season-long battle with the Ferrari F2008s.

'The car was an evolution of the MP4/22,' explains McLaren technical director Neil Oatley. 'It was really just a case of optimising the aerodynamics.' The 2007 design was a race winner and nearly took both titles that year, so it was a good starting point. A higher nose and revised airbox surround were the most obvious differences, but the front suspension was also re-worked and the wheelbase lengthened. Indeed, a number of teams went longer with their 2008 designs and that trend continued into 2009. 'The wheelbase change was purely an aerodynamic decision,'

LAT

TECH SPEC

MCLAREN MP4/23

Powertrain:

Gearbox: seven forward and one reverse gear

Semi-auto: yes

Driveshafts: McLaren

Clutch: multi-plate, hand-operated

Chassis: McLaren moulded carbon fibre / aluminium honeycomb composite, incorporating front and side impact structures

Suspension: inboard torsion bar / damper systems operated by pushrods and bell cranks and with double wishbone arrangements front and rear

Dampers: Koni

Electronics: McLaren Electronic Systems' control units with electronics for chassis, engine and data acquisition. McLaren Electronic Systems also supplies the electronic dashboard, alternator voltage control, sensors, data analysis and telemetry systems

Bodywork: one-piece engine cover, separate sidepod covers, separate floor section, structural nose with integral wing

Tyres: Bridgestone Potenza

Radios: Kenwood

Wheels: Enkei

Brakes: Akebono callipers and master cylinder

Batteries: GS Yuasa Corporation

Steering: McLaren power-assisted

Fuel cell: ATL

Engine: Mercedes-Benz FO 108V

Capacity: 2.4-litre

No of cylinders: 8

Max rpm: 19,000 (FIA regulatory limit since 2007)

Bank angle: 90deg

Piston bore (max): 98mm

Number of valves: 32

Fuel: Mobil 1 Unleaded (5.75 per cent bio fuel)

Lubricants: Mobil 1, newly developed 2008 formula for lower friction and better wear resistance

Engine weight: 95kg (minimum FIA regulation)

McLaren started the season with a shaped extension ahead of the sidepods and connected to the chimneys. This quickly grew in size (see left in Monza trim) and the whole assembly was revised for the high downforce Singapore Grand Prix, with the sidepod extension lengthened by around 100mm (as shown below left)

Photographs: LAT

reasons Oatley, and other teams' engineers echo this, explaining that longer wheelbases give the cars more stability and larger surfaces to work with.

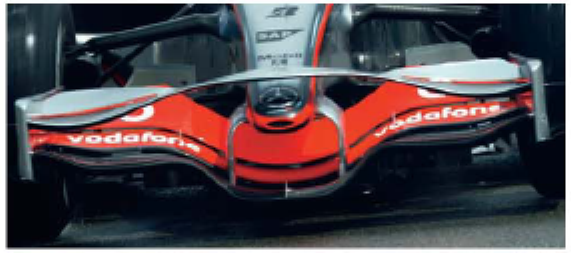
Design work on the new car started in March 2007, with the first chassis being constructed six months later, and from the first layout work until the car's launch it spent in excess of 3000 hours in the wind tunnel.

The car took to the racetrack for the first time at Jerez in Spain in early January, and in the lead-up to the season covered 14,275km in 21 days.

From the outset it was clear that the MP4/23 and Ferrari F2008 were fairly evenly matched and that it would be a tight battle between the pair to gain the upper hand technologically. By the first race, in March, in Melbourne, Australia the McLaren was already starting to feature new components, and countless further developments were integrated into the car's design throughout the season: 'It's difficult to pinpoint one area of the car where we made a particular jump,' explains Oatley, 'it was all iterative development. Of course there were a huge amount of upgrades over the winter, but we probably picked up more performance during the season. We constantly chipped away at every little bit. If you compare pictures of the car from every race you'll see loads of little aero bits appearing.'

> **"the wheelbase change was purely an aerodynamic decision"**

At Silverstone the cars ran with asymmetric radiator ducts. The team also introduced the small blades on the sides of the chassis ahead of the cockpit at the French Grand Prix (NB Ferrari and Renault also employed similar devices)



The front wing was an area where McLaren carried out major work, adding an increasing number of elements. By Silverstone (middle left) the wing had six elements, while at the Hungarian Grand Prix (bottom left) the count was up to seven, wth an extra slot in the rear-most element fitted under the car's nose. This wing was only used in conjuction with the 'dumbo' wings that appeared at the same race. The final iteration of the front wing on the MP4/23 can be seen on the next page

MP4-23 DEVELOPMENT

2006

NOVEMBER
The first design meeting for the MP4/23 takes place

2007

MARCH
Early layout work started

MAY
Wind tunnel work commences

SEPTEMBER
Drivers Lewis Hamilton, Pedro de la Rosa and Gary Paffett have provisional seat fittings

NOVEMBER
The first chassis is ready for bonding

DECEMBER
The car build process for chassis 1 begins

2008

JANUARY
The build process for chassis 1 is finished and the MP4/23 makes its track debut

CONSTANT TRICKLE

McLaren's approach varies from that of some of the other big teams in that it does not tend to do big package updates, rather a constant trickle of developments. 'We just put every little bit on as soon as we get it,' Oatley explains. 'Assuming it is not inter-related with other things, if you can get a part on one or two races earlier then why not do it? If you can get on little bits all the time, all of which make you a little bit faster, then your whole year performance must be improved. We just put bits on as soon as we are comfortable that they are quicker. With big package upgrades it's easy to see that the car has gone a second a lap quicker, and you know that's because you've put all those new parts on the car, but you may not know which are really worth it. We are looking at things that are potentially almost immeasurable as an individual change on the car, so you have to be certain that your data is giving you the right answers.'

With so many iterations appearing on the car over the year and with limited testing you might have imagined it would be difficult for the drivers to adapt, but the two McLaren pilots coped well, and there was minimal variance between the components run on each driver's chassis. 'Drivers are all slightly different, albeit more in the details,' explains Oatley. 'On the aerodynamic side it's not often that one driver varies to another in what they like. The exception to that may be on front wings where they are reasonably effected by the yawing of the car and the steer angle of the front wheels. Different wings and end plates can give different characteristics, and occasionally you'll find that one solution suits a particular driver's style more than another, but that is fairly rare. Anything rearward of the front wing is never really an issue. There was certainly not a big difference between our drivers during this period, but going back a bit when David Coulthard (DC) was driving for us, there were some more significant differences. The Finnish guys he was sharing with [Mika Hakkinen and Kimi Raikkonen] liked a looser car than he did. DC wanted it more neutral and that lead to some more differences.'

J-DAMPERS

During the season one of the things to be revealed was the application of the so-called j-damper on the MP4/23. This was believed at the time to be one of the team's secret weapons and team members referred to the device's capabilities in terms of 'zogs' – "we should fit an 18-zog j-damper", for example. It was said in some magazines and in the paddock that the j-damper was to make up for the loss of tuned mass dampers but, in reality, the 'j-damper' was the inerter developed by Professor Malcolm C Smith of Cambridge University and detailed in V18N9. In fact, according to Oatley, an inerter-equipped McLaren was nothing new: 'It goes back many years! I think we first had it in 2002, but it took a while for us to adopt it as a permanent feature on the car. We tested with it on the car for a year to 18 months before actually racing with it.'

Like the brake-steer system of 1997 (see p27) the use of the device came about by

At the German Grand Prix, the MP4/23 was fitted with the so-called 'anvil' wing, designed to increase stability in a lateral wind

NEIL OATLEY


LAT

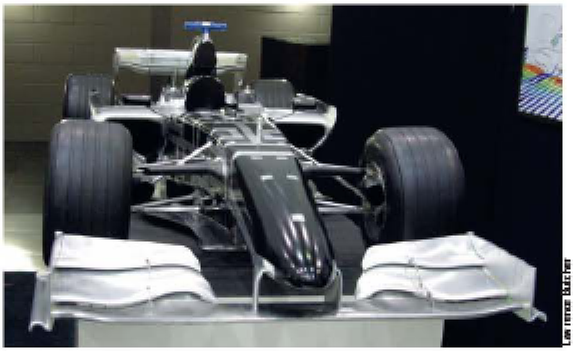
Neil Oatley graduated with an automotive engineering degree from Loughborough University in 1976. Late in 1977, Oatley, who was born on 12 June 1954, took a position in the drawing office of the Williams Formula 1 team as a design draughtsman, and during the seven years spent with the team he also assumed the role of race engineer.

At the end of 1984, Oatley was recruited to be the joint chief designer of the Force Formula 1 team and two years after that he joined McLaren. In 1988, he was promoted to chief designer, in charge of the design group for the following year's challenger, the MP4/5. His current role as design and development director has him overseeing the car specification and design programme, defining the specification for each race and supervising the build and approval processes for each new component used.

chance: 'It all came through a family connection,' explains Oatley, 'it was just something he [Professor Smith] was applying his considerable thought process to and thought it would be an interesting idea on the car.'

SUBTLE WEAKNESS

The battle with Ferrari throughout the year was a tense one, both on and off the track but, looking back, the McLaren may have had a subtle weakness. 'I don't think the car had any major vices, and it was reasonably good on all different types of circuit,' claims Oatley. 'However, one thing we didn't actually cure over the season was rear tyre wear. Our car was perhaps a little harder on them than the Ferrari.' Speculation on www.racecar-engineering.com suggested this was down to the fact that Ferrari may have been using the blended tyre gas detailed in V17N12 (50 per cent HFC R_40_4A with 50 per cent CO_2) but Oatley dismisses this. 'I don't think it was down to that. I think it was that on circuits where the tyres were closer to their durability levels or where they were more susceptible to graining we suffered a little bit more in terms of our race performance. It was something that was a bugbear for us and we never really got on top of.' However, as the saying goes, every cloud has a silver lining and this was no exception. Whilst


Lawrence Butcher

The MP4/23 model was subjected to thousands of hours of wind tunnel time. Note here it is in late 2008 MP4/23(K) spec with the 2009 wing

over a race distance the rear tyre usage put the Woking, UK-built cars at a disadvantage, in some circumstances it could actually help the team. 'On some circuits our one-lap performance was a lot stronger than that of Ferrari because we could light the tyres up more easily and qualify better, therefore getting a better race result, even if they [Ferrari] had perhaps a theoretically quicker race pace. Though the opposite could occur depending on the ambient conditions on the day.'

> "one thing we didn't actually cure over the season was tyre wear"

Following the end of the 2008 season the development of the MP4/23 did not stop. In fact, in some areas it increased as the car became a test bed for this year's chassis. Taking to the track with a revised front wing and, on occasion, with the Mercedes-Benz HPE KERS (see p24) the MP4/23(K), as it was now known, covered many more testing laps to prepare the team and drivers for the forthcoming MP4/24.

The MP4/23 was finally retired in January, when the MP4/24 was run for the first time in the Algarve. With six race wins, seven podium finishes and a Drivers' Championship to its credit, the car will undoubtedly take pride of place in McLaren's collection at its Technology Centre in Woking.

LAT

The final version of the MP4/23(K), also fitted with KERS. Note here the green dye coating for flow visualisation

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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Drag racing

The lesser-understood effects on drag of adjusting wing angles and ride heights

Photos: S McBeath

The Mansell Motor Sport EuroBOSS Benetton B199 being set up in the MIRA wind tunnel

The effects of adjusting wing angles on downforce and aerodynamic balance are well known, but it seems that the effects of these adjustments on drag are less well understood, even in some quarters of the specialist media.. So one of our topics this month is to look at the changes that occurred on the Mansell Motor Sport EuroBOSS Benetton B199 as the wing angles were altered during a half-day session in the MIRA full scale wind tunnel.

We'll start the session by looking at the rear wing. The moderately high, triple element downforce device seen in the pictures here was the sole rear wing that came with this Benetton package at the time of purchase. Though the end plates on the car offer a number of adjustment holes, the only ones that were compatible with the wing set gave just two alternative angles of attack, 26 degrees and 23.5 degrees. So while it wasn't possible to map the wing's 'lift slope', at least some idea of the car's sensitivity to rear wing angle could be gleaned, as table 1 below shows.

The baseline configuration had the rear wing at the steeper angle of 26 degrees, so relating changes to this, the lower angle created three per cent less rear downforce and 3.4 per cent less drag. Naturally, balance shifted more to the front as the rear wing angle was reduced.

In the case of the front wing the available adjustment was infinite within a range of 14-18 degrees, measured across the top of the whole wing at the maximum chord portion just inboard of the end plates, including the fixed Gurneys. Time being short, just three front flap angles were tested, the results shown in table 2.

A number of key points jump out from this table, but the general one that is often not appreciated is that in spite of the large changes to downforce and

TABLE 1

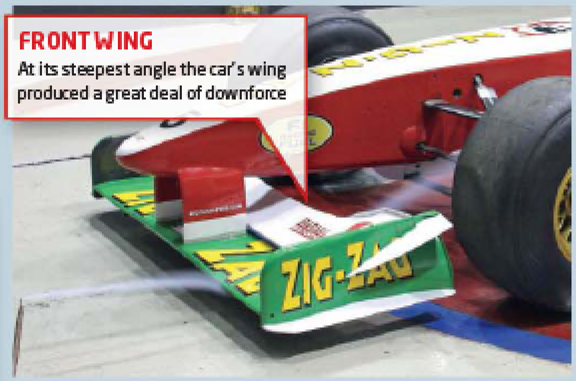
The effect on the coefficients of changing rear wing angle

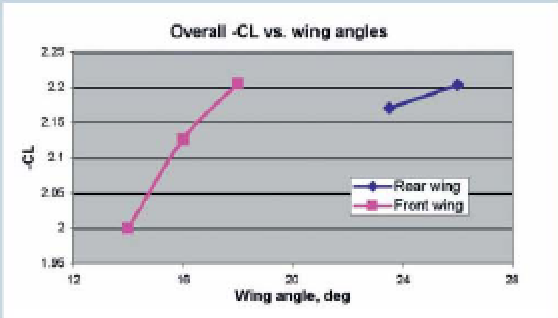
Rear wing angle	CD	-CL	-CLf	-CLr	% front	-L/D
23.3 degrees	0.978	2.170	0.894	1.276	41.18	2.219
26 degrees	1.002	2.203	0.889	1.314	40.35	2.200

TABLE 2

The effect on the coefficients of changing front wing angle

Front wing angle	CD	-CL	-CLf	-CLr	% front	-L/D
14 degrees	1.000	-1.999	0.571	1.428	28.56	1.999
16 degrees	0.999	2.126	0.746	1.380	35.10	2.129
18 degrees	1.000	2.205	0.873	1.332	39.58	2.205





Overall downforce (-CL) vs wing angle for the front and rear wing adjustments carried out in this session

balance that front wing angle sweeps achieve, the drag barely alters. Overall drag is rarely governed by the first thing the air encounters and, in simplistic terms, what the front wing doesn't extract from the airflow the rest of the car downstream from it will. In practical terms it means we don't have to worry about directly inducing extra drag by running more front wing, although in maintaining a balance, more front wing generally means more rear wing, which does add extra drag.

The other obvious point is that the front wing's downforce contribution changed significantly with quite small angle changes, something that is even more evident when looking at the plot of front and rear wing angle adjustments in figure 1. Given that adding front downforce reduced rear downforce, small changes of front wing flap angle altered the aerodynamic balance significantly. In fact, just half a degree of wing flap made over one per cent difference to the balance, which explains why fine tuning front wings is a good idea.

RIDE HEIGHT CHANGES

Moving on to ride height changes, there was only time to look at one (large) adjustment to front and rear ride height, but the results were thought provoking, as table 3 demonstrates. The wings were at their maximum angles in each case here, and the ride height reductions were measured as if at the axle lines.

Dropping the front ride height produced less front and less overall downforce, together with more drag. In fact, this was the highest drag figure seen during this session. This is obviously not what one would ordinarily expect, but there seems to be a simple explanation. The front wing had already been lowered by 17mm, as discussed in last month's issue, a change that produced a small gain in front downforce and a very small increase in drag. In the context of the discussion here, how do these drag increases from ground clearance reductions fit in?

The obvious answer is that by dropping the front of the car by a further 12mm (which equates to more at the wing) the wing had been lowered further into the wind tunnel floor's boundary layer, which would see a reduction in the energy of the flow under the wing. This, in turn, means there would be less downforce increase than might have been expected, and that as the wing was lowered further it was probably stalling. This would explain the loss of downforce and the increase in drag. We can see from figure 1 that the front wing's lift slope was already beginning to tail off at its steepest angle before the two height reductions, and would then be prone to stall as the flow beneath it became less energetic.

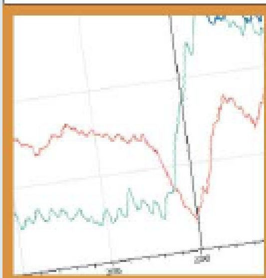
This is not to say the wing (and underbody) would suffer these problems on track. There, although the front wing would be more sensitive at lower ground clearances, it would not be because of a boundary layer near the ground. In fact, there could well be efficient gains to be had from running the front at reduced ride height. But this was a useful lesson in seeing why certain aspects of low ground clearance aerodynamics can't be properly quantified in a fixed floor tunnel.

TABLE 3

The effects on the coefficients of ride height adjustments

	CD	-CL	-CLf	-CLr	% front	-L/D
Previous configuration	1.003	2.244	0.886	1.359	39.48	2.172
Drop front by 12mm	1.042	2.214	0.853	1.361	38.53	2.124
Drop rear by 12mm	1.024	2.219	0.842	1.377	37.94	2.167

Many thanks to Kevin Mansell at Mansell Motor Sport



FIRST PRINCIPLES

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

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

Data management

Using Windows file structure intelligently to better control your racecar data

With the large numbers of sensors used these days and the need to do system checks on a regular basis it is easy to generate a massive amount of data during the course of a race weekend or test. Correct management of this data ensures it will be easy to find in the future, and also enables multiple datasets of the same type to be loaded simultaneously.

This Databytes will show how procedures can be established to catalogue and store data for easy retrieval, as well as some tips and tricks that can be used to assist this. Please note that many different avenues are possible using this technique and that this represents just one way of storing data. It should also be noted that this article assumes that a Windows XP environment is being used.

DATA STORAGE

File management in its most basic application can simply take the form of intelligently creating your Windows file structure.

All data systems provide the option of how to store data on the user's computer. Figure 1 shows an example of the configuration screen of a data system where the data should be stored on off load.

Here we can see that a default location of D:\Data has been specified (a partition of a drive so we are not using the same drive as the OS), and then the rest of the storage path and file structure is defined based on a number of variables. We see that a series of '\' are used to create new folders within the Windows folder structure.

Choosing our track name (see figure 2), we can again be sensible and exploit the useful

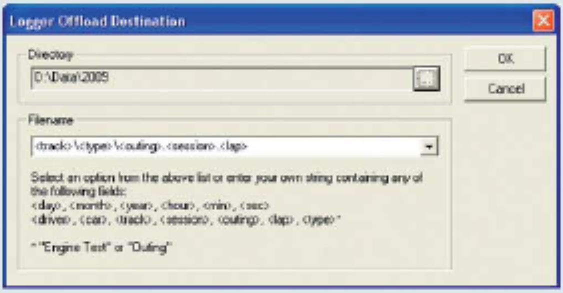


Figure 1

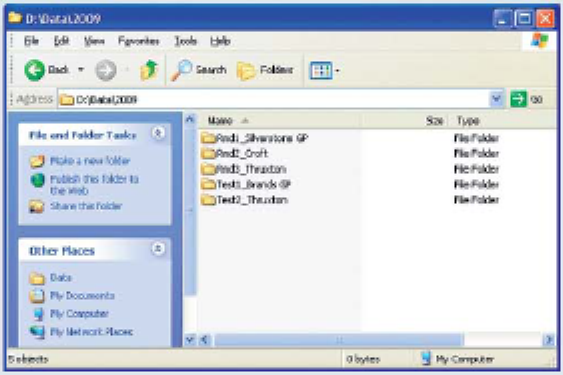


Figure 3

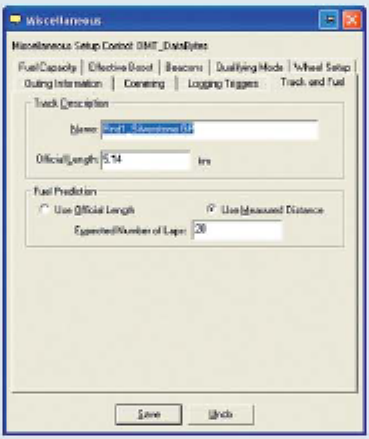


Figure 2

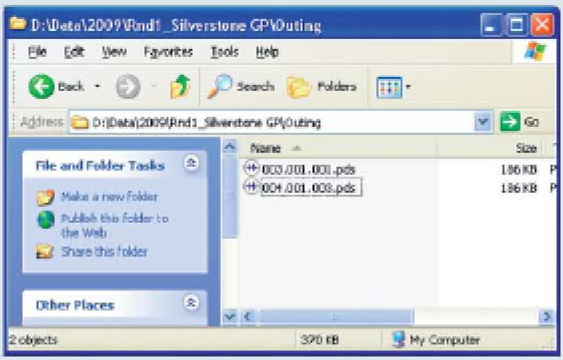


Figure 4

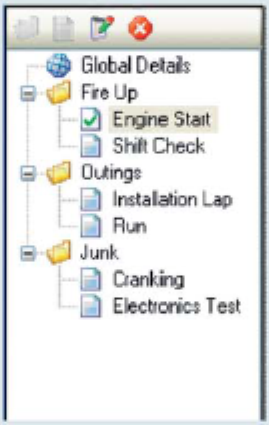


Figure 5

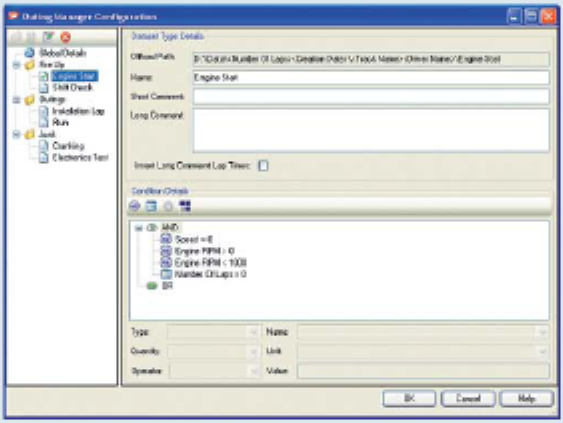


Figure 6

fact that Windows sorts folders alphabetically. So if, for example, we choose to store our data round by round, or test by test, we could use:

"Rnd1_Silverstone"
"Test1_Thruxton"

As well as being an obvious convention, this also results in all races being in the correct order (see figure 3 on previous page).

An alternative to sorting by race and test is to use the date. To ensure Windows sorts folders named in this style correctly, and in round order, a format of Year_Month_Day is required (see figure 4 on previous page).

Referring back to figure 1, you will also see that we have a delimiter of 'type'. This allows us to sort data by whether it is an 'Engine Test' – defined in this instance as engine speed being greater than zero, but vehicle speed being less than a pre-defined outing speed – or an 'Outing', where engine speed is non zero and vehicle speed is greater than this threshold.

Within the file structure defined, the name of the datafile has also been specified. Again using the format of <session>.<outing>.<lap> results in the data appearing in chronological order (see figure 4).

AUTOMATING DATA STORAGE

Taking this procedure one step further, several software packages now include a 'Data Management' suite that sorts

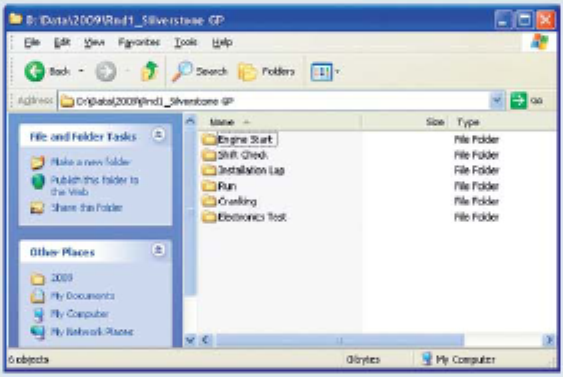


Figure 7

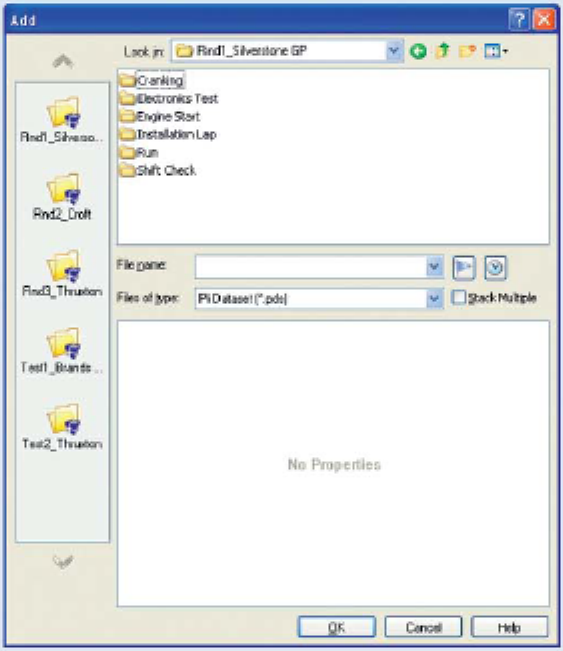


Figure 8

data in a more detailed format.

We have already seen how data can be stored as either an Engine Test or Outing, but a dedicated suite sorts this into more discrete folders, as shown in figure 5.

To allow the data to be intelligently sorted, we have to define a series of conditions to allow the software to know which data set to put into which folder. If we consider the example of an Engine Start, we can define this as in figure 6. The reasons we have chosen these particular conditions are as follows:

- [Speed] represents the overall car speed. Because this is not a shift check, only an engine start, we do not anticipate any of the wheels to move so the overall car speed will remain zero.
- [Engine RPM]: we have two qualifiers for rpm. If it is greater than zero the engine must be turning. We know the idle speed of this particular engine is less than 1000 and, as we don't anticipate blipping the throttle during this engine start, we can be sure the Engine RPM will not go above 1000. We also know the cranking speed is less than 1000, so for the type of 'Cranking' this is how we would define it.
- [Number of Laps]: a final qualifier is to ensure that the lap number is not increasing, just to make sure the car is static.

Defining these conditions for all of our different scenarios means we end up with a tidy folder structure without too many datasets within each subfolder, therefore reducing the time it takes to find data.

If we now link this into our data analysis software, we can define some shortcuts to allow easy and rapid browsing of this data (see figure 8).

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New approach

Lithium-ion battery technology heralds the lightest KERS yet

BY SAM COLLINS

Kinetic Energy Recovery Systems (KERS) have been a controversial technology since they first appeared in Formula 1 in 1998. McLaren Mercedes was the first team to test a system, but whispers of its existence soon saw it outlawed – a move that some people at the time suggested was short sighted.

Eleven years on, a KERS-equipped McLaren Mercedes finally started a race at the 2009 Australian Grand Prix. Quickly the system was said to be the best on the grid – reliable, effective and used to great effect by driver Lewis Hamilton in particular. From the start of the project to getting the system to racing standard took Mercedes-Benz HPE engineers at Brixworth, England, working in collaboration with the Daimler / Mercedes-Benz research and development department, just 24 months. It was intended to aid the firm's corporate objective of sustainability, particularly with regard to innovative and efficient propulsion technology, and it appears to have done just that. It has since been used in most races by McLaren and has a 100 per cent reliability record, with no failures during races.

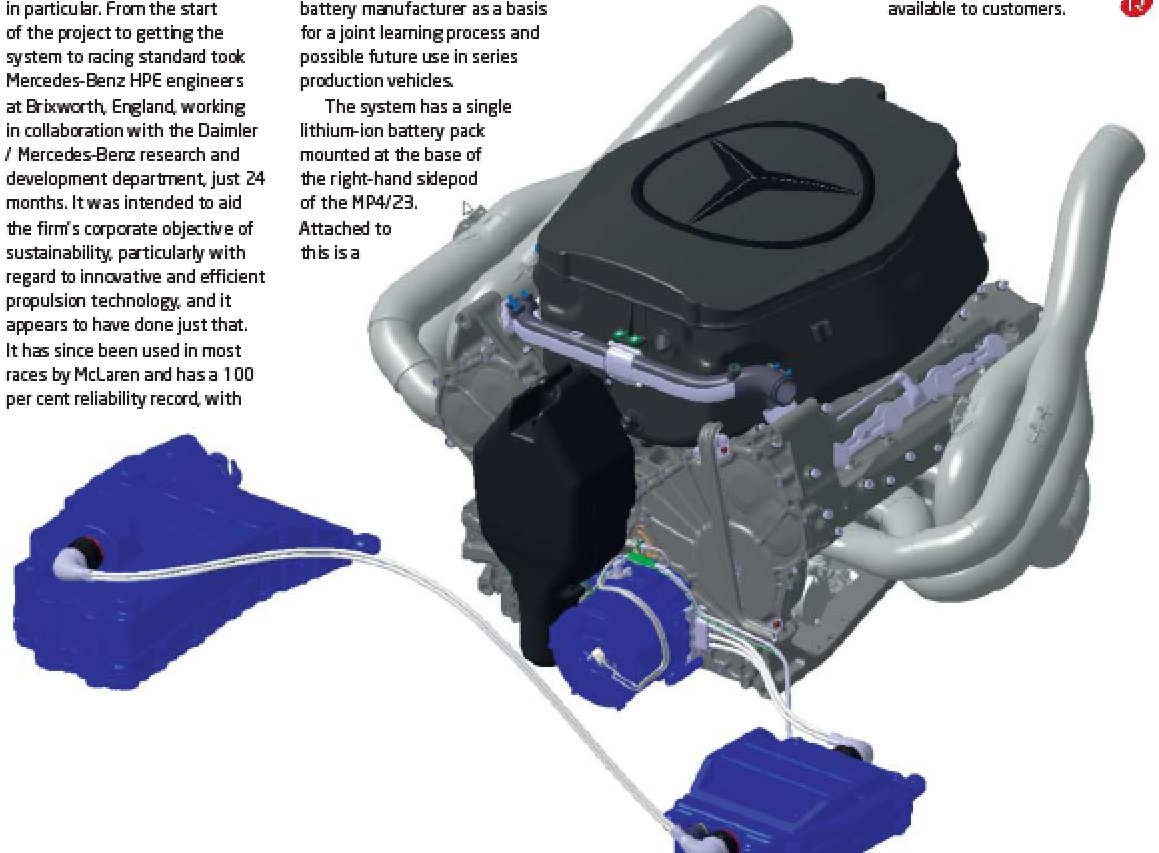
It is also said to be the lightest in Formula 1, weighing in at just 25.3kg complete with storage and motor. Much of the system's low weight is down to the battery technology involved. This was developed by a partner of Mercedes as part of an existing exclusive contract with a leading battery manufacturer as a basis for a joint learning process and possible future use in series production vehicles.

> "the system's low weight is down to the battery technology involved"

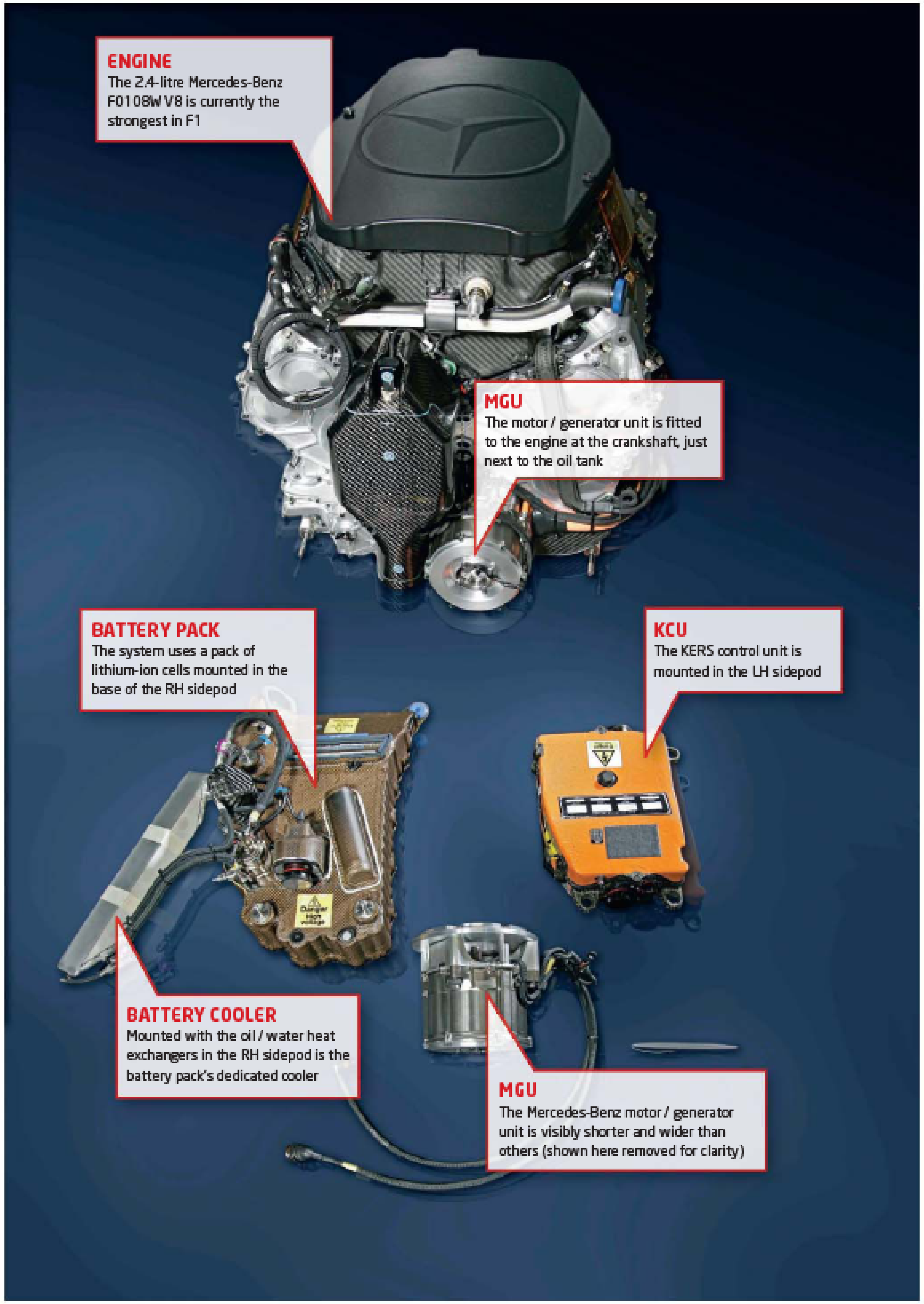
The system has a single lithium-ion battery pack mounted at the base of the right-hand sidepod of the MP4/23. Attached to this is a radiator to cool the battery system. The 2009 Formula 1 technical regulations prevent teams from using cut outs or 'gills' to evacuate under-body heat so most use the space around the exhaust exits to serve this purpose. At some tracks, such as Silverstone, where McLaren opted against using KERS, the radiator was not fitted and so the right-hand side exhaust exit was a different size and shape.

Mounted in the left-hand sidepod is the KERS control unit (KCU), linked to the battery module by two heavy-duty cables. The KCU is, in turn, linked to the motor generator unit, mounted at the base of the oil tank at the front of the engine, and is connected to the crankshaft with a splined shaft.

This system is currently only used by McLaren Mercedes and not by either of the two customer Mercedes teams – Brawn GP and Force India – though Norbert Haug has stated on a number of occasions that the system is available to customers.



Computer rendering showing the KERS layout. The main KERS components are coloured blue, with the battery, MGU and KCU clear to see



Darren Heath

Left foot forward

How McLaren used a cheap mechanical brake system to gain a performance advantage

BY SAM COLLINS

It took a while for anyone to notice, but there was something odd about the McLarens running at the 1997 Austrian Grand Prix. On the exit of some of the turns the carbon fibre rear brake discs were glowing red hot, yet the cars were clearly accelerating.

A few weeks later the situation became clearer. After the two McLaren MP4/12s failed in the European Grand Prix, photographer Darren Heath managed to photograph the pedal box in one of the cars. What the pictures revealed was an extra pedal in the car's footwell. The fiddle brake or 'brake-steer system' was now public knowledge.

'It was Steve Nichols' idea,' explains McLaren technical director, Neil Oatley. 'He was racing a Formula Ford 2000 at that time and it occurred to him whilst driving that if the car had a fiddle brake he could overcome its understeer. Once he had the idea it was fairly easy to implement.'

> "very similar to the systems commonly found on farm tractors"

The system allowed the driver to use the extra pedal to apply braking force to the inside rear wheel on the exit of a turn, allowing the car to hold a better line through a corner. Mechanically, both in design and operation, it was very similar to the systems commonly found on farm tractors and trials cars.

'The extra pedal was actually in one of the lines to the rear but, when the pedal was not actuated, it was just a free route through the master cylinder and normal braking,' explains Oatley. 'So when the driver actuated the pedal he just put pressure on one of the rear wheels. At that time we were just in the process of getting rid of a foot-operated clutch, and the extra pedal was actually the clutch pedal that we used, along with the clutch master cylinder, with an extra loop of pipe that ran through

TECH SPEC

MCLAREN MP4/12

Engine: Mercedes-Benz FO110E/F

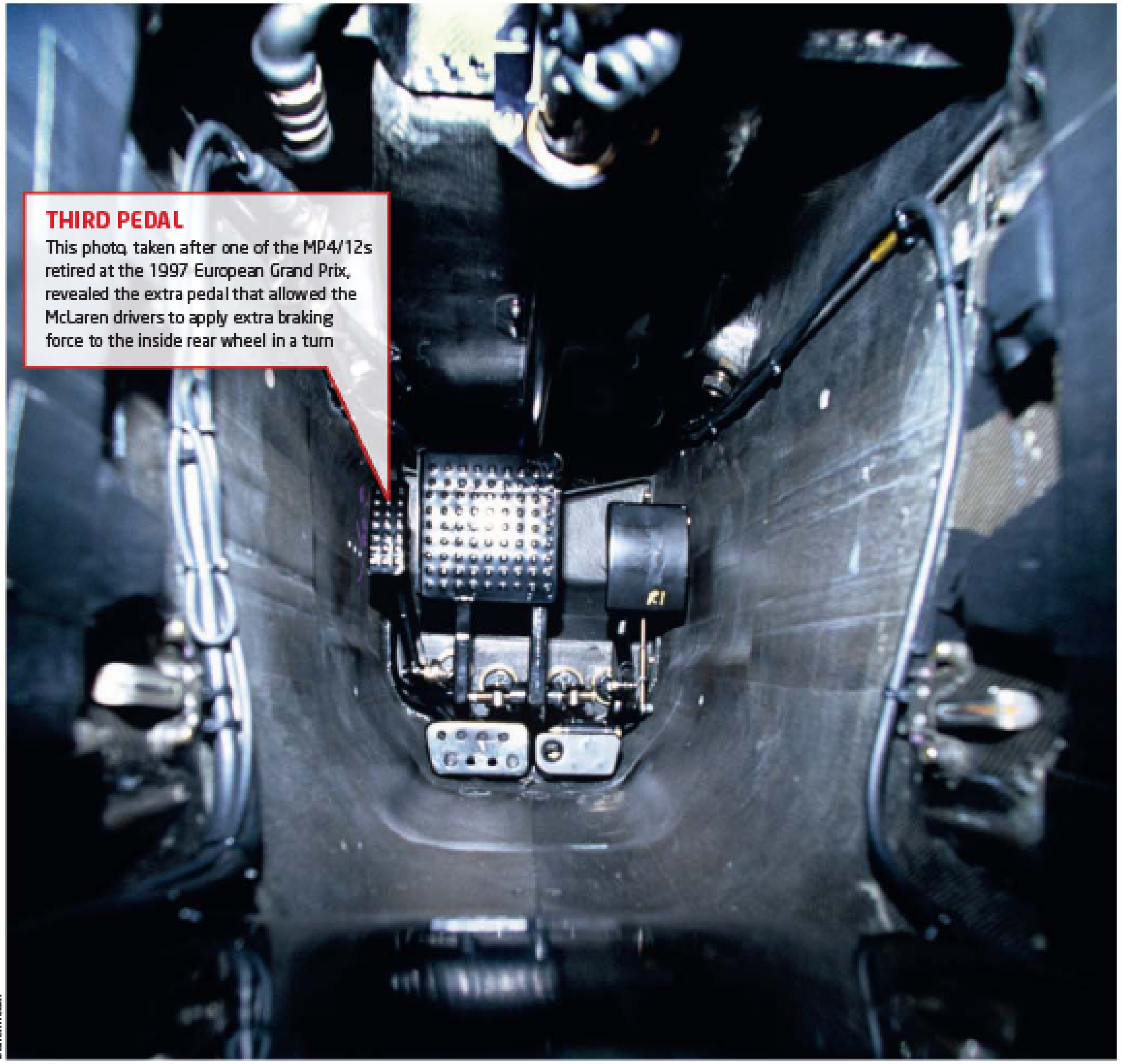
Brake calipers: AP Racing

Electronics: TAG

Brake discs and pads: Carbon Industrie

Wheels: Enkei

Tyres: Goodyear slicks



THIRD PEDAL
This photo, taken after one of the MP4/12s retired at the 1997 European Grand Prix, revealed the extra pedal that allowed the McLaren drivers to apply extra braking force to the inside rear wheel in a turn

Darren Heath

from the brakes to the clutch pedal and then off to the rear brake systems.'

As the system could only be used on one rear wheel, not both, McLaren engineers had to decide which of the rear wheels to run the system on before the event, a choice which naturally depended on the nature of the circuit. This meant that on some corners the system could not be applied – on right handers if the system was on the left rear for example. But McLaren had a plan to solve that on the MP4/13 of 1998. 'Over the winter we developed a system where we could hook it up to both wheels, with a selector device allowing the driver to switch from left to right. That was the more advanced version of the system. It was a little electronic valve the driver could operate, selecting whether he wanted the system on the right or left [rear] wheel.'

However, using an electronic valve in the braking system could contravene a technical regulation that prohibits anything but the force of the driver's foot being used on the brakes. Oatley explains how McLaren got around this: 'The regulation said that you could not add any power when braking but, as the driver was using the electronic valve when he was going down the straight, there was no power added during braking, nothing but the power of his own left foot.'

> "it may have been worth a tenth or two..."

It all sounds straightforward from a technical standpoint, but from the driving seat it could have meant a big increase in workload, although as Oatley reveals, the McLaren drivers David Coulthard and Mika Hakkinen were comfortable with it very quickly. 'We only did one or two tests with it before racing it. It was such a simple thing that it could just be put on or taken off the car. They all liked it. You only used it from mid-corner to exit during that time your left foot is doing nothing, so it was fairly easy for them to get the hang of it. They could play with it and adjust the trajectory of the car fairly easily and they took to it really quickly.'

The simplicity of the system is underlined by its incredibly low cost. 'There was nothing silly in it. When it was plumbed to just one wheel the total cost of it was probably only £200,' claims Oatley. 'The switchable system was more complex and cost more, but it really was not expensive.'

LAT

That glowing rear brake disc under acceleration was the giveaway that the 1997 MP4/12s had a brake steer system. Unsurprisingly, it was soon banned

Despite the system being simple and cost effective, it was banned after the first race of the 1998 season in Australia, a race which McLaren dominated. Many thought that brake steer was the big advantage of the silver cars, but it wasn't. The MP4/13s were just as dominant without it, going on to win nine races and both world titles. 'It was disappointing to see the system banned,' says Oatley, 'but I honestly don't know how much lap time it was worth. Certainly, with the '98 car [in testing] we had it on right from the beginning so we never ran without it. Then, after the first GP, we never ran with it, so there was no comparative testing done. I think it may have been worth a tenth or two, something of that order, but it's hard to be certain. Initially, when it was only used on one wheel the effect was obviously less than what we could have got from the 1998 version.'

Whilst brake steer was banned in Formula 1 and a few other series, it remains legal in many other formulae to this day and, with such cheap implementation, one has to ask how long it will be until we hear of its return elsewhere. Or perhaps it's already with us...

Unobtainium

Veronika Urbanova/dreamstime.com

Just over a decade ago, aluminium beryllium appeared in Formula 1 and, almost as quickly, disappeared again. But what did it offer and why was it so quickly excluded?

BY CHARLES ARMSTRONG-WILSON

Formula 1 has a long reputation of bringing exotic new materials into motorsport and forcing the pace of their development. It happened with carbon fibre composites, with titanium and even, for a short while, with depleted uranium. Just over a decade ago another material appeared on the F1 scene with enormous promise and potential, yet within two seasons it had been legislated out of the sport, never to be seen again. That material was aluminium beryllium (AlBe) alloy, and the story of its short life in the series is fascinating in a number of ways.

Mario Illien of Ilmor recalls what first attracted him to the material: 'I looked at materials we could make a piston out of instead of aluminium because we wanted to increase the revs, put more stress on the piston and I wanted to make things lighter.'

'We had been aware of it much earlier, but the price was hideous and there were all sorts of issues machining it,' recalls Oliver Allan of Advanced Engine Research who, at the time, was working for Ilmor on the Mercedes engines used by McLaren. 'There was a beryllium bicycle that we were all aware of 10 years before our use of the material.' In 1997, the company had run into problems with its big end bearings, which were proving a limiting factor in achieving higher revs. 'I think we were just under the 18,000[rpm] mark. We were working very hard on bearings to make those survive but, obviously, if you can reduce the piston mass you can have quite a dramatic effect on what load the bearing is seeing.'

> “We had been aware of it much earlier, but the price was hideous”
>
> **MARIO ILLIEN, ILMOR**

At the time the company was using variants of the established RR58 alloy developed by Rolls-Royce and used in the wartime Merlin aero engine. It was the staple piston material for all racing engines and had not been bettered. 'Our piston mass was somewhere around the 230g mark,' notes Allan of the RR58 items, but all that changed when they switched to aluminium beryllium. 'Overnight it allowed us to reduce piston mass pretty dramatically. I think the first iterations were about 170g.' The subsequent effect on bearing life was instantaneous and all the bearing problems disappeared. 'We then went through a period of very good reliability,' he continues. 'It was one of those satisfying periods in engineering when we could concentrate on just upping the revs and developing performance.'

But the advantages went way beyond giving the bearings an easier time. According to Allan, 'As a piston material it has every property in the book going in the right direction. Obviously, it is very low density, so that's good, but at the same time you have dramatically increased stiffness and a reduction in the coefficient of expansion, which allows you to make the piston more stable over a greater degree of operating temperatures. There was the friction improvement too – because the skirts are very stiff you could have a very small skirt. Piston mass obviously has an effect on thrust loads so we had a reduction in friction there as well. And we could run less oil to the piston because it didn't have any problems with micro welding the piston rings. And you also have higher thermal conductivity, which means it runs cooler, and that gives you an added benefit in terms of volumetric efficiency. So really, in every direction you had a benefit.'

This seemingly impossible scenario of benefits in every direction is echoed by Richard Bass of AP Racing. Around the same time, the company adopted the material for its F1 brake calipers and saw an immediate

As well as pistons, AlBe also had nothing but positive benefits for use in brake calipers, which were found to be both lighter and stiffer, pleasing both drivers and engineers. Shown is a 1997 Formula 1 caliper from Brembo

stiffness improvement, but also a weight advantage, too. 'There was less pedal travel, which pleases the driver,' says Bass, 'but also a lighter caliper, which pleases the designer. It's rare that we can please both. Usually, you make a very light caliper, which makes the designer happy, until it gets on the car and the driver doesn't like it. So we are always playing the two off against each other.'

HAZARDOUS MATERIAL

The key to the material's fantastic performance is its stiffness. Aluminium has a modulus of 72-73GPa and the metal matrix composites AP Racing was using for its calipers previously were typically around 125GPa. In comparison, the AlBe alloy the company used had a modulus of 192GPa. Add to that the lower density than aluminium (2.1g/cc against 2.75g/cc) and it seems like no contest. So, were there any issues with using the material? The first was that it is registered as a hazardous material, which calls for it to be processed under special conditions. In its solid form, Beryllium and its alloys are harmless but dust particles can cause problems if inhaled.

> "as a piston material it has every property in the book going in the right direction"

'It's quite simple to make it safe,' says Bass. 'Basically, you need some kind of vacuum cleaner on the machine. It was a minor risk but, because it had a government registration, it was quite difficult to set up to use it. Getting registered was the problem. It was a long process.' With this in mind, AP Racing put its AlBe machining out to a sub-contractor already licenced to handle the material.

Ilmor, however, jumped through the government hoops to get the certification and did its machining in house. The first issue it came across was how hard it was to work. 'It meant we had to go almost exclusively to diamond tools to machine it, so initially the tooling costs were quite high,' recalls Allan.

The next issue was a series of piston failures on the Mercedes engines that took some time to get to the bottom of. 'When an AlBe piston let go there was nothing more than shrapnel left,' recalls Allan. 'It was gravel and it was very difficult to be sure why the piston had failed. You never saw any precursor cracks. We isolated the root cause eventually as being inclusions in the material. They don't have any inherent strength and, if they happen to fall in the wrong part of the piston, typically in the key areas such as the gudgeon pin bores, you would end up with a problem. But we had a very strong materials department at Ilmor that allowed us to develop it and our materials experts spent an awful long time with Brush Wellman. It was just careful optimisation of the processing route. We had the way the material was made analysed, the way it was extruded, modified and we did some rough forging to get some grain flow.' Heat treatment was another important part, according to Illien.

LAT

Hakkinen was forced to retire from the British Grand Prix in '97 after an AlBe piston failure in his Mercedes engine

'It wasn't really fit to be used in that sort of environment,' he says of the material when they first started working with it. 'But we had a major programme because I was determined I could make it work.'

STRENGTH IN DESIGN

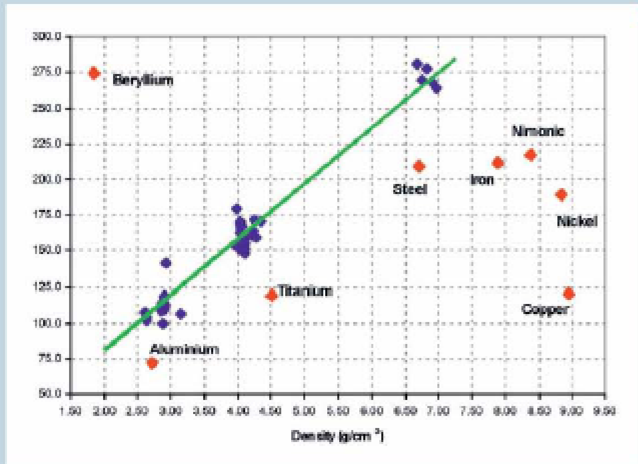


Figure 1
One of the inherent benefits of beryllium was its strength. Where contemporary Metal Matrix Composites had a modulus around 125GPa, AlBe came in at 192GPa

DESIGN LIMITATIONS

Another issue that confronted AP Racing was that, although the stiffness of AlBe was far higher than aluminium, the ultimate tensile strength [UTS] was not and this presented design limitations. 'Usually with most materials, if it's stiff enough it's strong enough,' says Bass, but with AlBe that was not always the case. The UTS of aluminium is 405MPa, while AlBe is higher at 448 MPa, but the difference is not proportionate to its stiffness. So sometimes a design would be limited by the material's fatigue life and burst strength rather than by the desired stiffness of the component.

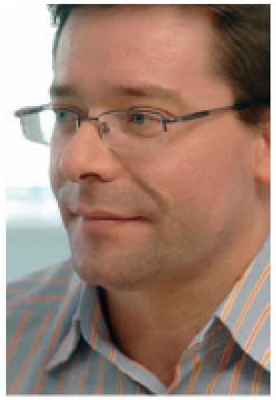
Then, of course, there was the cost. 'They were very expensive calipers in their day,' notes Bass, 'and we probably haven't topped that even with all the extra work we put into designing the latest ones. Machining the new calipers is more difficult because they are more intricate, but it still hasn't got up to the relative cost of where we were with AlBe. I think we more or less doubled the price of a caliper when we went to Be. An MMC caliper at the time was £3500, while the AlBe version came in at around £7500.'

However, Bass is quick to point out that this should be considered in the context of the cost of an F1 car. 'A caliper is not a consumable, so the team buys maybe four to five car sets of brakes, depending on the teams, some maybe buy eight sets, but they last all year. The big cost in brakes is the carbon, where they will use maybe three sets per race weekend. The cost was a concern but not the biggest one.'

In fact, the cost of the material was a bigger concern for AP Racing. 'It was quite risky for us financially because if you have to scrap a caliper in aluminium it's a lot cheaper than scrapping a beryllium caliper. It was always a big disaster if we wrote off a beryllium caliper during the machining stage.'

> "When an AlBe piston let go there was nothing more than shrapnel left"
>
> **OLIVER ALLAN, ADVANCED ENGINE RESEARCH, EX-ILMOR**

At Ilmor, the experience was more positive. Allan: 'I think overall on the programme, we ended up being fairly satisfied that we had actually saved ourselves money because we certainly made fewer pistons in a year and we had fewer engine failures. Also the life of the piston was that much longer so effectively the life of the engine was increased. Overall, I think it was a cost-saving venture and that made it all the more frustrating when it got removed.' Illien concurs: 'Obviously, beryllium is quite expensive per kilo, but when you look at it overall it was still very cheap, despite the material costs being high, because you didn't use much material per piston and it lasted about three times as long as an aluminium piston. So overall, it was actually a cost benefit.'



So, with all these apparent benefits, why did it get removed from the sport? Health and cost are the commonly cited reasons, but does that really stand up? It seems from the accounts of the people there at the time that cost was not a major issue. But, as development progressed, would it have become one? Certainly, even the prospect of the alloy being banned was a cause of expense for those using it. 'There was always a parallel programme going on,' Allan remembers. 'In the time we were using AlBe, I was spending more time designing aluminium RR58 pistons than AlBe pistons. We were concerned as we had a few things on the car that were legal one weekend and illegal the next weekend - brake steer is one thing that sticks in my mind. So, with the spectre of the safety issue being raised, you never knew that it wasn't going to get so serious that they would say "you're not allowed to turn up to the next GP with AlBe". So we had single-cylinder programmes with aluminium running throughout that period.'

MEDICAL CONDITIONS

But what about the health risks? Beryllium is listed as a category 1 carcinogen, along with nickel, chromium and benzene. This is to say that they have all shown some evidence of cancers at some time and long-term exposure to beryllium dust can increase the risk of developing lung cancer. A greater danger is the risk of chronic beryllium disease [CBD]. Some people become sensitive to beryllium, developing an inflammatory reaction on the skin and in the lungs days, months or even years after being exposed to higher than normal levels of the metal. It is thought to be a danger to

TABLE 1

Physical properties of Brush Wellman AlBeMet AM 162 AlBeMet HIP'd billet, annealed

	Metric	English
Density	2.071g/cc	0.07482lb/in³

TABLE 2

Mechanical properties Brush Wellman AlBeMet AM 162 AlBeMet HIP'd billet, annealed

	Metric	English	Comments
Tensile strength, ultimate	307MPa	44500psi	307MPa typical, 262MPa minimum
Tensile strength, yield	226MPa	32800psi	226MPa typical, 193MPa minimum
Elongation at break	5.00%	5.00%	5% typical, 2% minimum
Modulus of elasticity	193GPa	28000ksi	
Poissons ratio	0.170	0.170	

ALUMINIUM BERYLLIUM

The material used in Formula 1 was supplied by Brush Wellman, a US company set up in 1931 to exploit the commercial possibilities of beryllium and its alloys. Founded on work by the Brush laboratories, business took off during the Second World War as applications in defence and aerospace created a demand. In motorsport, beryllium was used for valve seats during the turbo era in the 1980s, but it was as brake calipers and pistons that aluminium beryllium found its way into the sport in the late 1990s. Brush Wellman markets the material under the trade name AlBeMet and it is still used widely in aerospace and defence applications today.

between one and 15 per cent of the population.

Obviously, this was taken care of during the manufacturing stage with specially vented machinery legislated under the government certification. But what if the material was released into the atmosphere in particle form at a race meeting following, say, an accident or engine failure? Allan: 'That may happen, but the amount of dust released is insignificant. In my personal view, it didn't stand up as an argument.' Illien concurs: 'In reality, beryllium is no more harmful than hardwood dust.'

POLITICAL IMPLICATIONS

Allan thinks the real reasons lie in the politics of Formula 1. The ban was not an FIA initiative and was actually the result of a collective decision among the teams, and he feels the reason behind it was the battle for competitiveness. 'It is a material that is in use in aerospace a great deal. There are people out there who still use it and use it safely.'

Illien has his own views on why it was banned: 'It's always the same problem. If somebody has something others can't have then you either try to get into the programme with something similar and compete, or you get it banned. It's the easiest way to eliminate the competition.'

As history records, it was excluded from the sport, but where did that leave those who had exploited the benefits of the material? 'When it was withdrawn,' remembers Bass, 'we dropped a long way back from 192GPa to 80GPa. We then spent a lot more time doing design work, finite element analysis etc. Whereas typically we would have spent a month or two on a caliper design, straight after the demise of AlBe we did four or five months on the job and really stretched ourselves. We didn't lose all the stiffness that the change of material lost us. And that's what we do more of nowadays. We're always working on the caliper design for longer and longer periods.' Most notably, this approach is manifested in the company's Radi-Cal range.

The prospect of the material being banned was always a factor in Ilmor's strategy. 'When I was doing detail studies into how far you could take it I was looking at piston masses of about 140g,' reveals Allan. 'But we made a conscious decision not to go to that level because by the time we started racing it we were aware of the political pressures from elsewhere in the sport to get the material banned. We were fully aware that we were going to have a short run of this. If we developed the engine to make full use of the AlBe piston we would have more of a problem in the future when it got banned. We were half expecting it to get banned practically over night. There was an awful lot of political pressure at that point.

'I was always frustrated, as the piston guy, that we didn't take it as far as we could. If we had followed it to its logical conclusion it would have been a really, really light piece. The logical extension would have been smaller big end bearings so you get those back up to a more stressed level. Then you've got a lighter crankshaft and lighter con rods. The knock-on effect really does start multiplying.

'We had a step where there was a reduced beryllium content for a period, at which point it was almost not worth doing, although it was still, just. Then a period of RR58 again, and then subsequent alloys tended to be refinements of RR58. Then there were the nanotechnology materials – using aluminium alloys that have very fine and controlled grain structures to try and increase strength at temperatures.' It all sent the company back down the road of analysis in an attempt to recover some of the lost performance. 'During the AlBe period we didn't spend much time going down that route. Certainly, the first RR58 piston that we ran competitively again was nowhere near as heavy as the RR58 piston that we had run prior to AlBe. It was a whisker over 200g.'

And that was the end of an era that nudged F1 engineering in a new direction, driven by computers rather than metallurgy. Better or just different, in the long term it has probably proved no cheaper.

> **"There are people out there who still use it and use it safely"**

THE DESIGNERS

BRUCE ASHMORE

> I believe that racecars have first to finish the race, so mine have tended to be a bit overweight

With a highly successful background in designing customer race cars, Bruce Ashmore explains what drives his design philosophy and why he now gets his thrills from the brutal USAC sprint cars

BY IAN WAGSTAFF

Bruce Ashmore once had a theory that Lola would win the Indianapolis 500 every 12 years. Certainly, from the mid-1960s to the first of Arie Luyendyk's victories, that held true, with the company leading the field in 1966, 1978 and 1990. And the T90/00 that achieved the last of these was arguably Ashmore's finest work.

'In terms of my favourite designs, that is the one that sticks out the most,' he recalls. 'It won the pole and the 500 at Indianapolis with Luyendyk and the championship with Al Unser jnr but it was more than just that. It was a major departure from the 1989 model, the T89/00. I had worked on the Indy cars from 1983 and taken over the project in 1987. The T88/00 was the first one for which I was the chief designer. We won some races with that, but everything revolved around Indy at that time so you compromised on all the other tracks to make sure you were fast there. We had put everything into lowering the centre of gravity and making it stiffer and more reliable, but we were slower than the Penskes.

'The time carried out in the wind tunnel was increased for the 1989 car. We lowered the centre of gravity further and made sure that there was less frictional drag by working on the transmission, the wheel bearings and the uprights. It was a little bit quicker than the previous year but the Penskes had moved up another step by then. So I then put everything into aerodynamics. The 1990 car had the minimum chassis size – the sidepods were minimum height and maximum width – and the wheelbase was stretched to give more room for the components. The turbo was also moved so that the engine cover was lower. I took out all the adjustment for the suspension geometry as this had been affecting the aerodynamics. It was a 100 per cent aerodynamic project. The Indy 500 is fast so I decided we had to have the lowest drag and the most downforce.'

States Ashmore, 'My driving force has always been aerodynamics. I would compromise anything for this. I would not worry about such as raising the centre of gravity or increasing the weight.' And speaking with him it's not hard to see where that influence comes from. The last year of his apprenticeship at Lola, 1980, was spent in the drawing office. The Lotus 79 had proved that ground effects were the way to go and subsequently aerodynamics became the big thing. Lola had also just started to make use of the quarter scale wind tunnel at Imperial College, London.

'Another car that sticks out in my mind was the T640E Formula Ford that won the Townsend Thoresen championship and Formula Ford Festival, driven by Julian Bailey.' This car was actually designed by Andrew Thorby, but Ashmore also worked on it, taking over the project and carrying out the development. 'The Van Diemens that had been winning before were very boxy, but we started to smooth things out. We used oval tubes for the wishbones and all the bodywork underneath the gearbox was smooth. We could not afford aerofoil tubes so we squashed the mild steel round tubes into an aerofoil shape. There were little winglets at the back and we stretched every shape that could be into an aerofoil. The car never went into a wind tunnel but we made everything as smooth as possible. We just knew that was how the car should look.'

> My driving force has always been aerodynamics

The T640 American version went on to win in the US driven by Michael Andretti, but it is another Formula Ford design that Ashmore perhaps remembers more, as this was to feature ground effects. The T740 would have had side-mounted radiators with an underwing, but for a couple of week's wind tunnel testing was carried out at Imperial College. 'We had got

These days, Ashmore gets his kicks engineering sprint cars, such as this RW Motorsports Silver Crown Beast, seen here at the Indiana State Fairground

so heavily into Indy cars that it never ran. I reckon it would have been a really good car because we tested the level of downforce that it would have had by adding illegal test parts on the T642, and it was fast,' Ashmore recalls. Lola briefly looked into the possibility of the T740 being built by outside contractors but unfortunately it never happened.

AERO EMPHASIS

Ashmore's recurring theme can be seen again in his 1985 T594 Sports 2000. 'Again, the emphasis was on aerodynamics, with more of a tear drop shape, and the car was a success. Our previous Sports 2000 had been a very boxy little car, but the T594 had the two philosophies I like.' In addition to the aerodynamic emphasis, the chassis was as stiff as we could make it.'

Aside from aerodynamics, there are other themes that have occurred regularly in Ashmore's designs. 'I have never been one for building superlight cars,' he says. 'I believe that racecars have first to finish the race, so mine have tended to be a bit overweight. Growing up in the customer car sector and never doing anything in Formula 1 taught me that you won by the numbers. If your cars finished and people liked them then they would work to develop them. You would then win races, then the championship, then more customers would buy them. Reliability was all-important.

> "I have never been one for building superlight cars"

'However, I didn't worry so much about this with the 1990 Indy car. I had saved a lot of weight on the mechanical components but we had more bodywork so it was still a little bit overweight. The one-piece underwing was much stiffer and heavier. There were many gaps and leaks on the previous car so I designed this one so that all the suspension was on top of the underwing. It was a big jump from the car before and it came out of the frustration of coming second at Indy all the time.'

His 1991 design was more reliable. The suspension was moved for the 1992 version, making it easier to work on, and there were some changes made for 1993 to meet new rules, but all were essentially developments of the T90/00, which remains Ashmore's favourite.

Ashmore recalls that, during Lola's early days of wind tunnel use, 'we didn't really know if reducing drag or adding downforce was going to make a car go faster so we did a lot of testing. We also often misled ourselves as the wind tunnels and the models weren't that good. There were a lot of cars at that time that just did not work and we built some at Lola. The 1983 Indy T700 was a real 'dog' when we first took it out. However, by the end of the year we had won at Elkhart Lake, which we achieved mainly by increasing the stiffness of the chassis and adding sealed and moulded carbon underwings to replace the old ones with gaps and leaks that we had at Indy.'

LAT

Ashmore's 1985 Sports 2000 racer, the T594, embodied his two design philosophies perfectly – a chassis as stiff as possible and a body as aerodynamic as possible. The teardrop-shaped car proved to be a success

ROGUE RUNS

In the late 1980s Ashmore began to realise that to design a better car you had to design a better wind tunnel. 'We started off using wind tunnels that were left over from World War 2 aircraft design,' he remembers. But by this point Lola was using the Cranfield tunnel where it owned the rolling road and electronics system. By the end of 1989 the Lola team could, recalls Ashmore, rely on the tunnel 'to tell the truth. However, it was still not a fantastic instrument and you had to keep an eye on the electronics, as every now and again you would get a rogue run.'

A second car that comes to mind as less than successful was the 1986 Indy T86/00. 'I was assistant designer on that car to Nigel Bennett. It caught us both out. There had been a big rule change and the 1985 car had been a pretty good one. We then spent a lot of time with the regulations people and thought we were on top of all the changes, which had been brought in to slow the cars down. Then we looked at the opposition and we were so far behind. The car did not have enough downforce, it was big, it was heavy. That car drove it home to me that aerodynamics were so important.'

> "to design a better car you had to design a better wind tunnel"

Another of Ashmore's *leitmotifs* is to try and make a car with a minimum number of components. Wishbones, for instance, are generally non-handed so can be swapped side for side. 'I will force the design into being like that. I think this came from the time of drawing by hand. I also started in a machine shop so I knew how hard it was to set up and make a component. The fewer components, the shorter time you need to make the car, or the fewer people you needed to do so. That way you could get it on the track before anyone else and start testing it.

'I remember when Penske and Lolas used to line up together on the front row of the grid at Indianapolis with almost exactly the same speeds. One year I caught Roger Penske examining our car. He looked down at the top wishbone and the brackets that held it onto the tub. He could see each bracket was the same piece and the lower wishbone brackets were similar to the top. He shook his head and then looked at the complexity of his car. Every wishbone bracket was different and the bolts were in at different angles. He just looked over at me and smiled.'

LAYOUT IS PARAMOUNT

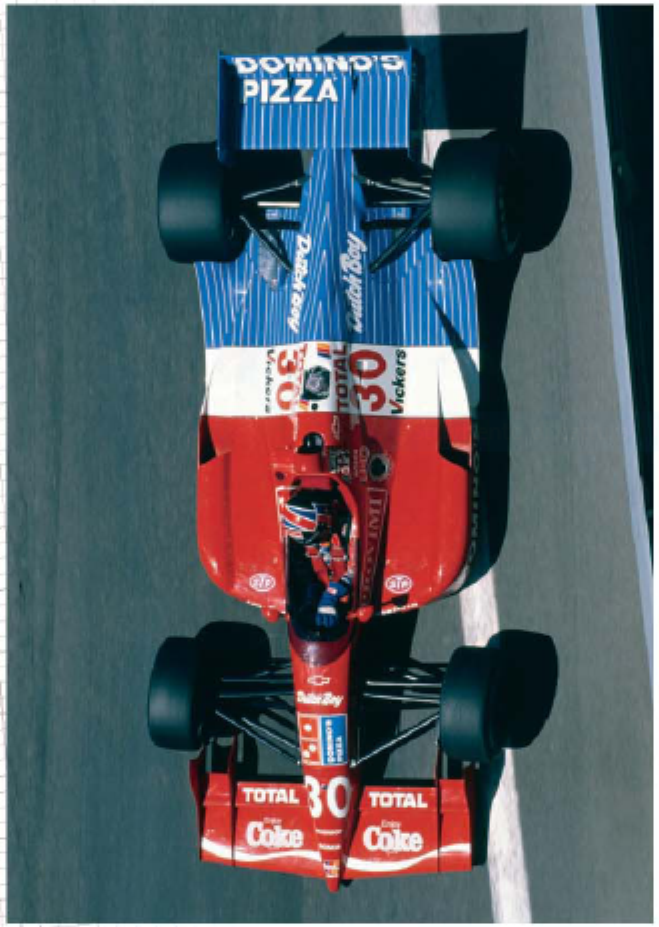
When designing a car, the first thing that concerns Ashmore is layout – as he puts it, 'where everything goes.'

'You are usually racing against somebody else, so you look at

BRUCE ASHMORE

Coincidentally born five miles from Lola's factory, Ashmore graduated from Cambridge Technical University and joined Eric Broadley's company. During a 17-year period there he progressed from apprentice to senior designer. In that time he designed five of the company's Indy cars, including the 1990 500 winning T90/00.

In 1993, Ashmore moved to Reynard to work on its Indy car project and was subsequently described by Adrian Reynard as 'a star designer who isn't starry'. Within two years, Reynard had overtaken Lola as the leading chassis supplier to CART. Ashmore then moved to the USA to help establish Reynard North America and later the Auto Research Center. After two years with Players Forsythe Racing, he formed Indianapolis-based Ashmore Design at the end of 2002.



Arguably Ashmore's finest hour, the 1990 Lola T90/00 that took pole position and the win at the Indy 500 that year

their layouts, their history and ask where did they get where they are? Then you think in broad strokes – where do all the bits fit on the cars?

'The next thought is that if they are doing things like that, where can I move things around and get a performance advantage? When I was growing up, the cars were changing, going from a wedge shape and getting into ground effects. We were moving components like turbochargers, radiators and radiator ducts to squeeze in tunnels and bigger wings.

'I then try to stretch something, such as a longer wheelbase or a wider track. It is always to get more downforce and maybe less drag. I have to ask why nobody else has gone that long, that narrow, that big or that small. When I came into designing cars, regulations were already in place governing overall width and length. However, there were not minimum tracks or maximum wheelbase regulations. It is the same today, only the numbers are smaller.

'I write all the regulations down and look at where the minimums and maximums are. When you are an engineer, everything you do is in tolerances. It doesn't matter

> "I write all the regulations down and look at where the minimums and maximums are"

whether it is plus or minus half a thou or plus or minus five inches. So, you put down all the boxes you are allowed to go into, reckon on what would be different to what everybody else has done and then ask can you make it work? Wheelbases and body width should be maximums, chassis need to be minimums. You just push everything as far as you can.'

2D SKETCHES

Ashmore points out that he likes sketching, usually in 2D. 'I'm not that good at 3D sketching. Eric Broadley was fantastic. We would have a big sheet of paper on the desk and over a period of two or three days a three-dimensional car would appear. However, those 3D sketches did not generally work. They would be very nice drawings but the car would often not lay out. I therefore found that my job was to do the 2D sketches – plan views, side views, front views and probably three cross sections. I would have to force

GOING FOR GOLD

Bruce Ashmore is practising what he preaches in his role as series coordinator for the projected USAC Gold Crown Championship. The series may be a phoenix rising from the ashes of the New Generation Silver Crown Championship but it does have a certain appeal and, in a world dominmated by spec racing, it could be something totally different. Tradition is to be combined with a modern look, but there is more to it than just that.

Ashmore claims it may be the answer to those who bemoan the dominance of the overseas drivers in the IndyCar series in that its combination of road and oval courses could be the final rung of a ladder that takes American drivers to the Indianapolis 500.

The USAC Gold Crown Championship has already met with approval from potential car owners. At an initial meeting they unanimously agreed to a series roll out with the first cars due to appear later this year.

Production will now commence with four different chassis constructors – Ashmore Design, Devin Race Cars, Riley Technologies and Rock Chassis. Testing and development will follow in 2010 with a 10-race programme scheduled for the year after.

The Gold Crown Championship is to be the Destination Series of USAC, as well as being on the ladder system of open-wheel racing for drivers aspiring to the Indy 500. Gold Crown construction will be tube framed, front engined, open-wheel cars, specially designed to race on both superspeedways and road courses.

The design of the Gold Crown car combines a traditional front-engined configuration with modern styling, the work of Chevrolet designer Randy Wittine. The front body panel of each car will be sculptured to depict the engine used, encouraging manufacturer support from the fans. The engines will be the same as those used for the current Silver Crown series – 800+ bhp, 358ci (5.9-litre), aluminium-headed V8s from Chevrolet, Ford, Mopar and Toyota.

Traditional chassis technology combines with modern looks in the USAC Gold Crown Championship, with a choice of chassis, a choice of engines and a definite route onto the US open-wheel ladder

Eric's 3D drawing into something that would lay out. I developed this as a technique.

'Now we are in the CAD era, I still do 2D. There are those who tell me that they can design in 3D from the start, but I don't think you can do that. I design things that don't exist yet, whereas most 3D objects are already made in another form or come from a sketch or 2D layout.'

MODERN THINKING

Ashmore is not impressed by what he currently sees happening in motor racing. 'I think the sport is in trouble right now. I don't know whom the marketing guys are trying to convince. They seem to be trying to persuade people that the car is not important. And every sanctioning body is falling into the same trap, in which you eventually end up with a spec car. You start off with a number of constructors. Then the regulations get tighter, the team owners encourage this and eventually all the cars and engines are the same.

'Despite this, in a spec series it is the team that has the most money that wins. It is a time/quality graph. The more time and money you apply, so the quality goes up. The team owners have now agreed to regulations that

> "There is never going to be anything different until you open up the regulations"

mean they will not be slow just because they have bought the wrong chassis or engine. They have removed some of the risky decision making, but it's just that risk that excites a large percentage of race fans.'

Despite this, Ashmore does not pine for the past. He has ideas as to the direction in which motor racing should be heading, some of which can be seen in the projected USAC Gold Crown Championship for which he is responsible (see sidebar above). 'I think that we need to open things up and that spec component racing is the way to go. You have a selection of parts – transmission, wheels, uprights, maybe even the chassis – you put these out to tender from various different manufacturers and then you join the dots up. You have freedom between the pieces and can move the components around.

'Once sponsors become interested you open up some of the areas. You let that be driven by something that needs to be developed for the road car world – perhaps an electric motor or a fuel. Right now, an engine is a piston with con rods and a crank. It evolved that way when development was free but now you are told that it has to be this. There is never going to be anything different until you open up the regulations. However, we cannot afford to change the whole car in one go. We cannot go back to where we used to be.'

This May, Ashmore could be found working enthusiastically on the Gold Crown project and engineering a RW Motorsports Silver Crown Beast at the Indiana State Fairground. Perhaps it is significant that a designer and engineer such as this should be finding more to motivate him at this level than if he were to be a few miles down the road at the Indianapolis Motor Speedway where one of his designs once drove into victory lane.

The anti controversy

In response to a previous article on the matter, Mark Ortiz offers some further thoughts on controversial chassis phenomena

BY MARK ORTIZ

A number of people have asked me to respond to an article in the March 2009 *Racecar Engineering*, in which the author, Danny Nowlan, makes some assertions that challenge conventional thinking about anti-squat and other geometric pitch and roll resistance phenomena, contradicting some of what I say in my *Minding Your Anti* video. That is what I will try to do in this article.

Let me begin by emphasising that I intend no disparagement to the integrity, intelligence or intentions of the author of the aforementioned piece, nor to those of any of my colleagues in the field of vehicle dynamics. One might suppose that vehicle dynamics, being merely Newtonian physics, would not be controversial or hard to understand for educated people in the 21st century, yet anyone who has delved into the field will have noticed that there is a lot of disagreement, and sorting through all the contradictions is anything but easy. Given this situation, anybody who makes an honest effort to understand the laws of nature, and to deliver honest goods and services to the public, deserves the benefit of the doubt regarding their intentions.

For the benefit of readers who may not have seen Mr. Nowlan's article, I will summarise his assertions, as faithfully as I can, in my own words:

1. We must not be slaves to orthodoxy. We must be willing to think things through from first principles, and entertain any conclusions that may result, even if they contradict what accepted authorities say.
2. The car has only one centre of mass. It is not a string of separate masses, and should not be analysed as such.
3. All dynamic effects should be analysed as forces and moments about that single centre of mass.
4. The laws of physics act similarly in all directions. Therefore, we should be able to use fundamentally similar methods to analyse front-view and side-view suspension geometry.
5. In front-view geometry, the point where the force line intercepts the c of g plane is the roll centre.
6. Similarly, in side view, the point where the side-view force line intercepts the c of g plane may be taken as a pitch centre.
7. All forces exerted by the tyre upon the road, and by the road upon the tyre, act at the ground plane, not at the wheel centre.
8. Any time a tyre is exerting a longitudinal force, it is necessarily transmitting a torque.
9. Therefore, there is no dynamic difference between systems with inboard and outboard brakes, or between systems with sprung and unsprung differentials.
10. Accepted theory asserts that with inboard brakes or sprung diffs, forces are applied to the car at wheel centre height.
11. Accepted theory predicts ample longitudinal anti for such systems, but data traces from actual cars contradict this. Suspension displacements are very nearly what we would expect from pitch moments about the ground, reacted entirely by the car's springs, implying little or no anti, or a low pitch centre.

> the car is a collection of masses that are rigidly attached to each other

Taking these more or less in order, I agree with number one. Willingness to re-examine and question accepted theory is the difference between science and dogma, and is an important foundational principle of human liberty in general.

Number two is correct, almost. That is, the car is a collection of masses that are rigidly attached to each other, and can therefore be considered a single body – except that when the car has a suspension system, some of the attachments within it are not rigid, and some components can move with respect to others, albeit in a (hopefully) limited and carefully controlled manner. For some purposes, rigorous analysis requires us to treat these masses separately. Moreover, the masses are separate to different degrees in different modes. The nuances of this will make a good future article or newsletter.

However, we can examine the principles of anti effects using an assumption that all of the car's mass is sprung, and the masses and inertias of unsprung components are zero. Real cars aren't like that, of course, but imagining they are so greatly simplifies the discussion and the associated equations.

Since we will be presenting equations, it is time for some definitions, so let's start with the vehicle axis system:

As per SAE convention, x is longitudinal, y is transverse, and z is normal or vertical. Unless otherwise stated, sign conventions are as follows: x – positive forward, y – positive rightward and z – positive downward. Unless otherwise stated, vehicle origin is per SAE aerodynamic axis system: on the ground plane, mid-way along the wheelbase, and centred with respect to the front and rear tracks. However, for particular purposes, we may use local origins and sign conventions may deviate, so it is necessary to pay attention to context. Even then, x will always be longitudinal, y transverse, and z vertical, in some sense that is appropriate to the context.

SAE vehicle axis convention takes as origin a point on the roll axis, directly below the sprung mass centre of mass or c of g. I don't care for that, because the points in question move and are subject to uncertainties. Actually, there is no origin that is completely immune to some uncertainties and relative movements, but for our purposes here, we will use the SAE aerodynamic convention *(right)*.

CONTACT PATCH FORCES

Returning to Mr Nowlan's assertions, point three isn't necessarily correct. In particular, it is incorrect to suppose that forces at the contact patches act along the force lines or force planes of the suspension geometry, and therefore exert moments about the centre of mass according to their vertical or perpendicular distance from the centre of mass. This misconception stems from a misunderstanding of what the force lines and planes represent.

The car is not a body floating in space, acted upon by angular forces in the force planes. Nor is it an airplane with four wings or control surfaces, each exerting a lift and a drag force. It is a body with a centre of mass above the ground plane, supported through compliant suspension at four points in the ground plane, accelerated in the x and y directions by forces in the ground plane. These forces do not act on the car as a whole along the force planes, they act on the car as a whole along the ground plane. The ground-plane forces induce support forces within the car, in the suspension systems, according to the slopes of the force planes. These induced forces create moments within the vehicle that may oppose or exaggerate the suspension displacements in roll and pitch, and can alter the distribution of tyre normal forces.

This may seem merely a rhetorical distinction, but it's not. In particular, the anti-roll and anti-pitch moments do not depend on the proximity of the force plane to the centre of mass. Rather, they depend only on the spacing of the wheels, the magnitude of the ground-plane forces and the slopes of the force planes. The anti-roll and anti-pitch moments do not depend in any direct way on where the centre of mass is.

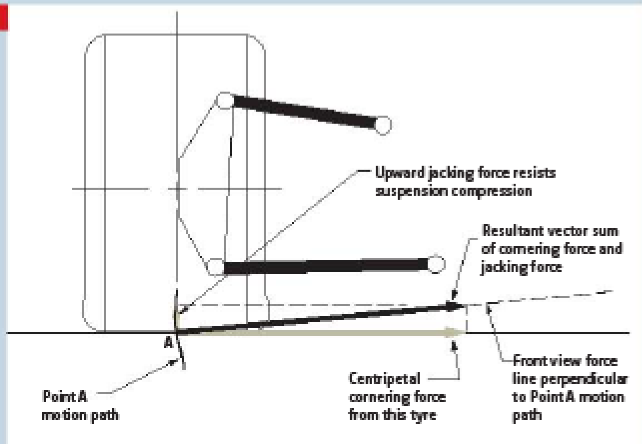
Number four is correct. The laws of physics do act similarly in all directions, and we should be able to apply fundamentally similar methodology for both side-view (pitch-related) and front-view (roll-related) phenomena. However, number five is incorrect, and consequently so is the following one, number six. The roll centre is not where a single wheel's force line intercepts the c of g plane. Correspondingly, applying similar thinking to the side view is likewise incorrect.

Indeed, we cannot meaningfully speak of a roll centre or pitch centre for a single wheel, even in simple two-dimensional modelling. Even in 2D, we need two points of support to resist an overturning moment, and it is the combined effects at these two support systems that create any moment. Likewise, we cannot meaningfully speak of right-side or left-side roll, or front-end or rear-end pitch.

We should note that when both wheels have anti-roll ie when both force lines slope

GEOMETRIC ANTI-ROLL

Figure 1
Origin of geometric anti-roll on an outside wheel. Induced support force in the linkage tries to extend suspension



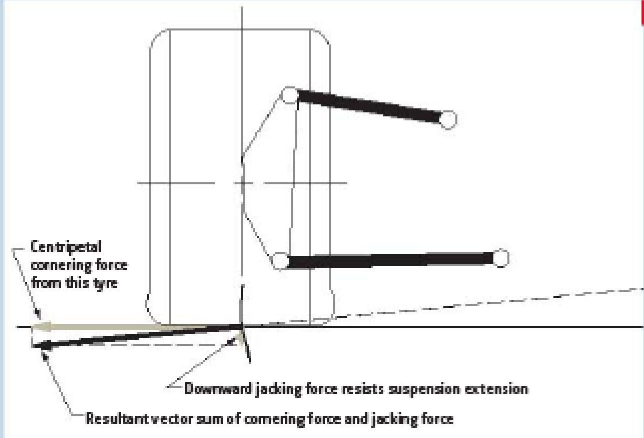


Figure 2
Geometric anti-roll on an inside wheel. Induced support force is negative, meaning it tries to hold the suspension compressed

THE SAE AERODYNAMIC CONVENTION

x, y and z may denote coordinates in this axis system, or linear displacements in this axis system.

Next, angular quantities about the axes:

ϕ (phi) is roll, or angular movement about an x axis, conventionally positive rightward, or clockwise as seen looking forward.
M_x or Mϕ is a moment in roll, or about an x axis.

θ (theta) is pitch, or angular movement about a y axis, conventionally positive rearward, or clockwise when looking from left to right.
M_y or M_θ is a moment in pitch, or about a y axis.

ψ (psi) is yaw, or angular movement about a z axis, conventionally positive rightward, or clockwise when looking down.
M_z or M_ψ is a moment in yaw, or about a z axis.

L is the centre spacing between two wheels of a pair under consideration.
L_x is wheelbase.
L_y is track.

r_t is tyre loaded radius.
For simplicity, we will ignore distinctions between loaded and effective tyre radius.

F is force. F with an x, y or z subscript is force in an x, y or z direction.
m is mass.
a is acceleration.
F = ma (when m is in lb, a should be in gs).
H is height.
H_{cg} is height of the centre of mass or centre of gravity (c of g).
H_{rc} is roll centre height.
H_{pc} is pitch centre height.

dx/dz is the instantaneous rate of change of a point's x coordinate with respect to change in its z coordinate: the first derivative of x displacement with respect to z displacement. dy/dz, similarly, is the first derivative of y displacement with respect to z displacement.

dx/dz and dy/dz are also the instantaneous slopes or inclinations, from vertical, of the contact patch centre's path of motion in side and front view respectively.

A force line is a notional line of action for the vector sum of an x or y ground-plane force at a tyre contact patch and the induced z-direction support force within the suspension system that results from angularities in the suspension linkage. In front-view geometry, the force line is the line from the contact patch centre to the front-view instant centre. The front-view force line is an instantaneous perpendicular to the contact patch centre's path of motion in front view, and has a slope or dz/dy, relative to ground plane, equal to the contact patch centre's dy/dz. The side view force line is an analogous construction in side view, whose slope is the contact patch centre's dx/dz. There are some subtleties to assigning that dx/dz, which we will address.

The front-view and side-view force lines define a plane, which we may call a force plane.

ROLL CENTRE

WHAT IS THE ROLL CENTRE THEN?

It is a notional coupling point for transmission of y forces between the notional front or rear axle and the sprung mass. Its height is the height at which the centrifugal inertia force for that end of the car would generate a roll moment exactly equal to the anti-roll moment induced by the linkage geometry, so no roll would result.

Importantly, the roll centre is not any sort of coupling point for z forces. It is analogous to a horizontal link, or a roller in a vertical slot, not a pin in a hole. When the car is in motion, a sustained z force does not induce a geometric roll moment. Engineers were confused about this for years, partly because when a car is tested sitting still on a shop floor, with no slip plates under the tyres, asymmetries in its anti-roll actually produce roll moments in response to z forces. But when the wheels are free to track in and out as they roll along, that effect goes away. This is why we roll a car before we scale it.

The equation for the roll moment Mx or Mϕ produced by a total wheel pair y force F_y acting at a height H is:

$$M_x = F_y H \qquad (1)$$

The equation for the anti-roll moment induced in the suspension by right and left wheel ground-plane y forces F_{yR} and F_{yL} is:

$$M_x = \left(F_{yR}(dy/dz)_R - F_{yL}(dy/dz)_L\right)L_y/2 \qquad (2)$$

Or, in English, the geometric anti-roll moment is equal to the difference of the two induced support forces times half the track (the sum of the two support forces is the net jacking force for the wheel pair). Stated another way, the moment in roll for the wheel pair induced by the linkage geometry has to equal the difference in the support forces induced, reacted on the half-track. If our modelling gives us some other value for this moment, there has to be an error in our modelling. Note also this equation includes no term representing c of g location.

Combining equations (1) and (2), for a condition where H is the height of the roll centre, H_{rc}, and the roll moment and the geometric anti-roll moment are equal in magnitude:

$$F_y H_{rc} = \left(F_{yR}(dy/dz)_R - F_L(dy/dz)_L\right)L_y/2 \qquad (3a)$$

Solving for H_{rc}:

$$H_{rc} = \left((F_{yR}/F_y)(dy/dz)_R - (F_{yL}/F_y)(dy/dz)_L\right)L_y/2$$

(3b)

This can also be written:

$$H_{rc} = \left(L_y(F_{yR}/F_y)(dy/dz)_R - L_y(F_{yL}/Fy)(dy/dz)_L\right)/2$$

(3c)

Or, in English, the portion of the total y force at the right wheel, times the track, times the right wheel's force line slope, minus the portion of total y force at the left wheel, times the track, times the left wheel's force line slope, all divided by two, is the roll centre height.

upward toward the centre of the car, those two force line slopes are mathematically of opposite sign, so the difference of the two products in the large parentheses ends up with a larger absolute value than either product by itself: the two products either add, because we're subtracting a negative, or add negatively, because we're subtracting a positive from a negative.

Doing the same thing graphically, we construct what I call a resolution line. This is a vertical line in our front-view drawing, whose y position relates to the distribution of y force between the right and left tyres. If, for example, the right tyre is estimated to make 70 per cent of the cornering force for the pair, the resolution line is 70 per cent of the track from that wheel (30 per cent of the track from the left wheel). We then find the two points where the front-view force lines intercept this resolution line, average those heights (add them and divide by two), and that's the roll centre height.

My video includes illustrations.

How does this compare with Bill Mitchell's force application point method? He draws a vertical line at the c of g, finds the force line intercepts of that, and does a weighted average of those, with the weighting based on the F_{yR}/F_{yL} distribution.

Turns out that the FAP method gives the same answer as the resolution line method, when the c of g is mid-way between the wheels. It also gives the same answer when the force lines have equal and opposite slope ie when they cross in the middle of the car, even if the c of g is offset. When the c of g is laterally offset, and the suspension is also markedly asymmetrical, it creates an error. If the c of g offset is small, the error is too small to measure experimentally on a kinematics and compliance rig. It would become a concern in a car that has a large lateral c of g offset, and markedly asymmetrical independent suspension – for example, perhaps a Supermodified with independent suspension, in a rolled condition (such cars did once exist, though Supermodifieds are now required to have beam axles at both ends).

FORCE LINE VISUALISATION

Figure 3

Assignment of resolution line for situation where the outside wheel makes 75 per cent of the cornering force

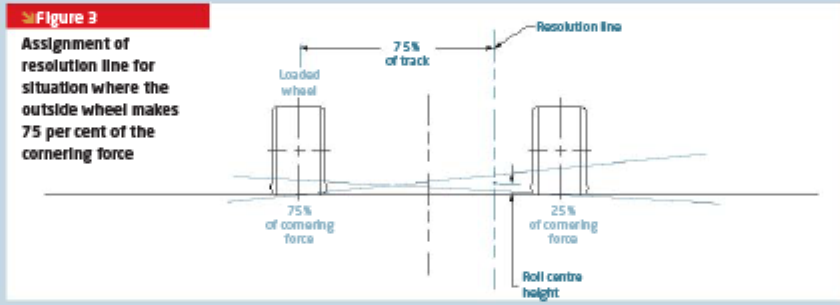


Figure 4

Suspension with force lines of equal and opposite slope, showing resolution lines for three different lateral force distributions

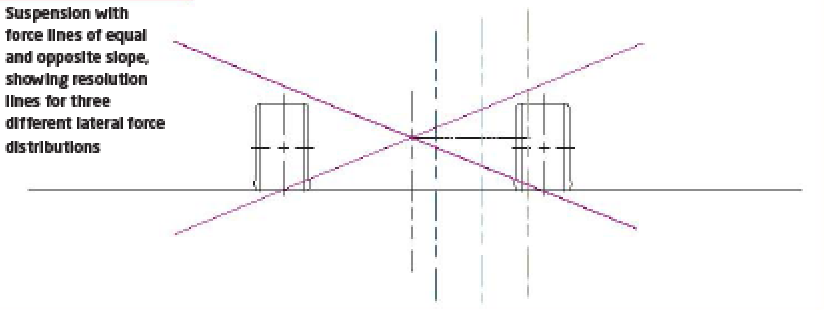


Figure 5

Roll centre when force lines are parallel and the loaded wheel makes 75 per cent of cornering force

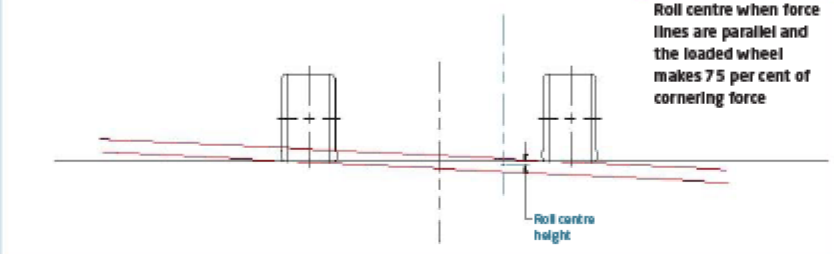
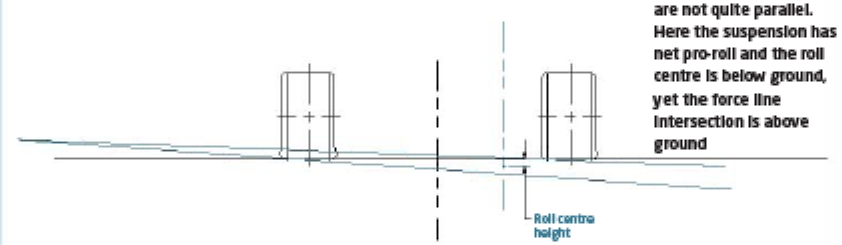


Figure 6

Same situation as fig 5, except the force lines are not quite parallel. Here the suspension has net pro-roll and the roll centre is below ground, yet the force line intersection is above ground



The oldest method of assigning a roll centre is to take the front-view force line intersection as the roll centre. The force line intersection method can also give a correct answer, but the only time it necessarily does is when the force line slopes are equal and opposite. The more asymmetry we introduce in the geometry, the more anomalous this model tends to become. The most obvious anomalies occur when one wheel has slight anti-roll and the other has slight pro-roll, so that the force line intersection lies a long way outside the vehicle. The intersection can then be far above or below the ground, despite the fact that the suspension generates little net pro-roll or anti-roll moment. If we further suppose that z forces generate moments about this point, the modelling anomalies can get outrageous. Finally, in some cases the force lines are parallel, and have no intersection.

Since the roll centre does not transmit z forces, it doesn't matter what its lateral location or y coordinate is. I call it undefined. If you like to think of it as being under the c of g, that's fine. If you like to think of it as midway between the wheels, that's fine. Just don't think of it as something that can transmit force vertically.

> "it does not mean that conventional thinking on anti-squat is incorrect"

Regarding numbers seven through 11, it is true that the car and the road can only apply force to each other where they touch ie at the contact patches. However, this does not mean that conventional thinking on anti-squat is incorrect, although it may be that some accepted presentations could be clearer.

It is also true that if there is an x force at the contact patch, there is a torque at the wheel, with the exception of the case where the x force is induced by the tyre running at a slip angle when cornering.

However, the torque may or may not act through the suspension linkage, and as such may or may not contribute to the Mθ in the suspension.

Let's imagine a free-body diagram for the wheel and stub axle in an independent rear suspension, in side view, when the wheel is propelling the car. The tyre exerts a rearward force upon the pavement, and the pavement exerts an equal and opposite forward force Fx upon the tyre, which propels the car. The wheel and axle assembly exerts an equal forward force on the rest of the car (remember we are imagining that the wheel assembly doesn't have any mass of its own). The remainder of the car, acting through the linkage and upright and bearings, exerts an equal and opposite rearward inertia force upon the axle. As such, the sum of the wheel and axle assembly's forces is zero, and there is a couple, equal to the wheel's torque My, which must be reacted somehow, for the sum of the moments to also be zero.

$$M_y = F_x r_t \quad (4)$$

In most independent suspensions, the torque is applied through the driveshaft and the driveshaft is jointed so it can only apply rotational force. It applies this force directly to the axle, it does not apply rotational force to the upright. The shaft sees a rearward torque at its outboard end and a forward torque at its inboard end. The stub axle at the diff, driving the axle, sees a rearward torque from the axle. This in turn reacts through the diff, the pinion bearings, and the transaxle mounts. This torque is then applied to the car as a whole, but the load path does not include the suspension linkage.

Imagining the free body diagram for the upright then, we have a forward force (thrust force) exerted at the wheel bearings, but no torque applied at the wheel axis. Both longitudinal links, or side view projected control arms (SVCAs), exert rearward force upon the upright and forward force upon the sprung structure. These forces are both smaller than the total Fx at the wheel centre, and both in the same direction. Their magnitudes are inversely proportional to the distances from the hub or wheel centre, and there are induced z forces within the suspension depending on the magnitude of the x forces and the SVCA angularities. The overall z force Fz induced is Fx times the dx/dz value at the wheel centre:

$$F_z = F_x(dx/dz) \quad (5)$$

Why not the dx/dz at the contact patch? Actually, the dx/dz at the contact patch centre is the same! If we constrain the wheel rotationally (lock it) at the inboard end of the driveshaft, and then move the suspension, the wheel doesn't rotate with the upright, and the point at the static contact patch centre stays directly below the wheel centre through the entire travel. Its dx/dz is then the same as that of the wheel centre. This differs from a situation where torque is applied to the upright and does act through the linkage, as with an outboard brake. In that case, the dx/dz that matters is that of the contact patch centre, assuming the wheel rotates with the upright. The force line then runs from the contact patch centre to the instant centre, and has a slope equal to the contact patch dx/dz for a wheel that rotates with the upright. Also, the forces at the SVCAs are opposite in direction, with the force on the lower opposite to and greater than the F_x at the contact patch, and the one on the upper in the same direction as the contact patch F_x and smaller than the force on the lower: clearly a different picture, and one that will usually produce a different induced z force.

Kinematics and compliance testing consistently confirms that it matters mightily whether torque reacts through the linkage or not. The only case where it does not matter is where the upright does not rotate in side view as the suspension moves (SVCAs parallel to each other).

With independent suspension or inboard brakes, the force line has the same slope as a line from the wheel centre to the side-view instant centre (SVIC), not the slope of a line from the contact patch centre to the SVIC. This is what some authors mean when they say that the force acts at the wheel centre. They don't mean that the rearward pitch moment Mθ is equal to $F_x(H_{cg} - r_t)$. It's still F_xH_{cg}. So conventional theory does not predict huge anti-squat for independent suspension. On the contrary, anti-squat by conventional theory is generally very modest for independent suspension.

So, in point 11, Mr Nowlan has misunderstood the theory he is attempting to refute, which is in fact confirmed by the data trace he presents.

Taking Terry Satchell's chapter in Milliken and Milliken's *Race Car Vehicle Dynamics* as an example of a conventional presentation, when F_x is considered as acting at wheel centre height, a different rule for determining percent anti is used, and the result is a correct calculation when the full method is taken together.

If we insist on considering the force line as passing through the instant centre, that method is correct. I prefer to say that the force line passes through the contact patch centre but has the same slope as a line from wheel centre to instant centre. I then use the same rule for percent anti as for a system where the torque does act through the linkage. I find this a slightly clearer way of thinking about the matter, but both methods give the same answer. At this point, we should probably review what is meant by percent anti-squat (see below).

Graphically, what Satchell and others do is shift the force line up to the wheel centre, but then determine anti-squat based on where the force line intercepts the front axle plane, not relative to the ground and the c of g height, but relative to a point a

PER CENT ANTI-SQUAT

This is the percentage by which the anti effect reduces rear suspension compression, compared to what would occur with zero anti. It is not the same as per cent anti-pitch. Here is the equation for percent anti-squat P_{as}, as per my method:

$$P_{as} = (L_x(dx/dz)/H_{cg})*100\% \quad (6a)$$

Or, by Mr Satchell's method:

$$P_{as} = (((r_t + L_x(dx/dz)) - r_t)/H_{cg})*100\% \quad (6b)$$

It will be apparent that (6a) and (6b) are algebraically equivalent.

tyre radius above the ground and a point a tyre radius above the c of g. In other words, they draw the same picture I do, except everything is moved up a tyre radius, and the final answer is the same.

Mr Nowlan poses an example where L_x(dx/dz) = .20H_{cg} (force line intercepts front axle plane at 20 per cent of c of g height), and the c of g is in the middle of the wheelbase, so that the height of the force line at the c of g plane is 10 per cent of c of g height. He says that the c of g plane/force line intersection should be considered the pitch centre, and also the anti-squat is 10 per cent.

Actually, the anti-squat is 20 per cent. But this doesn't mean the car pitches 20 per cent less than it would with no anti. It means the rear compresses 20 per cent less, and the front extends the same as it would with no anti-squat. Remember, there is no such thing as rear pitch. Pitch is the relative displacement of the front and rear, or alternatively, the angular displacement resulting from that. For the simplest case to analyse, where the front and rear have equal wheel rates in pitch as well as equal static weight, if the front and rear displacement with no anti is identical in magnitude, and we call that absolute displacement z, then with no anti, the relative displacement front to rear is z + z, or 2z. With the anti, the relative displacement is z + .80z, or 1.8z. That's 10 per cent less than 2z. So, for this simplified case, a 20 per cent squat reduction produces a 10 per cent pitch reduction.

Note, however, that we could move the c of g forward or back, and, if we don't change the springs, we still get the same deflections in response to a given z force, and the same anti-squat. If we make just the front springs softer, the pitch increases, because the front end rises more, but the squat and anti-squat stay the same.

Therefore, we cannot say that the c of g plane/force line intercept can be called a pitch centre, or that it necessarily tells us anything definite about what the car will do.

Mr Nowlan does not elaborate on what he recommends when both front and rear wheels are making x forces, but definitely neither will the average of the c of g plane / force line intercepts serve as a pitch centre, nor will a weighted average (except when the c of g is mid-way along the wheelbase), nor will the side-view intersection of the force lines.

So, is the idea of a pitch centre analogous to a roll centre useful or relevant at all? I think so. And we can assign it using a method closely resembling our front-view approach. Obviously, this will only work if the front-view approach is correct, and if we adapt it correctly.

One issue we need to address is that the term 'pitch centre' is already in use in another area of vehicle dynamics, with a meaning not analogous to a roll centre. Ride engineers speak of pitch centres and bounce centres. The pitch centre is a centre of rotation about which the car oscillates in response to sequential perturbations at the front and rear, as when going over a short speed bump. It is determined by the relationship of the front and rear static deflections or natural frequencies, and does not relate to pitch moments created by x accelerations, or opposing or exaggerating pitch moments induced within the suspension as a result of x ground-plane forces.

For anti-squat in a rear-drive car, F_{xf}/F_x = 1, and F_{xr}/F_x = 0. With all-wheel drive, F_{xf}/F_{xr} depends on the front/rear thrust ratio. In braking, F_{xf}/F_{xr} depends on the overall front / rear retardation force ratio.

With sprung diffs or inboard brakes, dx/dz is the value for a wheel that does not rotate with the upright. For outboard brakes, live axles, or odd cases such as Humvees and VW Transporters where the upright contains drop gears, dx/dz is the value for a wheel that does rotate with the upright or axle.

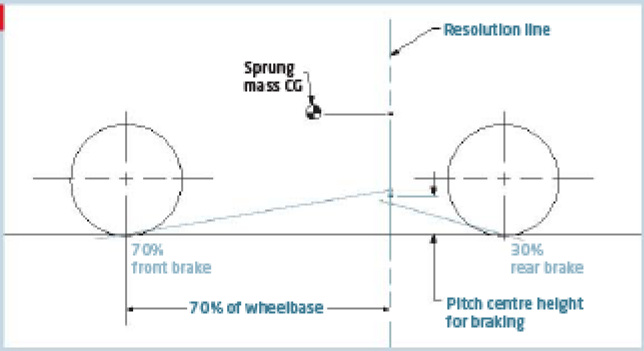
Doing the work graphically, we construct a vertical resolution line, positioned according to the F_{xf}/F_{xr} relationship. For propulsion with rear drive, the resolution line is at the front axle. For braking, it is aft of the front axle by a distance equal to the front overall retardation percentage times the wheelbase. Force lines are as described above: from the contact patch to the SVIC where torque does react through the linkage, and where torque does not react through the linkage, through the contact patch centre and parallel to a line through the wheel centre and SVIC. We then find the intercepts of the front and rear force lines with the resolution line, average these, and that gives us our pitch centre height.

The left and right pitch centres define a pitch axis, analogous to a roll axis. The left and right F_x values, times the respective Hpc values, divided by the respective wheelbases, are the left and right geometric load transfers. The total F_x for both sides, times the moment arm of the c of g about the pitch axis, divided by the total angular elastic pitch resistance rate, is the pitch angle. The right and left angular elastic anti-pitch moments, divided by the respective wheelbases, are the right and left elastic load transfers.

PITCH CENTRE

Figure 7

Application of the same principles to assignment of a pitch centre analogous to a roll centre



PITCH CENTRE ANALOGOUS TO ROLL CENTRE

What would a pitch centre analogous to a roll centre be? It would be a notional coupling point between sprung mass and wheel pair suspension, for the total x force of a right or left wheel pair, with front/rear x force distribution close to actual for the situation being modeled. It would have a height Hpc such that the total Fx for that side of the car, applied at a height Hpc, would produce no net pitch, because the geometry would produce an equal and opposite anti-pitch moment. The equations for this would be of the same form as equations (3a), (3b), and (3c):

$$F_x H_{pc} = \left(F_{xf}(dx/dz)_f - F_{xr}(dx/dz)_r\right)L_x/2 \qquad (7a)$$

$$H_{pc} = \left((F_{xf}/F_x)(dx/dz)_f - (F_{xr}/F_y)(dx/dz)_r\right)L_x/2 \qquad (7b)$$

$$H_{pc} = \left(L_x(F_{xf}/F_x)(dx/dz)_f - L_x(F_{xr}/F_x)(dx/dz)_r\right)/2 \qquad (7c)$$

Or, in English, the portion of the total x force at the front wheel, times the wheelbase, times the front wheel's force line slope, minus the portion of total x force at the rear wheel, times the wheelbase, times the rear wheel's force line slope, all divided by two, is the pitch centre height.

RACING GREENER

Against the grain

The case for the oldest, most versatile composite of them all

BY FORBES AIRD

Before Kevlar and carbon fibre, before glass fibre even, there was mud-brick, reinforced with straw. Composites, all of them. But long, long before any of that came the most astonishing and versatile composite of all: cellulose fibres in a matrix of lignin – wood, in other words.

It's amazing stuff, really. On an equal weight basis, it closely matches structural metals for stiffness and strength. You can shape it by hand with simple, familiar tools, you can even join it by driving nails into it (nails!) and it is both a renewable and biodegradable resource. Wood is also, however, bulky stuff – a certain mass of it occupies rather a lot of volume, compared with alternative structural materials. This can certainly be inconvenient when wood is used to handle bending loads – ie as a beam. Such beams may become so deep as to be annoying – especially if you bang your head on them. But, if arranged as a stressed skin, this very same bulkiness becomes a substantial virtue, as we shall see.

If it seems capricious to argue for wood as an attractive material, a preferable one even, for a high-performance structure, consider that history has demonstrated it to compete with structural metals in applications as diverse as boats, aircraft and cars – yes, even racecars.

THE PRACTICE

Several examples of successful wooden chassis for competition cars sprang from the drawing board of the late Frank Costin. His first, the original Marcos sports-racing coupé, staggered competitors and critics alike, both with its performance and its stupefying ugliness. Later, Nathan-Costin sports racers were far more attractive, yet equally successful. His F2 Protos, while sleek, performed disappointingly, though this was surely not the fault of its chassis material.

A much more recent effort is the 'Splinter' (see opening pic) – a high-performance coupé designed and built by graduate industrial design student Joe Harmon. This enterprise taxes credulity to the point of rupture. Not only is the primary structure of wood, the body is also of the same class of material (woven cherry wood), as are the suspension links and the front spring, a transverse leaf of laminated Osage orangewood. Doubters can check the website (see references at the end).

In the aviation field, one can point to the Lockheed Vega, the deHavilland Mosquito (perhaps the fastest propeller-driven bomber ever built), several thousand homebuilt aircraft and, of course, Howard Hughes' 'Spruce Goose'. This last, now reposing in its own museum in McMinville, Oregon, has the largest wingspan of any aircraft ever built at 97.54m. That it made only one, very brief, maiden flight in 1947 had nothing to do with the material of its construction and everything to do with the non-existence of adequately powerful engines, the eccentricity of Hughes himself and the timing of the end of WWII. The Bellanca Viking, still in production today, has a wing structure composed of plywood skins over a spruce spar.

Given even these few successful (structurally, at least) examples, it would seem hard to argue against the load-carrying efficiency of wood, yet one highly respected source dissents. Pazmany (see references) cites a 1945 SAE paper by Herb Rawdon (see references) in which the author compares outer wing panels in two generally similar aircraft – one made of wood, the other of aluminium – and concludes that wooden construction entails a 68 per cent weight penalty. A reading of the original source, however, makes clear that Rawdon was comparing apples and oranges. For economy and simplicity in manufacture, that particular wooden wing panel was made in such a way that it was distinctly non-optimal in weight vs strength and stiffness, while its metallic counterpart used best practice and was obviously more structurally efficient. The author's conclusion is unjustified, and Pazmany's acceptance of it seems odd.

Courtesy: Marcos Heritage

The gullwing Marcos sports coupé, otherwise known as the Ugly Duckling, successfully used a wooden chassis

> "it is both a renewable and biodegradable resource"

THE THEORY

So, it works in practice, but does it work in theory? Yes, and here's why: consider a roughly rectangular panel, thin in relation to its area. When you load such a panel in compression (stand it on edge and push down) or in shear (grab two opposite edges and try to warp the rectangle into a diamond shape), it will take only a comparatively small load before it buckles – before it 'runs away from the load'. In compression, the buckling will take the form of a simple curvature – it will bow into a 'C' shape, while in shear the result will be diagonal wrinkles. The panel has not broken (it would spring back if the load were removed) but it has, in a sense, failed – it has ceased to fight back.

Now, the ability of a panel to sustain such loads without buckling depends on just two things: the inherent stiffness of the material (its Young's modulus, represented by the letter E), and the panel's thickness. Reasonably enough, the effect of the Young's modulus is linear – a doubling of E yields twice the resistance. The effect of the thickness, however, is much more dramatic. The same parameter varies as the *cube* of the thickness – double the thickness yields *eight times* the resistance. It therefore follows that if two alternative materials are considered for such a panel, and if they have equal (or closely similar) values of stiffness (E) in relation to their density (D), then the less dense material will win, hands down.

Consider steel and aluminium. Steel is three times as stiff as aluminium, but has three times the density. For equal weight, the aluminium panel can therefore be three times as thick. A disadvantage of 1:3 (based on E) is overwhelmed by the advantage of the greater thickness (to the tune of relative thickness cubed – ie 27) so, in this respect, the aluminium panel outperforms the steel one by a factor of (27/3=) 9! That's one reason why they don't make the primary structure of aircraft out of steel.

The same argument can be applied to other candidate materials. Magnesium, for instance, has just 65 per cent the density of aluminium, yet has essentially the same value of E/D as aluminium or steel. On that basis, it ought to show a weight advantage of about 33 per cent. And it does. The reasons aircraft are not generally made from magnesium are threefold: flammability, corrosion and cost. Helicopters, however, where the price-to-weight ratio takes on a rather different complexion, do use lots of mag. The same argument can be extended to the least dense of all 'traditional' materials for stressed skin panels – wood, specifically plywood. Although it is slightly inferior to structural metals in weight-specific stiffness and strength (see chart), wood's low density (it floats, for Pete's sake!) permits panels that are very thick, and therefore well suited to resist wrinkling under compressive and shear loads.

This whole argument, of course, rests on the assumption of a nearly constant value of E/D for each candidate material. Among metals, wood and even low-tech composites using glass fibre, that assumption is, surprisingly, justified. Dr J E Gordon (see references) calls this 'one of God's little jokes.' But if that ratio strays significantly from that of traditional materials, then all bets are off.

Designers of aircraft and racecars have enthusiastically adopted modern synthetic fibres for composites – carbon fibre, Kevlar, Spectra etc – for this very reason. Their values of E/D are vastly superior to traditional materials, making possible structures of unprecedented efficiency. Composites also have the merit of being capable of being formed into complex, three-dimensional curves.

The benefits of modern composites are unarguable, but they are achieved at no small cost. One of the costs is, er, cost – this stuff is seriously expensive. Apart from the price of the raw materials, there is the need for a mould and, absent an NC mill, the mould requires a 'plug' – an original pattern. Moreover, the really high structural performance stuff is cured under pressure and at high temperature in an autoclave – a shatteringly expensive bit of kit. People working with aerospace budgets can afford this and those producing in quantity can amortise the tooling costs over umpteen parts. But for amateurs and one-offs, these costs are usually a deal breaker.

Even when the tooling and material expenses are covered by someone else's budget, the labour and logistical costs are high. Two consecutive technical directors of an FSAE team familiar to this writer have expressed the conviction that the potential structural benefits of their cars' carbon fibre tubs scarcely justify the student workers' hours of labour – about 800 hours in a recent case – time which might better have been spent in development and de-bugging of an earlier-completed vehicle. But, if such pragmatic considerations exclude advanced composites, then we are back to selecting from among materials that have a very similar value of E/D. And we have argued that this fact favours wood.

STRENGTH VS WEIGHT

Figure 1

Comparison of material bending stiffness relative to weight and thickness

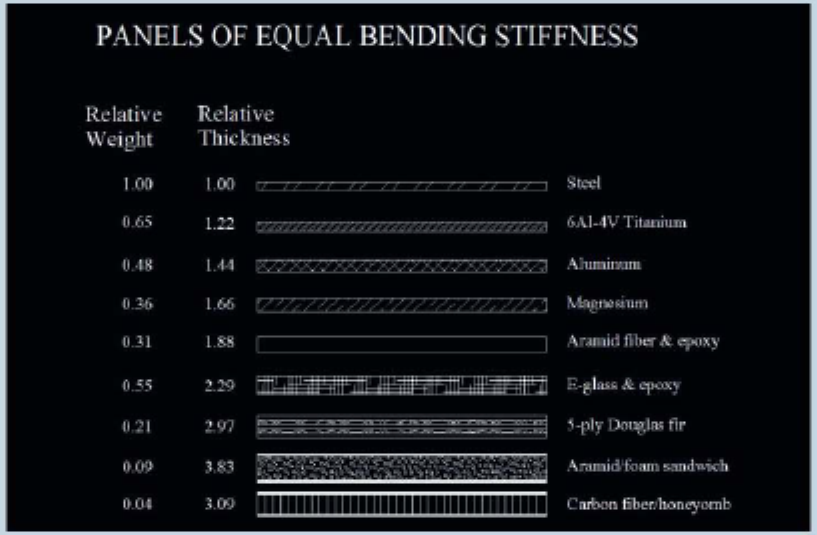


TABLE 1

Strength, stiffness and density of various materials

	UTS, ksi	D, lb/cu in	UTS/D	E, msi	E/D
SAE 1010 steel	60	0.3	200	30	100
SAE 4340 steel	195	0.3	650	30	100
6 Al-4V titanium	170	0.165	1030	16	94
SAE 2024 aluminium	67	0.10	670	10.6	106
AZ31B magnesium	42	0.065	646	6.5	108
Aramid fibre	435	0.05	8700	16.3	326
E-glass fibre	525	0.09	5833	10.5	117
Spruce wood	15	0.02	750	1.4	70
HS carbon fibre	600	0.07	8571	32	457
HM carbon fibre	325	0.07	4643	100	1429

SHORTCOMINGS

Of course, wood has its shortcomings, too. While concerns about rot and other biological infestations are well answered by modern chemical treatments and synthetic adhesives, other issues remain. We have explained that wood is a composite. As it happens, for the purpose and benefit of the tree from which it comes, the fibres in wood are all arranged parallel to each other, so wood is a unidirectional composite – it has a 'grain' – and so is much stiffer and stronger along the grain than across it. A rough averaging of the longitudinal and transverse properties can be achieved the same way as with other ud composites – multiple plies stacked at right angles to each other, in other words plywood. Also, unlike those in modern, man-made composites, the fibres in wood are hollow and contain water so, when the temperature approaches 100degC, the water begins to boil off and the wood shrinks and splits. This same sensitivity to water content also means that wood slowly changes size with changes in atmospheric humidity. Most of this dimensional change occurs in the cross-grain direction so, again, the plywood technique mitigates this.

> it closely matches structural metals for stiffness and strength

A remaining problem with plywood is the difficulty of forming it into complex shapes (though to all but the most skilled the same can be said of sheet metal). Simple, gentle curves in one plane are easy, tight radius curves are not. Three-dimensional curves would seem to be impossible but can, in fact, be achieved by essentially making the plywood in situ – laminating very thin strips of veneer over a form in successive plies, essentially at right angles to each other. This was the technique used by Costin for the previously mentioned Protos F2, and by Joe Harmon for the exterior surfaces of the Splinter. While highly convoluted surfaces may need tooling comparable to a mould for other types of composite work, simpler shapes may need nothing more than a handful of pre-cut planes perpendicular to the surface of the nascent panel – perhaps themselves forming bulkheads within the finished structure. While it is possible, easy even, to mis-apply modern synthetic composites (I have seen some rather dodgy efforts, even from bright engineering students), when used correctly their performance outstrips that of all traditional materials.

> wood is a unidirectional composite

Nevertheless, in many circumstances advanced composites are excluded from consideration because of their cost and that of the facilities necessary for their processing. In that event, a very strong case can be made for wood, specifically plywood, for stressed skin construction – its ease of working, the relatively low cost of both the material and of the tools necessary to cut and join it, its familiarity and its widespread availability... after all, it really does grow on trees. ®

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RACE MOVES

We have all heard the woodworm and dry rot jokes and I am for ever being asked about the longevity and problems experienced with a wooden chassis, so over the past year I have been monitoring the condition of all the wooden chassis cars that have been through our workshops, in order to prepare a qualified report on what I have discovered with cars up to 36 years old.

The main problems we have come across are 'cowboy repairs', including one owner who, and I quote, 'thought it would be stronger with steel plates either side of the wood…'

I cannot emphasise this enough – do not try to 'improve' a wooden chassis, it works extremely well as it is. If you have damage to the chassis then repair as per original. The most common reason for damage is the fitting of oversize wheels and tyres and too much power. The wooden chassis Marcos was designed to cope with up to around 125bhp delivered through 175 × 13 tyres. This limits the torque reaction set up in the chassis to the adhesion of the tyre contact patch. If this ratio is altered then problems will almost certainly occur.

> The main problems we have come across are 'cowboy repairs'

The second and only other real problem with the wooden chassis is water. It is perfectly capable of withstanding wet weather use and does not need any special attention in that area. What it will not tolerate, however, is water saturation. This is generally caused by leaks, allowing water to collect inside the car for long periods, which will then migrate into the structure and start to delaminate the plywood. Once this starts the only remedy is to remove the damaged area and replace. Do not be tempted to try to seal or waterproof the inside surfaces of a wooden chassis car as these must be left open to allow the wood to 'breathe'.

The Marcos' wooden chassis is a remarkable structure, being used in cars from 1964 to 1969. It has proven itself to be far superior to the later steel chassis cars, many of which are already on their second chassis. The 1800 version remains a competitive racecar, regularly winning in classic series, and will continue to do so for years to come.

Excerpt from *The Marcos Wooden Chassis* by Rory MacMath, courtesy of Marcos Heritage, UK – www.rory.uk.com

Courtesy Marcos Heritage

Wooden chassis Marcos continue to race competitively in classic Sportscar series today, often outliving and outperforming their steel counterparts

Force-based roll centres

LAT

Applying the concept to both symmetric and asymmetric suspension geometry

About two years ago, I read an article in *Racecar Engineering* by Bill Mitchell on force-based roll centres. This, for me, was one of those moments when the light bulb suddenly went on. It also illustrated for me the very powerful role this magazine plays. The unfortunate thing about motorsport is that there are precious few avenues where individuals can have a genuine technical discussion, but it has been my privilege to add in a small way to this discourse.

This article will follow on from the Mitchell feature and, in particular, will prove not only that his force-based approach was correct, but also that it applies for

BY DANNY NOWLAN

the asymmetric case as well.

Before launching into the subject, however, let me state what the significance of this article is. One of the first things I did when I started in motorsport was to generate a proof relating the forces and moments in roll to a symmetric suspension geometry arrangement. I was seeing all these diagrams and I wanted to prove it to myself. Anyway, as I read more about geometry and learned about the horizontal locations of roll centres, I began to incorporate all of this into ChassisSim. Most of the time it worked well, but every once in a while it would throw the odd 'joker' up, which struck me as odd. After reading Mitchell's article, I moved to the force-based approach, and those weird inconsistencies evaporated.

Without further ado then, let us set out the proof. This is illustrated in figure 1.

To make things as simple as possible, I've made the following assumptions:

- The lower control arms are parallel to the ground. This is to simplify the geometry, as I don't want us getting lost in the detail.
- The hub pick-up points are set at R/2 and 3R/2 for exactly the same reason.
- d1 is the half track length.
- I've also assumed the control arms are equally offset from

the axle line. This simplifies our view of how the forces act at the chassis. That is, we can view them as a straight line from the hub to the chassis on the axle line. I invite interested readers to work this out themselves.

The other simplifying assumption I'm going to consider is the pseudo-static case. That is, I'm just going to consider the forces transmitted through the suspension links and how they react around the c of g. I'll assume the bars and springs and ground reaction will keep the geometry in place. I'm simply doing this for clarity, because what we are after here is finding the relation between the geometry and how the forces are reacted. When we include the effects of bars and springs, these effectively form the full stop.

The first port of call then is to take a free body diagram of the tyres. Since the tyres aren't moving, and we are visualising this as a pseudo-static case, we can construct figure 2.

Analysing the forces and taking moments about the ground it can be shown,

$$\sum F_x = 0 = F_R - F_{13} + F_{24}\cos(\theta)$$
$$\sum M_O = 0 = F_{13}\cdot\frac{R}{2} - F_{24}\cos(\theta)\cdot\frac{3R}{2} \tag{1}$$

Solving for this it can be shown as follows:

$$F_{13} = \frac{3}{2}F_R$$
$$F_{24} = \frac{F_R}{2\cdot\cos(\theta)} \tag{2}$$

The astute reader will quickly recognise the same process applies for the left-hand side. Consequently, it may be shown as follows:

$$F_{13L} = \frac{3}{2}F_L$$
$$F_{24L} = \frac{F_L}{2\cdot\cos(\theta_1)} \tag{3}$$

Let's now check out what is going on with the sprung mass. Looking at the right-hand side and taking its component effects about the c of g, it can be shown that,

$$M_{c.g.RHS} = F_{13}\cdot d_y - F_{24}\cos(\theta)\cdot(d_y - c_y) - F_{24}\sin(\theta)\cdot(d_x + h_x)$$
$$= F_R\left(d_y + \frac{1}{2}\left(c_y - (d_x + h_x)\cdot\tan(\theta)\right)\right) \tag{4}$$

I have not tried to fudge equation (4), I've just spared you four lines of algebra. Similarly, looking at the left-hand side, it can be shown that,

$$M_{c.g.LHS} = F_{13L}\cdot d_y - F_{24L}\cos(\theta_1)\cdot(d_y - c_{y1}) + F_{24L}\sin(\theta)\cdot(h_x - d_x)$$
$$= F_L\left(d_y + \frac{1}{2}\left(c_{y1} - (d_x - h_x)\cdot\tan(\theta_1)\right)\right) \tag{5}$$

We now need to tie this into what is going on with the geometry. Let's re-visit figure 1, but this time let's look at the geometry. This is illustrated in figure 3 overleaf.

Looking at the instant centre for the right-hand side it can be shown that,

$$x_{IC} = d_1 - \frac{R}{\tan(\theta)}$$
$$y_{IC} = \frac{R}{2} \tag{6}$$

DIAGRAMMATIC ILLUSTRATION

Figure 1
A double wishbone arrangement with an asymmetric layout

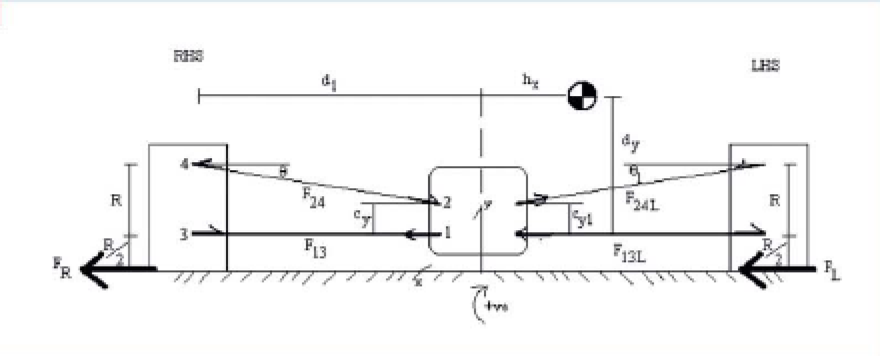
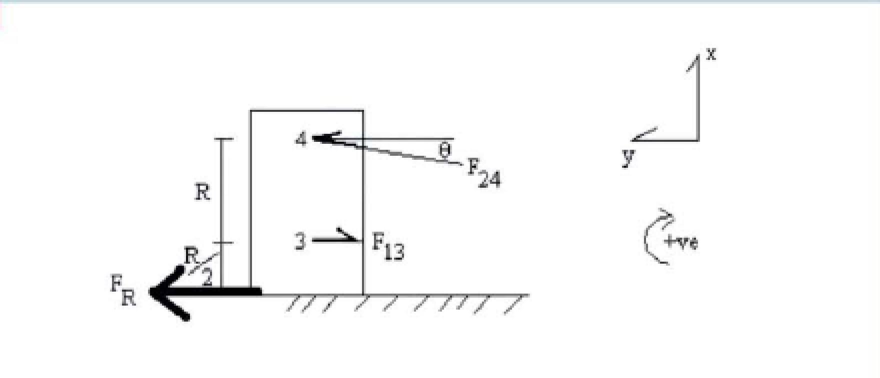


Figure 2
Free body diagram of the right-hand hub



This point is the intersection of the two arms on the right-hand side – I've simply saved you all the intermediate steps to get there. Given we have the instant centre location, we can now formulate the equation of the slope of the line from the contact patch of the tyre to the instant centre. This is given by,

$$y = \frac{-\tan(\theta)}{2}\cdot(x - d_1) \tag{7}$$

So at the c of g location at hx it can be shown that y is given by,

$$y = \frac{-\tan(\theta)}{2}\cdot(-h_x - d_1)$$
$$drc_{RHS} = \frac{\tan(\theta)}{2}\cdot(h_x + d_1) \tag{8}$$

We've had to put this in as negative because of where we have placed our origin at the centre line of the car. You might now be thinking, so what? The geometry seems to be completely disconnected from the forces. Here's where we produce our trump card. Looking at the geometry, it is readily seen that,

$$\tan(\theta) = \frac{\frac{3}{2}\cdot R - (c_y + R)}{d_1 - d_x}$$
$$d_1 = d_x + \frac{R - c_y}{\tan(\theta)} \tag{9}$$

At this point, we are ready to show something very profound. Let's now calculate the difference between the c of g height and the point specified in equation (8). It is seen that,

$$mom\_arm = h - drc_{RHS}$$
$$= h - \frac{\tan(\theta)}{2}\cdot(h_x + d_1)$$
$$= h - \frac{\tan(\theta)}{2}\cdot\left(h_x + d_x + \frac{R - c_y}{\tan(\theta_1)}\right)$$
$$= h - \frac{\tan(\theta)}{2}\cdot h_x - \frac{\tan(\theta)}{2}\cdot d_x - \frac{R}{2} + \frac{c_{y1}}{2}$$
$$= h - \frac{R}{2} + \frac{1}{2}\cdot\left(c_{y1} - (h_x + d_x)\tan(\theta)\right)$$
$$= d_y + \frac{1}{2}\cdot\left(c_y - (h_x + d_x)\tan(\theta)\right) \tag{10}$$

The astute reader will quickly recognise that the moment arm given in equation (4) is identical to the result shown in equation (10). What's even more significant is that our derivation of the geometry has come from completely different approaches. This is very telling. Knowing this, let's now consider the left-hand side. Looking at the geometry, it can be shown that the instant centre on the left-hand side is given by,

$$x_{IC} = \frac{R}{\tan(\theta)} - d_1$$
$$y_{IC} = \frac{R}{2} \tag{11}$$

So the equation of the line connecting the instant centre to the left-hand tyre contact patch is given by,

$$y = \frac{\tan(\theta_1)}{2}\cdot(x + d_1) \tag{12}$$

As such, the height above the ground at the c of g is given by,

$$drc_{LHS} = \frac{\tan(\theta_1)}{2}\cdot(d_1 - h_x) \tag{13}$$

The astute reader will recognise we'll have to employ the same trick as we did for the right-hand side to relate d1 to cy1 and tan(θ1). This is given by,

$$\tan(\theta_1) = \frac{\frac{3}{2}\cdot R - (c_{y1} + R)}{d_1 - d_x}$$
$$d_1 = d_x + \frac{R - c_{y1}}{\tan(\theta_1)} \tag{14}$$

So calculating the difference between the c of g height and drcLHS it is seen that

$$mom\_arm = h - drc_{LHS}$$
$$= h - \frac{\tan(\theta_1)}{2}\cdot(d_1 - h_x)$$
$$= h - \frac{\tan(\theta_1)}{2}\cdot\left(d_x + \frac{R - c_{y1}}{\tan(\theta_1)} - h_x\right)$$
$$= h + \frac{\tan(\theta)}{2}\cdot h_x - \frac{\tan(\theta)}{2}\cdot d_x - \frac{R}{2} + \frac{c_{y1}}{2}$$
$$= h - \frac{R}{2} + \frac{1}{2}\cdot\left(c_{y1} - (d_x - h_x)\tan(\theta)\right)$$
$$= d_y + \frac{1}{2}\cdot\left(c_y - (d_x - h_x)\tan(\theta)\right) \tag{15}$$

The astute reader will quickly recognise that the moment arm in (15) is identical to the moment arm given in equation (5). The significance of this is that it shows conclusively that Mitchell's force-based application methods apply not only for the symmetric case but also for the asymmetric case. Remember, in our construction we have not assumed symmetry for the arrangement of the suspension geometry. Yet the maths clearly indicates that for deducing forces and moments about the c of g, this method is valid, because the only assumptions we have made in our proof have been assumptions to make the maths and trigonometry simpler. For all intents and purposes, we have shown a very asymmetric case, and the reader will quickly recognise the symmetric case is simply a subset of the asymmetric case presented here. The question here then is that for convergent geometry, how do we work out forces and moments about the c of g? Let's illustrate this in figure 4 overleaf.

All we do is draw lines finding the instant centre and then draw lines from the relevant tyres to those instant centres. The moment arm is simply given by following the line from the tyre to the instant centre point under the c of g. This point I refer to as the force-based roll centre. It's that simple.

One question that remains unanswered, however, is how do we calculate the forces that are going straight into the tyre? These are often referred to as jacking forces. I could give another long proof on this, but the details are actually buried in the proof I presented earlier. It can be shown the jacking forces are given by,

$$F_t = F_y\cdot\tan(\phi_{IC}) \tag{16}$$

Where Ft is the force being applied straight to the tyre, Fy is the applied lateral force and ϕic is the angle of the line from the contact patch to the instant centre. I invite the interested reader to work this out on his or her own (motorsport engineering students, that means you).

Obviously, we have analysed the pseudo-static case, but what about the dynamic case? Looking at the numbers, the place where things will be affected will be in the moment equations because

“our derivation of the geometry has come from completely different approaches”

we now have to consider the effect of angular accelerations. The impact of these numbers, however, is very small. To illustrate this, let's consider a car with significant body movement. This is outlined in table 1.

Going through the numbers, the change in roll angle is about 0.02 rad. Making some relatively generous assumptions, we could approximate peak roll acceleration as 0.1 rad/s2. When we start multiplying this by the roll inertias we get about 25Nm for the body and 1Nm for the hub and tyre. Given that we have forces in the order of, say, at least 1g going through this, and assuming the car weighs 1000kg and a 50/50 weight distribution and a c of g height of, say, 0.4m, we are dealing with moments in the order of, say, 750Nm at the hub and numbers in the order of 4000Nm for the body. The

TABLE 1

Some representative numbers for a dynamic analysis of roll forces

Parameter	Value
Body roll	30mm
Track	1500mm
Time for the manoeuvre	1s
Body roll inertia	250 kgm²
Tyre/hub roll inertia	10 kgm²

reader will quickly appreciate this will have a critical impact on the third or maybe second significant figure for calculating roll angles and the like. Consequently, the analysis presented here can be used for real racecar work.

The only real question that remains now is what do we do when the arms are parallel? Well, if the reader will recall my article in *Stockcar Engineering* (RE V19N6/SE 4) on live axle toe steer, I looked at this to analyse what was going on with anti-squat / dive. Applying those same techniques and assuming the c of g is at the centre of the car, we can conclude that,

$$\sum M_{cg} = F_y \cdot \left(h - \frac{t}{2}\cdot\tan(\phi)\right)$$

$$mom\_arm = \left(h - \frac{t}{2}\cdot\tan(\phi)\right) \quad (17)$$

Here t is the track, and ϕ is the angle of the arms relative to the ground. I'm going to leave the derivation of this to the interested reader. I would also invite the reader to extend this for the asymmetric case. I'm leaving this to readers because they will realise there is an elegant link between what we can do with suspension geometry forces and anti-dive and anti-squat. I will be talking about this at length in a future article.

In closing, we have shown without a shadow of doubt that not only are the force application methods of Mitchell valid, but also apply for the asymmetric case as well. We also discussed some very useful methods along the way of calculating this, and the jacking forces came out of this as a by-product. Lastly, I've left interested readers with a teaser that I trust will have them pulling out pen and paper and considering the matter further. Trust me, the rewards will be worth the work involved.

DIAGRAMMATIC ILLUSTRATION

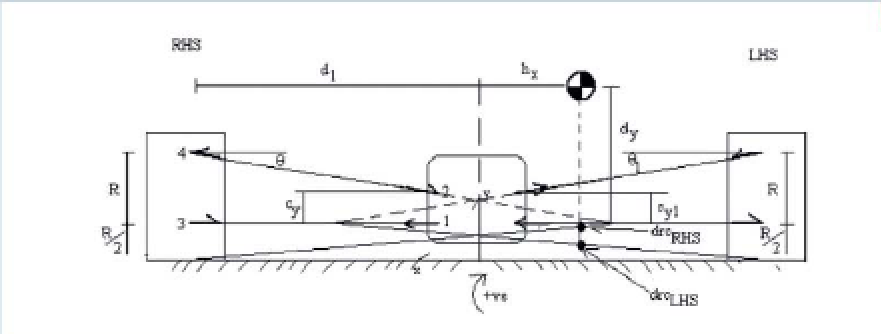


Figure 3

Illustration of the instant centres

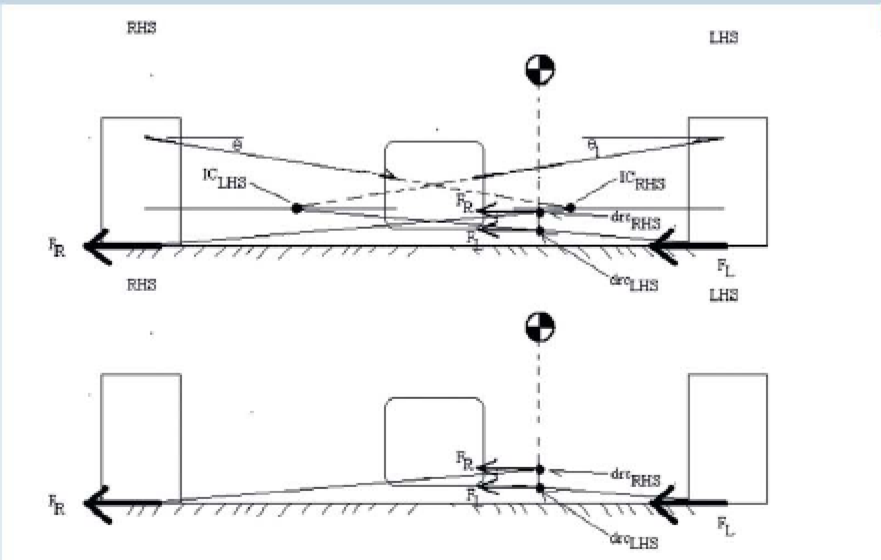


Figure 4

Graphically calculating force-based roll centres

Formula future

Some quality engineering and design this year, but the real surprises were to come in the low carbon class

BY RACECAR STAFF

For the second year running Rennteam Stuttgart took the top honours at Silverstone in the increasingly prestigious British FSAE round, Formula Student. The German team's F0711-4 (above) dominated the Sprint event, completing the course almost two seconds faster than anyone else and looked set to repeat that performance in the Endurance event until the British weather intervened and left the car a distant 13th (including the new Class 1A runners).

'All the statics went quite well,' adds Ronald Mueller, the team's leader. Whilst the car did not make it into the Design final it was the best of the rest, and looking over the neat white car revealed plenty of interesting detail. 'The main difference to last year's winning car is that we replaced the tubular steel chassis with a carbon fibre monocoque,' reveals Mueller. 'This was mainly due to the new rules in FSAE regarding cockpits and the templates they have to conform to. With a monocoque you have more freedom with shapes and you can put the suspension pick-ups wherever you want without having to worry about the nodes

OVERALL WINNERS

FSAE VIR

1ST
Missouri University of Science
852.8 points
2ND
University of Oklahoma
808.4 points
3RD
University of Illinois – Urbana Champ
787.3 points

FSAE Michigan

1ST
Graz University of Technology
833.5 points
2ND
Rochester Institute of Technology
813.6 points
3RD
ETS
789.6 points

FSAE California

1ST
Rochester Institute of Technology
885.6 points
2ND
Oregon State
876.7 points
3RD
University of Kansas – Lawrence
815.3 points

Formula Student

1ST
University of Stuttgart
791.5 points
2ND
TU Delft
786.3 points
3RD
ETH Zurich
766.4 points

Formula Hybrid

1ST
Texas A&M
980.9 points
2ND
Colorado State
757.7 points
3RD
Drexel University
689.4

Now featuring a carbon fibre monocoque the Stuttgart entry soundly thrashed the opposition in the Sprint event

as you would have to with a tube frame. The other reason we opted to go for a carbon tub is so we could increase stiffness. Last year when we increased the stiffness of the steel frame from the second car to the third car we found 20 per cent, which improved the driver feedback, so we thought that more stiffness could improve it even more.'

Handling and responsiveness were something the German students focussed on, and with such excellent dynamic performance it seems to have worked. 'The increased stiffness, in combination with our very low friction dampers, makes for very good driver feedback. In testing, we found that even small changes to the damping and the anti-roll bar gave the drivers good feedback, so we could find a good race set up in a short time.'

The F0711-4 is fitted with Formula 3-spec dampers from ZF Sachs. 'They have through-rod technology, so they run at minimum gas pressures,' explains Mueller. 'Also, on the spring there is an axial bearing because when you compress the spring this leads to a torsion and the bearing reduces friction.'

As well as the dynamic benefits, Mueller argues that there are cost benefits to running a carbon chassis. 'The advantage of a monocoque is that when you consider everything is meant to be based on a production run of 1000, it becomes quite affordable as you can re-use the tooling. Therefore it is not much more expensive.' Stuttgart came 35th in Cost.

FUEL CONSUMPTION

For 2009, FSAE rule changes put extra importance on the cars' fuel consumption, and the Stuttgart engine team kept that in mind when developing the car. 'Our main goal was to reduce consumption. We cut the maximum engine speed to 11,000rpm when last year we had 13,000rpm. However, we have kept the power and torque at about the same level.'

The transmission is the standard Honda unit, rather than the bespoke unit the team used last year. 'The advantage of it was outweighed by the cost and and reliability issues so that led us to the Honda unit. We would have liked to develop ours but our financial situation didn't allow it.'

> "We cut the maximum engine speed to 11,000rpm"

TECH SPEC

RENNTEAM STUTTGART F0711-4

- Class: FSAE
- Chassis: carbon fibre monocoque
- Length: 2697mm
- Width: 1420mm
- Height: 1055mm
- Wheelbase: 1635mm
- Track: 1214mm front/ 1142mm rear
- Suspension: double wishbone
- Dampers: pushrod-actuated Sachs F3
- Brakes: outboard discs all round, Bosch ABS M4
- Tyres: 7 × 13 Hoosier
- Differential: Drexler
- Diveshafts: in-house fabricated carbon fibre
- Final drive: 3.8:1
- Weight: 209kg
- Engine: Honda CBR-600 RR
- Power: 95bhp
- Torque: 68Nm
- Bore: 67mm
- Stroke: 42.5mm
- Management: MoTeC
- Lubrication: dry sump

RACING GREENER

Electric shock

The University of Hertforshire's UH12A impressed many with its simplicity and speed, finishing sixth in the Endurance in wet conditions

Oxford Brookes entered a petrol / electric hybrid car in the 1A class for the second year running. It performed adequately but not spectacularly

The all-electric UH12A has 240 LiFeBATT lithium-iron phosphate cells, which provided more than enough power to finish the Endurance section

The ETH Zurich hybrid appeared to be well engineered, but struggled to finish the full Endurance course, slowing drastically in the final laps

Environmentally friendly, or 'green', motorsport is something the industry is currently consumed with, but Formula Student has been ahead of the game on this for some time, with biofuels, hydrogen and hybrid-drive vehicles all running in competition since 2007 (though admittedly the first year was a demonstration event only).

But last year, IMechE formally launched Class 1A – a category specifically for low-carbon designs. It is open to cars that meet all the normal regulations for Class 1 cars, except those that relate to powertrain. In place of the original rules, which allow only a petrol- (or E85) burning engine to power the vehicle, the new Class 1A rules allow a wider range of fuels and hybrid vehicles with more than one form of power. Cars using petrol or E85 may be eligible for either Class 1 or Class 1A and may be entered in either (but not both), although naturally Class 1A rules favour the low CO_2 nature of the chosen fuel and smaller engine capacity.

COMING OF AGE

In previous years the 1A cars have been slow and unreliable, but in 2009 they came of age. In the wet conditions cars from the University of Hertfordshire (electric), UCLAN (250cc E85), ETH Zurich (gas / electric hybrid) and Oxford Brookes University (gas / electric hybrid) more than matched their conventional rivals. Eventual 1A winners, the University of Hertfordshire, finished the Endurance event in sixth place overall.

TECH SPEC

UNIVERSITY OF HERTFORSHIRE UH12A
Class: FSAE (FS 1A)
Chassis: tubular steel frame
Length: 2565mm
Width: 1398mm
Height: 1249mm
Wheelbase: 1535mm
Track: 1200mm front/ 1190mm rear
Suspension: double wishbone
Tyres: Avon A45 slicks
Final drive: 4:1
Weight: 195kg
Engine: 2 × LMC 72v permanent magnet DC motor

Herts entered two cars into competition – its four cylinder, Yamaha-powered UH12 into class 1 and its all-electric UH12A into class 1A. The latter stunned onlookers with its simplicity and pace. 'We wanted to make a 1A car that would match the speed of class 1, and it's essentially the same as the class 1 version,' explains team leader James Major, 'with pretty much the same dimensions, the same chassis and suspension, just a different powertrain. It's a high voltage, pure electric system – 144v with a 50Ah capacity. There are two brushless, direct current electric motors connected in series on a single shaft, so they are mechanically connected together and run through a differential and sprocket. It's the same as we run on the class 1 chassis.'

AWARD WINNERS

CLASS 1 (200)
TU Munich

CLASS 2
Liverpool John Moore

CLASS 3
Isfahan University

SUSTAINABILITY
UCLAN

COST
University of Bath

PRESENTATION
University of Karlsruhe

ACCELERATION
UAS Kiel

SKID PAD
TU Graz

SPRINT
University of Stuttgart

ENDURANCE
Swansea

FUEL EFFICIENCY
University of Aberdeen

LOWEST CARBON
University of Hertfordshire

BEST NEWCOMER
University of Aberdeen

MOST PROFESSIONAL
UAS Graz

TEAMWORK
University of Aberdeen

WEIGHT
TU Delft

INNOVATIVE DESIGN
Imperial College London

DATA ACQUISITION
Queens University Belfast

ELECTRICAL SYSTEMS
ETH Zurich

COMPOSITES
TU Munich

ENGINEERING
TU Delft

Providing power to the twin motors are 240 prototype lithium-iron phosphate 10Ah cells. 'It has a LifeBatt management system, which consists of a management circuit for every four cells, and each one is balanced by one more,' Major explains. 'The cells themselves are capable of 3000 cycles and are quite recyclable. There is only a trace of lithium, the majority of the cell make-up is copper and aluminium, so when you look at actual usage you are talking about a penny a mile.' At the competition, a number of people were overheard commenting on how nobody had actually seen the team charging the batteries, and Major explains why: 'We charged it for about half an hour before the Sprint and for about an hour before the Enduro. We have enough capacity to do a fair bit more than the Endurance run, though. In theory, you could increase the discharge rate but we are quite close to the limit already, both on the batteries and the controller. It's the greenest car here, we have zero emissions and with green resources you can get zero emission electricity.'

One amusing incident relating to the UH12A was when it was forced to go through the noise test. 'Unfortunately, we achieved 99db, but that's purely to do the test as we had to have the chain rotating, and that's not the case for any other car,' Major concludes with a smile.

Cool, calm and connected

Swedes learn from year one and produce a great contender

One of a number of vehicles to catch the *Racecar Engineering* eye at this year's Formula Student event was the Clear River Racing entry of Sweden's Karlstad University. Only competing for the second year in FS, these students had obviously observed and learned the lessons well from their initial experience last year.

Beautifully presented, with the body design and paint scheme inspired by the 2001 Lola B1/00 CART chassis of Swedish racing star Kenny Brack, our initial attention was drawn by the car's performance during the Friday practice sessions.

Where a number of teams were struggling with engine or handling problems – or both – and appeared occasionally flustered, the Karlstad entry started on the button every time, ran strongly and displayed good performance and handling, albeit initially with some lifting of the inside rear wheel when turning tightly. The Swedes also appeared to be working calmly and effectively. In short, it looked to be a very well-sorted effort.

The impression was confirmed when we spoke with team leader Mattias Karlsson. 'We wanted to improve almost everything on the car from last year, as that was very much a learning experience,' he observed. 'We have read a

> "the Karlstad entry... ran strongly and displayed good performance and handling"

Well prepared, well organised and good looking, the Karlstad University entry was a model Formula Student entry

TECH SPEC

CLEAR RIVER RACING (KARLSTAD)

Chassis: tubular steel spaceframe
Length: 2750mm
Width: 1590mm
Height: 1240mm
Wheelbase: 1750mm
Track: 1340mm front/ 1290mm rear
Suspension: double wishbone
Tyres: Hoosier slicks
Differential: in-house built Torsen unit
Final drive: 5:1
Weight: 200kg
Engine: Yamaha YZF-R6
Bore: 65.5mm
Stroke: 44.5mm

DESIGN CLASS

Six cars were selected for the Design final – Oxford Brookes (100), UAS Zwikau (96), UAS Graz (3), Helsinki (5), TU Vienna (41) and TU Delft (2). In the end, the lightweight car from Holland was considered the best of the group. Its ergonomics and reliability were critical factors, as was its very low weight However, on track the little car struggled to match the pace of Stuttgart and its drivers complained of understeer. Ultimately, that cost the team overall victory

The Design category winner, from TU Delft

lot more books in between and looked at other cars.'

He explained that the team's focus for 2009 was on building a light, reliable, simple car, but one that addressed what were felt to be two particular weak points of last year's machine: suspension design and engine management.

DESIGN PHILOSOPHY

Knowing that, it could be seen how Karlstad's decisions on design philosophy for its new car were reflected in all aspects of the finished product. Last year's chassis, for example, was very stiff but deemed unnecessarily heavy. The 2009 chassis – again, a tidy, tubular steel spaceframe – was simulated in Ansys before being fabricated in the Karlstad University workshops. 'We have two excellent welders, one of whom is very good at aluminium,' explained Karlsson. 'We spent a lot of time and money having the chassis made really well.'

Connected to the chassis was a conventional suspension arrangement of unequal length wishbones (tubular stainless steel) with pushrods acting on horizontal spring/damper units at the front and vertical units at the rear. Significantly, the new design eliminated the suspension flex detected in last year's car.

> "a light, reliable, simple car"

Other notable features of the 2009 car included:

- Power Commander control unit to manage the fuelling of the Yamaha YZF-R6 engine.
- A sintered nylon plenum to increase airflow through the restrictor.
- Tuned inlet manifold lengths to improve low-speed response.
- Exhaust primary lengths matched to within 1cm.
- Hollow driveshafts and the removal of fourth, fifth and sixth gears from the transmission to reduce inertia
- FEM-optimised uprights, plus hubs and differential brackets of high-strength aluminium alloy to reduce unsprung weight.
- Adjustable Torsen differential in a student-designed housing
- Electronic, solenoid-operated, paddle shift system with lever-operated mechanical back up using push-pull wires.
- Racing clutch to eliminate potential of wheel lock-up on downshifts.

The cost attached to the finished car? A very precise $80,131 (£48,550), according to the team leader, with most 'sponsorship' coming in the form of parts and manufacturing assistance from a number of Swedish companies enthusiastic about motorsport.

With the Karlstad University entry looking strong at Silverstone, it seemed a fair assumption the students would be pleased with their performance. 'Yes, very, it has gone super so far,' responded Karlsson. 'We are aiming for the top 25 this year and, if we accomplish that, we will be more than satisfied.'

In the event, they finished an excellent, and deserved, 17th in the final standings. Definitely a team to watch in the future.

Eibach UK to act as motorsport hub

German suspension manufacturer expands its operation in Europe

Increased stockholding and centralised logistics are set to increase support

Eibach UK, the wholly-owned subsidiary of Eibach GmbH, the respected German suspension manufacturer, is to become the hub of a pan-European network to further improve the company's levels of service and delivery to its motorsport clientele.

Currently enjoying a busy season, the move sees an expansion of the UK division's role in maintaining its existing customer base while growing new relationships with other teams and manufacturers. With many of the sport's big names being based in the UK, much of Eibach's burgeoning order book was already serviced domestically, but the new deal sees responsibilities much further afield for the Midlands-based outfit.

> “further improve the company's levels of service”

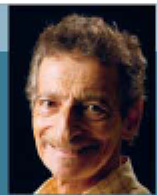
'By centralising stock, logistics and planning, we're hoping to improve yet further on our levels of support,' commented UK managing director, Julian Gill. 'We will still be working closely with all of our local importers and distributors in each territory, but this new structure means we can increase investment in stockholding and staffing to make life even easier for our clients. The message is "We're here to help" and I believe this new structure will facilitate that.'

Eibach's current order book includes many of the leading Formula 1, WRC, GT and BTCC teams, and it is hoped that this latest move will put more of Europe's grids onto the company's ERS spring range.

For more information, visit www.eibach.co.uk or call the team on 01455 285851.

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

SHOW TIME



TONY TOBIAS

Be prepared...

More showtime tips from Tony Tobias. This month, preparation before the show

AUTOSPORT INTERNATIONAL Engineering Show

14 - 15 January 2010 NEC Birmingham, UK

In association with Racecar engineering

TRAVEL
Aim to book airline tickets as early as possible to get the best prices. The same advice applies to car ferries and trains.

HOTELS
Reserve accommodation early too, but also make a point of trying to find out where the popular hotel is. After-show networking is a valuable opportunity to meet important individuals in the industry, ideally over a meal or drink and away from the show, and your competitors.

> “choose effective communicators who show passion and enthusiasm”

STAND RENTAL
Consider your options carefully. It may be cheaper to rent a stand locally if there are expensive haulage charges involved in shipping your own. Look in the show catalogue to get an idea of rental costs.

STAND DESIGN
Prepare your stand design early and make sure the graphics and colour scheme, including carpets and furniture, are carefully considered. Order lights, power points and telephone connections in advance, and remember to take the necessary adaptors for overseas shows.

If you are shipping product, choose a reliable freight company and obtain tracking details in case anything goes missing or is late arriving. Make a point of taking a few samples and some display material with you, again just in case your stand shipment gets held up.

STAFFING
When selecting staff for your stand, choose effective communicators who will show passion and enthusiasm for your products and are fully conversant with them. They will need to be able to provide information about company origin, production processes, shelf life and shipping methods quickly and accurately. They should also be well schooled on stand etiquette and best practices for making visitors feel welcome.

Dress smartly, displaying the company id and name tags where applicable as it identifies the staff with the brand and helps break the ice with visitors. Ensure eating and drinking on the stand is kept to a minimum, and always arrive early each day, to be prepared and just in case there has been a problem on the stand.

Walk the show to check on other companies – it will always provide you with some useful tips – and, at the end of each day, have a 10-minute catch-up with your colleagues to compare notes.

MARKETING
Ensure you prepare enough media kits and brochures as it would be more than embarrassing to run out on the first day – and yes, it does happen. Take sufficient quantities of business cards too, as it is highly unlikely you will be able to have new ones printed while at the venue that are to the quality you require.

Consider advertising in the show guide or show media, and be sure to always put your stand number on any promotional material to help direct visitors to your stand.

Try to look at a list of the other exhibitors before arriving at the show and, if you know who some of the show visitors are, send them an email inviting them to visit you. Again, always give your stand number.

AFTER THE SHOW
For canny exhibitors, the show doesn't end when the doors close on the final day. To get the most from any exhibition, make sure you retrieve all your leads and business cards and, once back in the office, follow up every lead and enquiry by mailing your company brochures and, if it's appropriate, a promotional gift.

Effective display stands are as much about the people as the products

Gripping developments from Titan

New markets open up for well known engineering company

Titan Motorsport, a regular exhibitor at Autosport Engineering and already booked to appear at the NEC next January, has been having an encouraging year, despite the current economic gloom. A new range of differentials, said to provide extremely smooth and progressive torque transfer, plus increased business arising from a recent trip to the US, are just part of the story.

St Neots-based Titan was formed in the late 1960s, manufacturing Formula 3 and Formula Ford chassis. It has evolved over the years into a high-quality component manufacturer, known particularly for its steering systems, but also involved in a variety of power unit-related products. The new Titan Traction Master is the latest addition – a limited slip differential that will be on display on the company's stand at Autosport Engineering.

Traction Master has been developed directly from a clutch-plate LSD and is purpose built for motorsport. Three variants are initially available: the Sierra 7-inch, Atlas and English. Titan's sintered clutch plate coating, Sintrak, ensures the unit increases load to the slipping wheel in a smooth and linear manner. The company also claims its coated clutch plates are able to transfer significantly more torque across the rear axle to the tyres with higher levels of grip than steel-plated differentials. A further benefit of the coating is that it reduces and, in some cases, eliminates the high levels of NVH often experienced with clutch-plate LSDs.

Titan is also currently working with a technical partner to introduce variable ratio steering into more forms of motorsport. This technology has been popular in Formula 1 and Zoë Timbrell, from Titan's sales and marketing department, says the company is keen to make it more accessible.

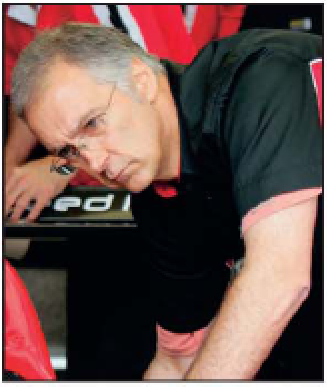
> “smooth and progressive torque transfer”

As a direct result of a recent visit to the US, the company is now developing a range of products to suit the drag racing market, too. It is working closely with Top Fuel and Pro Modified chassis builders to ensure the components meet the exacting requirements of this highly specialised branch of motorsport. Details will be announced shortly.

Furthermore, Titan Motorsport has now established solid working relationships with a number of new technical partners to further develop and expand its business in the US. The opportunity to meet North American companies is also available to exhibitors at Autosport Engineering, as many of these attend the show.

'This will be Titan's fifth year at Autosport,' says Timbrell. 'It provides an opportunity to meet new and existing customers and is an important date on our sales and marketing calendar. We very much look forward to attending.'

STEVE KENCHINGTON
THE INTERVIEW



Q Litespeed was among the new teams looking for a slot on the F1 grid. Was it disappointing not to be among the chosen three?
Yes, it was. F1 was always in our business plan, but the advent of the budget cap accelerated that process and gave a real opportunity for new teams to join. I think the budget cap was a very good thing for F1, and also a good thing for aspiring teams.

We're maintaining our design efforts, so if a slot does occur in the near future, we should be able to tap into that. We're designing the car in conjunction with Mike Gascoyne, and the car will be built here in Norfolk... We're ex-Lotus people, so the initial thought was, why not try and bring Lotus back.

Q In the meantime, you campaign the Litespeed R1 in the British Formula 3 Championship. How did that project come about?
Through an acquaintance I became aware that the SLC project cars, and the rights to the design were available. We were interested in going on to understand how the cars worked and then to design our own car in the future.

At the moment, we're just racing the cars in the National Class and the ability to develop them is very restricted.

We are gaining experience running the cars and, with our design strengths, we anticipate we should be able to design quite a reasonable car in the future. We probably operate slightly differently to other F3 teams in that we don't have any mechanics. Everyone that works on our cars is a degree qualified design engineer. The reason for this is that when you design a car, if your design engineers don't understand what's good in terms of assembly or detail engineering then they will design a car that is difficult to work on. It's like an accelerated learning programme.

Q How does the Litespeed differ from the Dallara?
The Litespeed's monocoque is slimmer and tapers in more, so the car is reasonably quick in a straight line when compared to a Dallara – that's probably the key thing. Also, the detail engineering on the car, especially the carbon composites, is very nice compared with the Dallara.

Q How has the team performed so far?
On occasion we've done quite well. We did well in our second race at Brands Hatch, where we finished a strong second, so we've had our moments.
But, to be honest, the biggest issue we have is that most of the teams we're racing against in the National Class have been running their cars since 2005, so they have a large database of how to set their cars up.

Q What are Litespeed's future plans in F3?
Next year we will be consolidating and running some cars in the International Class, and we want to grow the F3 side of the business. We still want to design a car, but it's not reasonable to design a car until 2011 because they have extended the life of the cars to four years, so we will probably run another manufacturer's car in the meantime, whether it's a Dallara or a Mygale.

Steve Kenchington, director of engineering, Litespeed
- 1982-1988: raced and engineered in club-level Formula Ford
- 1991-2003: Stevens Motorsport, ARP F3 and FF1600. Designed SM01 FF1600 chassis
- 1992-2008: Lotus Engineering, director of control systems and one of the originators of Lotus Active for Team Lotus F1. Also worked on control systems projects for race, road and military applications.
- 2008-2009: Litespeed F3, director of engineering

RACE MOVES

Geoff Willis has left the Red Bull Formula 1 team. Willis joined Red Bull in 2007 after five years at BAR/Honda. He has also worked at Leyton House and Williams during a long F1 career. A team spokesman said that Willis' position had become redundant.


Geoff Willis

The Motorsport Industry Association has recognised **Ross Brawn** for his 'most outstanding contribution' to the motor racing world. Brawn's award was presented by the right honourable Paul Drayson, UK minister of state for innovation, at the MIA's annual summer reception at the House of Lords.

Grant Rushton has left Menard Competition Technology to take up a post at Oxford Technologies. Rushton worked at Menard for six years, during which time he was involved in many of the company's engine projects, including the Infiniti IRL, NASCAR Chevrolet SB2 as well as Superleague Formula V12.

Brawn GP's deputy technical director, **Joerg Zander**, has left the team. Zander joined Brawn in 2007, when it was still operating as Honda, and is said to have played a role in the creation of the BGP 001 racecar. The German has previously worked at BMW-Sauber and Williams.


Malcolm Wilson

M-Sport boss **Malcolm Wilson**, the man behind Ford's World Rally Championship effort, has been awarded an OBE for services to British Motorsport.

Francesco Nenci has left the Toyota F1 team. Nenci, who was Timo Glock's race engineer, has been placed on gardening leave until the end of the year – when his contract expires. **Juan Pablo Ramirez**, formerly a test engineer with the team, will take over Nenci's position in the interim.

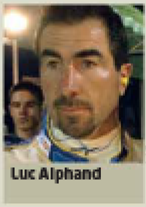

Tony George

Tony George has resigned from his post as head of both the Indianapolis Motor Speedway and the IndyCar series. However, he remains

RACE MOVES

on the board of Hulman-George – the company that owns the track and the championship – and will continue to run his own team, Vision Racing, in IndyCar…

…meanwhile, the role of president at Hulman-George vacated by George will now be filled by **W Curtis Brighton**, formerly the group's executive vice president and chief legal counsel, while **Jeffrey G Belskus** is now the president and CEO of the Indianapolis Motor Speedway.



Luc Alphand

LAT

Sportscar owner/driver **Luc Alphand** has suffered severe back injuries in an off-road motorcycling accident. Alphand, a former ski racer and Dakar front runner whose eponymous team runs cars in the FIA GT Championship and the Le Mans Series, is to be out of action for some time.

Trip Bruce is the new crew chief on the Rusty Wallace Racing no 66 Nationwide NASCAR entry. The car's former crew chief, **Dale Ferguson**, has been promoted to the role of lead engineer in the team.

Silverstone Holdings Ltd, the company which manages the British GP-hosting venue, has announced **Peter Williams** and **Stephen Morris** as non-executive directors.

Tempus Sport team director **Richard Coleman** has split from the Chevrolet Lacetti BTCC team to form his own outfit, Bamboo Engineering. Coleman has taken the car, driver and engineering set-up with him and will continue in the BTCC, while Tempus has ceased its involvement.

Brawn boss **Ross Brawn** is to be the patron of the SKIDZ Motor Projects charity – a scheme that provides opportunities for disadvantaged children to gain motor trade and engineering skills and experience.

Karting legend and one-time Formula Zip racecar constructor, **Martin Hines**, is said to be considering a move into racecar preparation, most probably in historic saloon cars.

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

STRAIGHT TALK

Formula for life

PETER WRIGHT

Thoughts on the future of motor racing's premier series from the FIA's technical consultant

I started working in Formula 1 in 1967, and it has been an abiding passion for me ever since. In the 40-plus years of being involved I have seen enormous change take place, much of it guided and controlled by Max [Mosley] and Bernie [Ecclestone], until now. Formula 1 has become an economic and technical *tour de force*, but it now faces uncertainty, both due to environmental concerns for the sustainability of human life on the planet and the economic sustainability of a global trade system based on exponential growth. Mosley understands these threats and is leading the governing body of International Motor Sport, the FIA, in an attempt to change Formula 1 such that it survives.

There has been much talk of maintaining the DNA of Formula 1, and using this as an argument against radical change. However, this seems to me to be confused. DNA is the formula for life and, as such, exists in a wide variety of host organisms. Its main objective is to reproduce. It doesn't die when its host dies, but it can't reproduce itself once its host expires. Darwin's evolutionary theories are often quoted as survival of the fittest, and this seems to be how Formula 1 sees its DNA should be preserved. However, this ignores Darwin's overriding theory that life's primary purpose is to reproduce itself, and to do that it must first ensure its host organism survives. Life and DNA have evolved one particular, very clever characteristic that enables it to be successful in this quest, as it interacts with the environment in which it exists. It randomly mutates, and natural selection promotes those mutations that are best suited to the environment ie it adapts to a changing environment. History is full of life forms that failed to adapt, of particular note is the extinction of the dinosaurs at a time when the environment underwent major change. The much smaller mammals were able to adapt and survive.

> "[F1] needs mutations to enable the new world order"

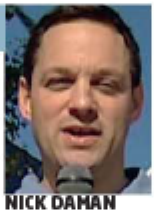
Formula 1 needs to change. What is debatable is what it should change into. It needs mutations to enable the new world order, whatever that turns out to be, and can select the form most suited to survival and success. So far, all mechanisms for major change initiated by the FIA have or are in the process of being rebuffed. Whilst writing this piece, a settlement has been brokered between the FIA, CVC and the F1 teams. There is change embodied in it, but whether this is enough to enable F1 to survive remains to be seen.

LAT

Life and thus DNA evolves, and in the past Formula 1 has done so too, as these historic Mercedes-Benz grand prix cars show. Is it time for another step?

OPINION

Small scale engineering



NICK DAMAN

The cheapest, most accessible form of motorsport known to man?

The most technically advanced racecar in production today is a Touring Car. Now before you all reach for your keyboards to shoot off a stream of nay-saying missives, let me elaborate. I'm not talking about a WTCC or BTCC production econobox, or even a spaceframed silhouette DTM car, but a 1/10th scale radio control electric racecar.

Let's look at the headlines: electric power; four wheel belt drive; adjustable limited slip differential; easily adjustable spring, damper and roll bar rates; fully adjustable roll centres, camber, castor, wheelbase and flexible weight distribution. Performance? Scale speeds in excess of 650mph and an actual 0-60mph time of less than two seconds. And rather impressive cornering, too. Add to this that it is the cheapest form of motorsport available (The UK governing body, the British Radio Car Association (BRCA), is affiliated to the MSA) and has no age limits, and you have a powerful argument in favour of R/C racing's accessibility.

Radio control car racing started in the early '70s, initially with fuel-powered, large-scale cars racing on kart tracks, and over time has successfully branched into off road, with both 8th and 10th scale off-road buggies (the larger powered by exotic nitro-methane fuels, the smaller electric) and indoors with small and incredibly nimble 12th scale electric 'LMP'-style cars, but the premier class worldwide is 1/10th electric Touring. And it really is a worldwide sport. At the recent world championships in Thailand drivers from 19 nations covering all the inhabited continents competed together. Chassis manufacturers from Britain, the US, Japan, Korea and Russia sent their works drivers, many accompanied by personal mechanics!

LATEST TECHNOLOGY

So let's look in more detail at the current fastest car in the world, manufactured by Hot Bodies of Japan and piloted by native driver Atsushi Hara. Power comes from the latest maintenance free, brushless motors, powered by 7.2V lithium or NiMh batteries – a combination which can produce as much as 3/4bhp and immense torque, all at zero revs. Putting all this power onto the ground takes some pretty advanced chassis technology. The chassis itself is constructed of high grade 2.5mm carbon fibre sheet, precision cut to allow the rest of the elements to be hung from it. There is also a carbon fibre top deck, which comes in many different designs to enable chassis flex to be fine tuned to the circuit conditions.

Carbon chassis, limited slip diffs, adjustable damping, roll bars and roll centres… and you still think these things are toys?

The drivetrain combines light weight with great strength. Being electric powered there is no need for a gearbox, but the overall ratio is adjusted using either pinion or spur gears to suit the power delivery of the motor fitted and the design of the track. Lightweight, ultra flexible belts take the power front and back, at the rear to an infinitely adjustable limited slip differential. This component is interesting in itself, being based on a principle first invented for lawn mowers in Edwardian times but resurrected and refined by Cecil Schumacher, a senior engineer who left his job at Cosworth to set up his own company manufacturing these differentials for the RC market. These days there is no longer a differential at the front, racers preferring a locked front end, or spool, for its better traction out of corners.

Shocks and springs are oil filled coilovers with damping being adjusted by the viscosity of the oil and the 'holes' in the pistons. Springs are available in many different weights and changing them is the work of a minute. The same can be said for the roll bars.

> "the technical grounding is useful for youngsters looking to progress in racecar engineering"

The greatest illustration of the chassis flexibility is that adjusting the roll centres takes just seconds. In a full-sized racecar, suspension pick-up points are often mandated or fixed to those of the donor vehicle. When rules allow them to be adjusted it's a major engineering exercise, but with RC Touring cars it is simply a case of moving spacers and shims around, or using a different wishbone location entirely. And whilst we're talking flexibility, the wheelbase can also be altered at the touch of a hex spanner. As most race series run control tyres, the rewards of getting the set up right are immense.

One of the beneficial spin offs is that the chassis tweaks all work in full scale, so the technical grounding is useful for youngsters looking to progress in racecar engineering, too. It's also great fun and the cheapest form of motorsport bar none.

To see some of these machines in action check out the website of the only dedicated RC Racing programme on TV – www.rcracing.tv or for specific car info, www.hpieurope.com

Fifty per cent rise in motorsport jobseekers

Motorsport recruitment specialists in the UK are reporting an increase of around 50 per cent in the number of skilled people looking for work since the economic downturn.

Keith Blain, a recruitment consultant with TXM Recruit, told *Racecar*: 'Compared to this time last year I would say the amount of people sending us their CVs looking for work in motorsport has gone up around about 50 per cent. And that's right across the spectrum... we're definitely getting a lot more Formula 1 people.'

"we have more people coming out of colleges than we have places for"

Steve Bailey of MotorsportRecruitment.com agrees: 'There's a significant increase... and some of the people looking for work are extremely good and very experienced.'

But while the amount of people looking for work has increased, the amount of companies looking for workers has decreased. 'Last year we had between 10 and 12 [motorsport] clients, whereas now we've got about four,' says Blain, whose company covers all areas of engineering, not just motorsport.

Yet while there are ever more people looking for work in the sector some experts say there are still jobs available for those with the right skills. A head hunter working in the industry on a strictly confidential basis told *Racecar*: 'There is generally a shortage of good calibre aerodynamicists, they are always in demand. And anyone who is into CFD or simulation, again there is always a demand for those skills.'

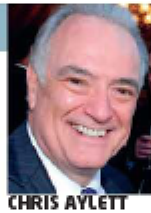
One area where there is definitely not a shortage, however, is with recent graduates with motorsport engineering degrees: 'I have a concern that we have more people coming out of colleges than we have places for. That's my perception.'

Blain, however, insists that there are still places for graduates in the motorsport workplace. 'It depends on the company. There are companies I am recruiting for that are taking on graduates, especially those that have some experience and really want a career in motorsport. If they have a great interest in the sport and come over really enthusiastic then that really helps, too.'

THE BUSINESS

Support the winners

What value Government can deliver to motorsport



CHRIS AYLETT

The MIA has just completed its first 'Industry Day in Parliament' for its members, and the lessons learned in the UK can apply to any national government. No business operates in isolation, whether large or small, and national and regional governments can make a real difference to business, profits and employment.

Planning, tax, rates, recruitment, education, business development, access to finance and international trade development are just a few areas that are directly affected.

An election in the UK will occur within the next 12 months and change is in the air. This is the right time for UK motorsport employers to approach their local Members of Parliament, who need to secure votes. Your workforce is important to them.

"All politicians want to be linked to success and motorsport delivers this"

Ask questions in writing and they *will* answer. But make them simple and to the point – 'what do you plan... what is your position on... what is your view on?' Then form your own opinion as to how to vote. If you're not in agreement with the response, argue your point constructively, try to persuade your MP to your view.

And always include a paragraph describing your business, how many you employ in the constituency, your future employment plans and business growth.

Copy this to a Minister or, very importantly right now, a Shadow Minister to make them aware of your point of view. Check www.parliament.uk to find your contact point.

During the MIA's Parliamentary visit, 25 leading motorsport employers explained the success of our industry on a global stage. We encouraged government to 'back winners – don't bail out losers'. All politicians want to be linked to success and motorsport delivers this on a global stage.

We asked for their help in continuing that success by, for example, increasing research and development tax credits for SMEs and financial support for international trade development, helping with apprenticeships and graduate retention so we do not lose top quality employees and finally, more honest and positive banking support, particularly from those banks recently rescued by the tax payer.

The Conservative Party has a good chance of forming the next government in the UK and is now forming its policies. This is the right time for high-performance engineering companies to secure a place within its policies.

Our industry offers well-rewarded employment by focussing on cutting-edge technology and, with a global reputation for success, attracts young engineers into employment with SMEs. This is the perfect recipe for any government, but it is up to us to tell them of our successes.

I encourage all readers to make an effort to inform, encourage and improve government relations, wherever you are in the world, to benefit motorsport as a whole.

Chris Aylett is CEO of the Motorsport Industry Association www.the-mia.com

Motorsport voice: the MIA Industry Day in Parliament

Racecar engineering

PIT CREW

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LATE APEX

Faith restored

I was a Formula Student virgin until just recently which, considering my advancing years and best part of a working lifetime spent in and around motorsport, is something of an embarrassing admission. In any event, I attended Formula Student (FS) at Silverstone this year for the first time – and loved it. In fact, for anyone in a similar position, who is feeling jaded by the soap opera dramas, overweening egos and incomprehensible behaviour currently dominating the top levels of the sport, FS is a guaranteed restorative.

Ultimately, FS is about the things that really matter, the things that make motorsport the fascinating field of endeavour it is – studying, understanding, putting knowledge into practise, experimenting, designing, fabricating, assembling and competing, with all of this driven by an overriding desire to improve and perform better than one's rivals. It was all there to be seen, in pure, unvarnished form, in the course of the Silverstone weekend.

> **"Formula Student is about the things that really matter"**

The contrast with what had been going on in that same paddock just a few weeks previously couldn't have been any more dramatic. Where the space had been occupied by rows of gleaming, perfectly aligned team transporters and dramatically large, look-at-me motorhomes during the British Grand Prix weekend, now there were temporary marquees for student registration and the various static events that form part of the overall FS judging process. Parked behind the garages was a motley collection of lorries, vans, trailers, tow cars and other assorted vehicles.

Inside the garages themselves, many of which still bore clear signs of the Formula 1 squads that had occupied them, were to be found the teams representing the many universities taking part in the competition. Packed in up to eight to a garage, organisation appeared to run the gamut from post-party, student dorm bomb site to professional race team orderliness.

Similarly, the spectrum of human activity went from calm, quiet and well organised to flustered, undirected and occasionally fractious. It was fascinating to observe.

The students themselves seemed oblivious to those of us wandering through the garages, looking at what was going on, as they were engrossed in the business of preparing their cars. The overall feel was reminiscent of the science fairs in which I competed during my high school years back in Canada.. Yes, I suppose the warning signs of 'geekdom' were beginning to manifest themselves even then.

Perhaps the most significant point from my perspective though involved some of the other non-participants spotted wandering around the garages, looking closely at the cars and teams. Ross Brawn, Pat Symonds, Gary Savage, Andrew Deakin, Tim Densham, Jon Hilton, Richard Noble and Lord Drayson were all there. Many of these motorsport high-fliers will have been at Silverstone several weeks earlier for the British GP because they had to be. They were here now because they chose to be.

Formula Student is exactly what its title says it is. It has no trappings, carries no baggage and displays not the slightest hint of pretentiousness. It is a wonderfully honest event and, although I may have come to it a bit late, I'm definitely hooked.

EDITOR
Graham Jones

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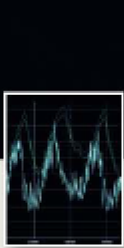
THE RISE OF THE MACHINES

Raetech's load cells

Fully programmable sensors for NASCAR Sprint Cup



Late Model data loggers

Running data acquisition systems in race situations

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'Recession, recession, green shoots and recession. Not having as much money as any of us might like means you tend to have to shop around, and go further to get that unfair advantage at the right price. Sometimes that means looking in unlikely places. In Europe, there is the immensely popular but amateur NHRPA National Hot Rod series, which pitches a range of tube-frame silhouettes fitted with highly tuned, 300bhp, 2.0-litre engines against each other on the short tracks of Northern Europe. These quarter-mile circuits are dotted all over the place, with a particular concentration in the East of England. With around 100 single-car teams racing most weekends in the top class it's no surprise a technical supply industry has grown up around it. Firms like Simpson Race Exhausts came from within the series and started supplying product to other short-track racers, but now the firm's standard of engineering is so high it is making components for grand prix cars and has NASCAR as the next target in its sights. And Simpson is not alone. Titan, a UK-based steering rack specialist, is another actively trying to break into the huge US market after years of supplying the short-track racers. Even gearboxes are on the list, with the Elite Racing Transmissions booth at PRI doing swift trade last year. I recommend you investigate this new breed of Stock Car supplier. Whilst you may not have heard of them, they combine the best of European road racing know how with a wealth of short track oval racing experience. Where else can you find that sort of pedigree?

EDITOR
Sam Collins

The return of the CoT

The long awaited Nationwide Car of Tomorrow could debut in Nationwide next year and go full time in 2011

NASCAR HAS NOW MADE it official that it will implement the 'Car of Tomorrow' in the Nationwide Series next season at the restrictor-plate events of Daytona and Talladega, plus the two road course races at Watkins Glen and Montreal. The car will have the same 110in wheelbase as the Sprint Cup cars, so is five inches longer than the current Nationwide Series cars, but will continue to use the lesser horsepower Nationwide Series engine. The bodies, however, will look like the images previously released in *Racecar Engineering* and will feature the Dodge Charger or Challenger and Ford Mustang, while the Camry and Impala will continued to be used by Toyota and Chevrolet respectively. The obvious plan from there forward would be for NASCAR to implement the car full time in 2011.

NASCAR held a mandatory 'town hall'-type meeting with owners and drivers during May and it has been viewed by the governing body as a success. The organising body held two two-hour meetings with the meeting split between different owners and drivers. At them the NASCAR drug policy was discussed, as was the competitiveness of the sport, possible changes to the new design car and getting more input from fans on what they are looking to see from the sport. Rick Hendrick and Felix Sabates were the only two owners to speak up in the first meeting, with Hendrick apparently advising Brian France he needs to attend more races and that he can't steer the ship from Daytona Beach. Several drivers brought up the subject of how to make the racing more competitive and one thing discussed that was implemented almost immediately (at Pocono) was the inception of double file re-starts, with all cars on the lead lap re-starting in front of the lap down car. A possible weight reduction of the car was also talked about.

MoTeC ADL3

AUSTRALIAN FIRM MoTeC has introduced a new dash logger, the ADL3. It is a fully programmable, all-in-one display, logger and controller whose performance is significantly increased over the ADL2, including 10 times more processing power than its predecessor, a 250Mb logging capability and fast ethernet download.

It provides two independent CAN buses, built-in advanced maths functions and an internal three-axis *g* force sensor. Data can be logged at up to 1000 samples per second, and over 300 channels can be derived from a mixture of analogue and digital inputs – both RS232 and CAN data channels.

Four auxiliary outputs enable user-defined control of external devices like pumps, fans and solenoids. Additional outputs are available as an upgrade or by using expander modules.

The ADL3 is easily integrated with MoTeC ECUs and CAN-based accessories such as SLM shift lights, LTC wideband lambda units and VIM modules for high resolution sensor inputs. Many GPS devices are also supported, allowing the ADL3 to record speed, generate lap times and measure position information, which can be used to create track maps and plot and compare driven lines.

The screen layout is fully configurable to display a multitude of data channels, warning alarms, lap times, fuel calculations, minimum corner speeds and maximum straight speeds.

For more information see www.motec.com.au

Speedcar falters in the Middle East

Despite big-name drivers, the road course-based Speedcar series has folded

SPEEDCAR, A RELATIVELY new Stock Car racing series based in the Middle East has ceased operation. It pitched famous former grand prix racers like Jean Alesi, Johnny Herbert and Jacques Villeneuve against each other with a few very wealthy Arabs making up the numbers. The racing, all on road courses, was undoubtedly exciting but the costs it seems were just too high for the series to keep going. All of the purpose-built cars are no longer fitted with engines as the lease deal they were supplied on has expired, and are likely to be sold off in the coming weeks.

It was just the latest failure in a string of attempts to make North American-style Stock Car racing work outside of the US. A visit to Japan by the Cup teams yielded little, a recent demonstration at Fuji Speedway saw Kyle Busch upstaged by a Formula 1 car, and in the UK the ASCAR series lost credibility after a series of name changes and dwindling grids and eventually became a class in a larger road course only series last year, leaving just the pick-up truck series running at the purpose-built Rockingham Speedway in England.

Prior to ASCAR the Eurocar championship looked strong, but a move from V6 engines to V8s hurt grid numbers and that series also failed.

IN BRIEF

■ As part of its ongoing efforts to curb costs in the Truck Series NASCAR is now allowing teams to transfer one set of tyres from one track to another if they are the same compound numbers used at the two different facilities. Under normal rules NASCAR does not permit tyres to be used at other tracks.

■ NASCAR is spreading its wings, albeit in a small way. In June, the infamous Winston Special Chevy 'T-Rex' was seen in action in England at the Goodwood Festival of Speed.

In July, three Roush Fenway Racing cars from Cup, Nationwide and Camping World were demonstrated in Argentina at Potrero de los Funes, a racetrack located in the San Luis province.

Late Model Series booming in Europe

Thirty drivers have scored points in the ELMS with new cars on the way. Stockcar Engineering will be entering some races this year

DESPITE THE DOOM AND gloom created by a failure of Speedcar, grid numbers have been rising steeply in the all new European Late Model Series, started this year. The new series accepts Late Models from the Belgian CAMSO V8 championship and cars from the defunct British ASCAR operation, with the emphasis placed on keeping the races exciting and the costs low. So far 30 drivers have points on the board and there are regularly over 25 cars at races.

Currently, Lefthander chassis fitted with the mandatory GM crate motor and Brinn transmission are the front runners, but both Tanner and Howe chassis have also run strongly.

The championship has proved popular with fans both at the tracks and those watching the regular television coverage on Saturday nights.

Stockcar Engineering will be running a car in selected races this year and will take the opportunity to use the series to evaluate some of the latest racing components. The first fruits of this exercise can be found on p24.

Racecar Engineering and *Stockcar Engineering* used P&O Ferries to get to Warneton Speedway in Belgium and we highly recommend the club lounge on board!

SCE would also like to thank Tony Roots, Jean Vassuer, Kelvin Hassell and Keith Whalley.

LAT

MODERN TECHNOLOGY There's no getting away from it, the lap top computer is replacing the pad and pencil in today's pit lane

MAN VS MACHINE

With the testing ban now in place, NASCAR has been forced into a new way of thinking. We look at how the teams are getting to grips with oval racing's latest black art

JONATHAN INGRAM

The small town created each race weekend in NASCAR Sprint Cup garages has one odd aspect when it comes to the often friendly exchanges among participants. The drivers swap information with one another, often regardless of team or manufacturer affiliations, much like neighbours across the back fence. And although they hardly exchange trade secrets, crew chiefs are also known to talk across these boundaries with their counterparts. Yet the engineers, the other key participants in car set up, stand apart, rarely speaking to those from another team about what they're doing. 'Our crew chief knows what other guys have on their cars a lot more than engineers know what other engineers have,' says Jeff Curtis, an engineer at Richard Childress Racing. 'Engineers don't talk to each other like the crew chiefs do. You don't really know what other programmes engineers have. You might hear comments here and there, but you don't really know.'

> "Engineers don't talk to each other like the crew chiefs do"

However, if engineers did occasionally exchange information, the hottest topic they'd want to discuss these days would be simulation programmes. The influence of sims programmes has risen dramatically this season, mainly because teams have been banned from testing on tracks hosting Sprint Cup events. Computer testing, on the other hand, has only the limits of a team's simulation programme to hold it back.

As recently as three years ago, and before the arrival of the CoT chassis, relying on simulations would have been considered anathema in NASCAR garages. But 2009 has been the first season in NASCAR history with a test ban, which has changed the outlook on sims completely. Coupled with the need to accelerate the learning curve on the CoT, simulation programmes are a necessary commodity these days. 'Simulation and the gathering of information is big business in our sport right now,' says the Childress team's Jeff Burton, a contender in the Chase for the Championship for the last two seasons, who gets the benefit of the sims programmes of Curtis. As you might expect, the jury is still out on whether a communicative, capable driver and a grizzled crew chief inclined to squint and ponder on prevailing conditions – the old-style magic – can beat a team with better simulation programmes. 'You could say simulation is more important than the driver,' says Burton. 'The other way to look at it is that the driver is more important. But by the end of this year, I think you're going to see some teams who do well that have really good simulation programmes and some teams that do really well with mediocre simulation programmes.'

UNCERTAIN TIMES

The significance of the simulations programmes was most obvious at the Daytona International Speedway in February during NASCAR Speed Weeks. Accustomed to testing at the 2.5-mile facility throughout January, this year teams arrived without a single day of open testing. Not only were drivers antsy after a long winter lay off, all team members were unsure of what to expect. 'The pressure's always there at Daytona,' says Doug Duchardt, vice president of development for Hendrick Motorsports, 'but this year there was a lot more uncertainty involved.'

The Daytona oval is unique, because there is no comparable facility to test on that simulates the 31-degree banking and 2.5-mile sweep, but there's ample practice time during Speed Weeks, plus the Budweiser Shootout exhibition and the twin 150-mile qualifying races at Daytona to gather data from. Unlike private testing though, no telemetry is allowed on the cars during these sessions. Consequently, the Hendrick team hedged its bets by adding two new sources of information – the human kind. The first move made by team owner Rick Hendrick was signing 50-year old Mark Martin to drive full time in 2009, both because of his ability to quickly set up cars and because Goodyear use him for tyre tests – both sources of information for all four of the Hendrick entries.

Secondly, Hendrick agreed to supply engines and chassis to the new Chevy team created by the partnership of driver Tony Stewart and team owner Gene Haas. This alliance gives each of the two independent Chevy teams more cars for sourcing information from during Goodyear's tyre tests or over race weekends.

'I think with the CoT chassis the drivers are more important,' explains Hendrick of his first decision. 'When it comes to getting the car comfortable, that's when you need drivers like Mark Martin, who know what they want. There's no replacement for great talent.'

But absent any testing, the driver side of the equation loses some of its significance and elevates the demands on simulations instead.

BIGGER DIVIDE

Andy Graves, vice president of engineering at Toyota Racing Development, predicted that simulations would spell the difference in the Daytona 500 while standing in the garage prior to this year's race: 'You're going to have to lean on your sim tools,' he said. 'The Roush team, Hendrick Motorsports and Joe Gibbs Racing, their sim tools are far enough advanced that I think you'll see a bigger divide between the faster teams and the mid-pack guys.'

This prediction was kept in doubt by a multi-car mêlée started by Hendrick's Dale Earnhardt jr mid-way through the race that took out several front runners. Then rain swept over the walls of the seaside track with 120 miles remaining. Nevertheless, it was the Ford of Roush Racing's Matt Kenseth that was hands-down fastest and in front when the skies opened up. One of the front runners that Earnhardt jr's hasty manoeuvre in turn three eliminated was Brian Vickers, driver of the Red Bull Toyota, the team credited with having one of the most sophisticated simulation programmes in NASCAR, thanks to a proprietary system developed by Red Bull Racing in Formula 1. The NASCAR team also uses the Formula 1 team's scale model wind tunnel for testing its Toyota Camrys.

> "Simulation and the gathering of information is big business in our sport right now"

The team's simulation programme was a priority of John Probst, Red Bull's technical director for the two-car NASCAR team, which now also includes ex-Formula 1 driver Scott Speed. 'My first hire was a software engineer,' said Probst of the start up that took place in 2006. The sim programme includes a calculator and a lap simulator, in addition to the Red Bull programme, which Probst declined to provide details on.

> "Practice time is now severely limited and playing catch up is rarely rewarded"

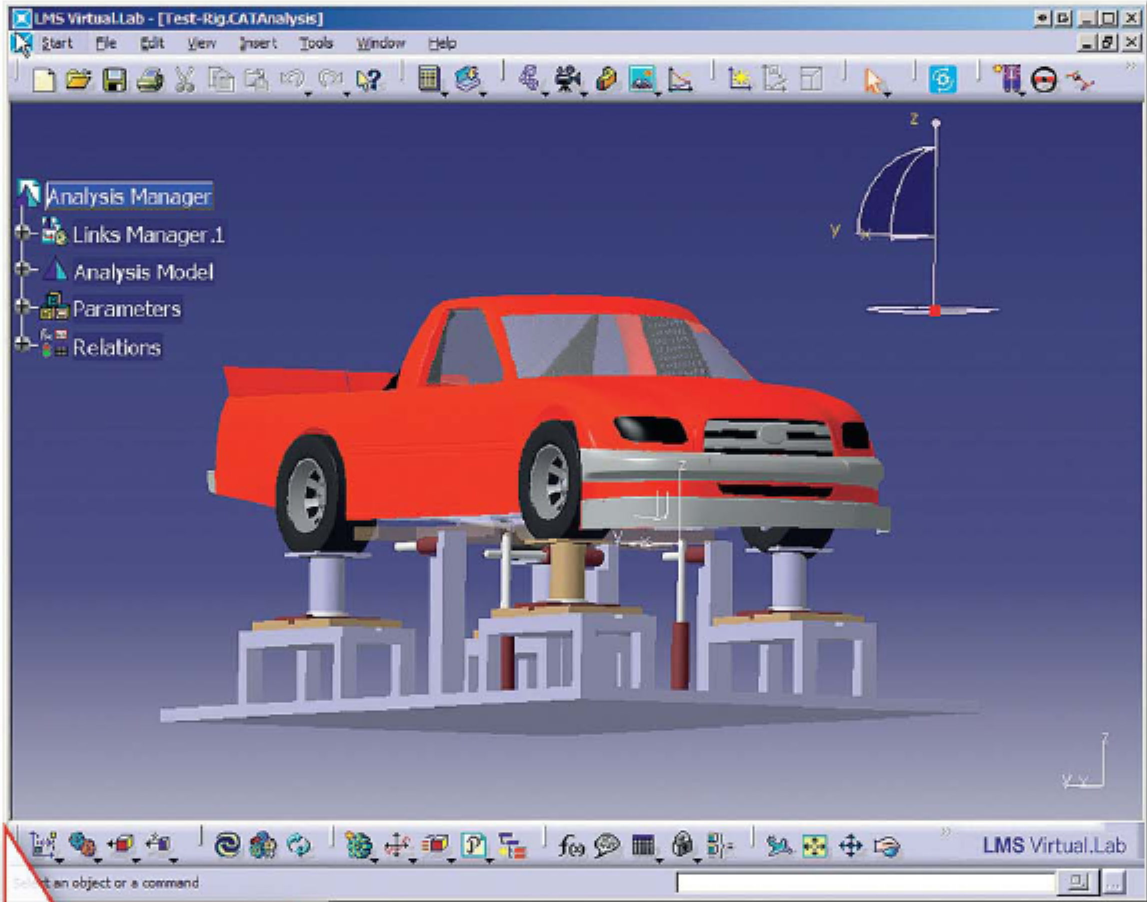
Vickers is one of the few who uses a laptop in his car during practice to review any changes made by crew chief Ryan Pemberton and the team's crew of engineers. So with all this experience to call upon does Probst think the driver or the computer simulation programmes have become more important in the absence of testing? 'In a lot of ways it's easier to say the simulation programmes are more important,' he replies. 'That being said, it's probably no more important than it was last year. If you do all the testing with telemetry, at the end of the day if the driver tells you something you're going to listen to that.'

After Daytona, the remaining 35 races of the Sprint Cup schedule are contested as weekend events, where simulation programmes are most significant when unloading off the truck. Gone are the days when a crew chief like Ray Evernham of Hendrick Motorsports would throw three different sets of shocks and springs under Jeff Gordon's Chevy in the first practice to accumulate the data needed for qualifying and the race. Practice time is now severely limited and playing catch up is rarely rewarded. If a driver's car comes off the truck quicker than the rest of the field, that's a huge advantage, and one that will rarely be caught over up over a race weekend.

DRIVER VS COMPUTER

But once the racing has begun, the debate of driver vs computer becomes more theoretical, says Cal Wells, a veteran of CART's Indy cars before he migrated into the NASCAR garage as a team owner and now as a principal at Michael Waltrip Racing. 'It's more about the process, rather than an individual who has a really big say or not,' he says of how things progress on race weekends. 'It's taking experience and melding it with real-time information, whether it's o-rings on the shock shaft or what's scraping on the ground and whatever tyre information you can get. If the crew chief can surround himself with some pretty smart guys and take the kinematic information off the car you've got some pretty good sources.'

From an engineer's perspective, Curtis says he's not necessarily providing answers for Burton's no 31 Chevy entry and crew chief Scott Miller once the race weekend has begun. 'We're just here to provide information. We're trying to make the crew chief smarter,' he says. 'Let them call the



MULTI BODY SIM
Even rig testing can be simulated as this LMS screen grab shows

shots. It helps to have a practical guy making the calls and decisions. That frees us up to live in the theoretical world and that takes away the pressure from us being the ones with the answers and allows us to be the ones who have information.'

The ideal scenario is a talented, communicative driver coupled with an engineering crew deeply versed in sims programmes and a crew chief to integrate these two elements, says Curtis. 'The teams that run the best in this garage have strong-headed crew chiefs who use the engineers' information with a strong degree of scepticism. If you have a crew chief who does what an engineer tells him, you're not going to run well in this sport.'

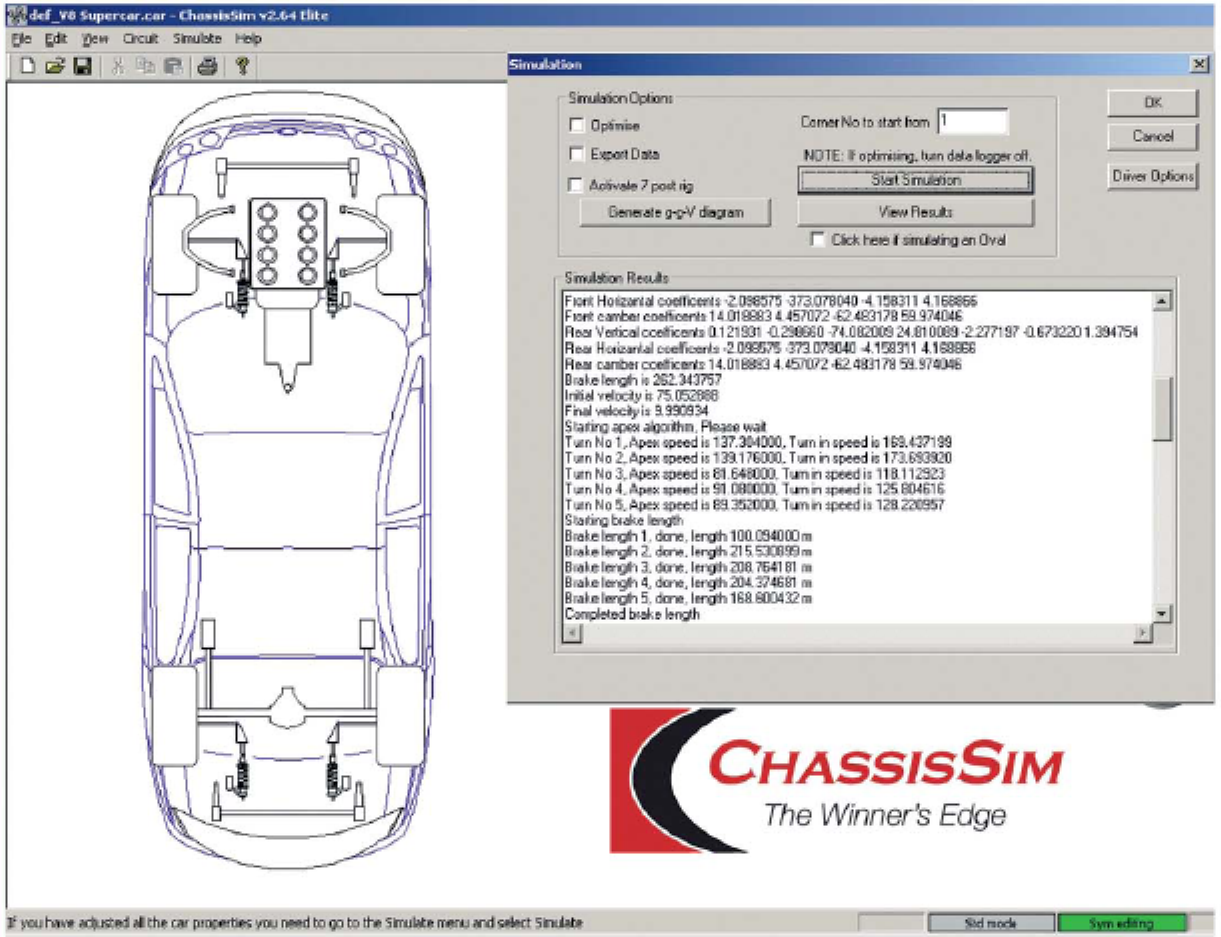
Certainly the engineering at Richard Childress Racing has improved since Curtis, who earned his degree at Cornell University, arrived five years ago, shortly after graduation. 'When I first came into the sport you had engineers,' he says. 'But they weren't computer geeks. You had practical engineers but they weren't living in the computer world. Now you've got smart people in it who have real experience.'

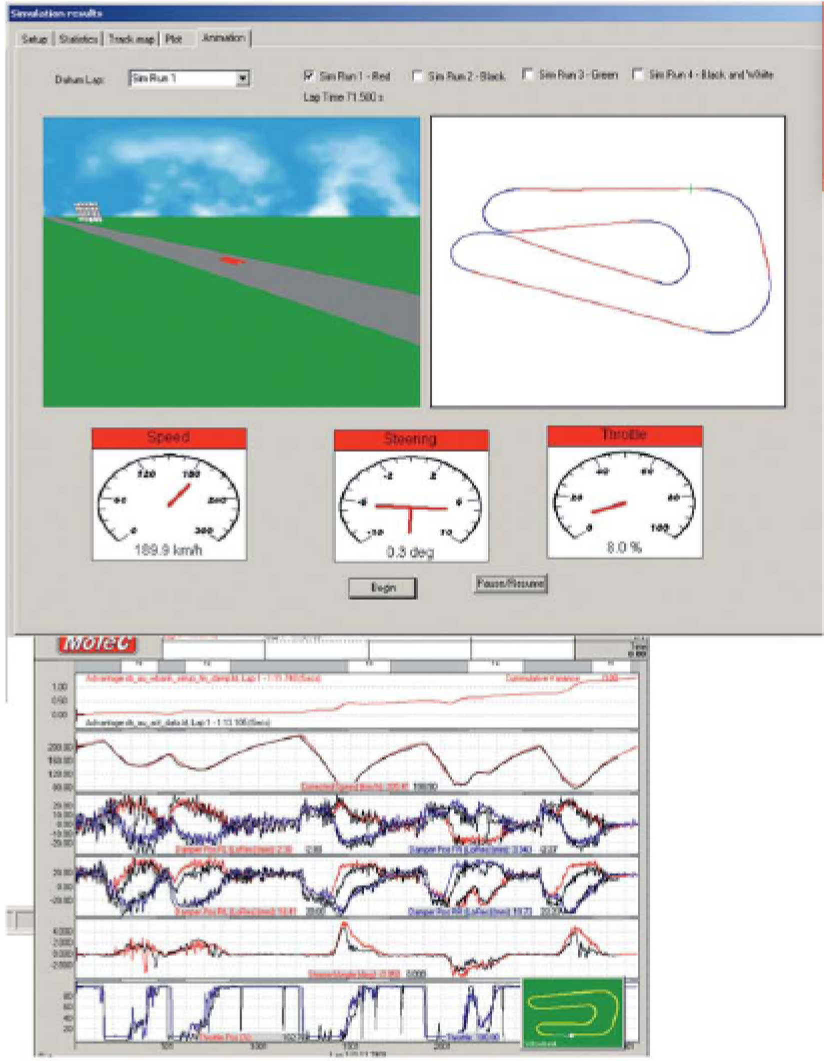
> "The emphasis now is on sorting the chassis according to track segments"

And the approach to set up at the track has changed, too. The emphasis now on race weekends is on sorting the chassis according to track segments. 'When I came in,' continues Curtis, 'I didn't have any experience, so to get a crew chief to listen to what I was saying was hard. In all honesty, he shouldn't have listened to what I was saying because I didn't have a freaking clue. Now though I've got experience in running simulation, I've got the practical experience in the sport, but it's more a matter of I know how to do the simulation better.'

These days telemetry at the track during a test is the lifeblood of a sims programme because it can confirm a programme's accuracy in the real world. Also, original sources such as the wind tunnel, pull-down rigs, seven-post shakers or kinetics and compliance rigs can be validated at tests. 'Simulation works better if you have data to validate,' explains Curtis. 'Without that, you have to go back to past tests and calibrate off them, put all your new information in and try to get a good relative comparison. It works pretty good, but I'd rather go testing. I can tell you if the simulation is dead on when I have data. If the simulation is saying you're seeing 4.5 degrees of side slip off turn four, I have a degree of confidence that it's going to be correct.'

Despite the rapidly changing environment, the teams are not bereft of





CHASSISSIM
A typical example of a sim package though some teams develop thier own sims

telemetry data gathered in the current season that can be used to update sims programmes. Teams compensate by testing at facilities that are similar layouts to those on the Sprint Cup circuit. But this process is complicated by the tyre-leasing programme established by NASCAR and Goodyear. None of the tyres used on race weekends are available for off-site testing at facilities like the 1.5-mile oval at Kentucky Motor Speedway or the high-banked mile at Rockingham, NC. The sweetest information comes from Goodyear's own tyre tests at tracks on the Sprint Cup schedule that determine constructions and compounds to be used at upcoming races. Goodyear chooses one representative from each manufacturer for each test and teams are allowed to run telemetry during the test. Because it is Goodyear's test, the information is limited to short runs on different sets of tyres and further limited because not every track on the schedule has a tyre test, but it's still useful information.

> "the tyre information is still the most important information"

The results are somewhat diminished by the limited data offered by Goodyear on the tyres the company chooses to bring on race weekends as a result of tests but, just as with the leasing operation instigated by NASCAR, the data distributed for tyres is fundamental to keeping the playing field level among teams of different economic means. 'We all have the same crappy tyre data,' reports Curtis. 'And we're all working with the same limited aerodynamic tools that we have at our disposal. If we got into a realm where we could test our own tyres and had five times the budget to test aerodynamics, then we'd be in a realm where a good sim would beat a bad one. You could work from now until you're dead on your sim, but the tyre information is still the most important information and we've all got the same.'

However, the degree to which information from tyre tests is shared differs with each manufacturer, according to Wells. 'We did the tyre test for Texas because we worked pretty good there,' he says of the Waltrip team. 'So we were the Toyota team. The Toyota teams have a series of data sets that they share. It does not include the track map, but it does include some things like tyres. 'We're allowed to run data at the tests. Then the Toyota teams have an agreement between them that actually helps TRD.'

INFORMATION SHARING

The original intent of TRD was to have all its teams run the same software to facilitate sharing, but Red Bull's unique programme was too expensive, according to Wells, and the arrival of the Gibbs team in Toyota's second season in 2008 skewed the process. 'Toyota has a lot of sharing,' reiterates Wells, 'but the teams still compete against themselves. Some, like us, are a little more cooperative. Joe Gibbs Racing would be the polar opposite and Red Bull is somewhere in the middle.'

Given this, perhaps overall Roush Racing has the best angle on testing. 'Jack Roush runs all the Fords,' explains Wells. 'He gets all the information from every test. The Chevys, I'm going to guess, are the ones who share the least. Because the CoT ran everywhere last year though, we all have a reasonably good idea of what to show up with.'

Likewise, the Dodge programme was set up like that of GM, each team operating independently. The wild card has been Penske Racing, since it also runs Indy Car and Sportscar programmes where sims have already been highly developed. And it shows. In the American Le Mans Series, for example, the qualifying outcomes between Audi Sport and the Penske team's Porsche Spyders were regularly and accurately predicted using simulations.

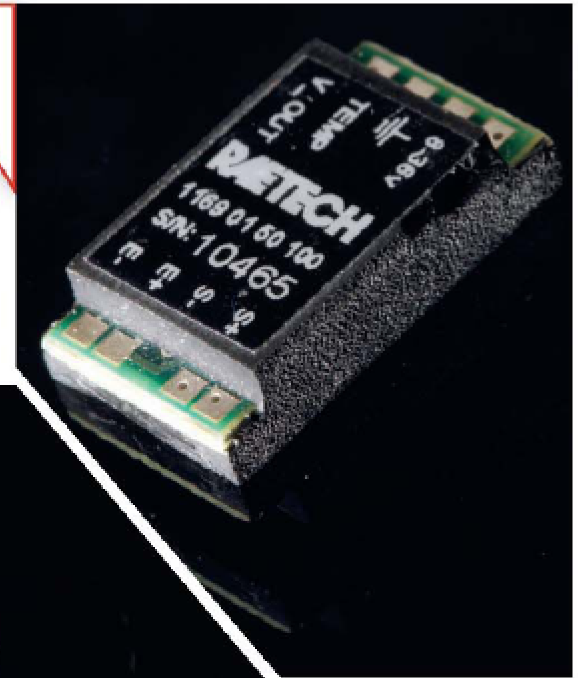
Back in NASCAR, in Atlanta this spring, Penske's team spanked the field when Kurt Busch led 234 of 330 laps, the strongest showing by the team in NASCAR since Rusty Wallace dominated the short oval in Bristol, Tennessee. In Atlanta, a lot of credit went to the use of Dodge's new NASCAR V8, but it was more than that. The team clearly had the best handle on car set up for the high speed, high-banked track.

As usual, Roger Penske credited the loyalty of his team for the company's 63rd career victory in NASCAR's premier series. And as usual, nobody said much about the simulation programmes frantically going on behind closed doors.

REFERENCE MATERIAL
Now it is possible to quantify and record the results of set up changes

LAT

FULLY PROGRAMMABLE
This feature allows teams to tune the cell to the exact range they desire



INPUT/OUTPUT
Voltage input is 8-36v and the output is compatible with any logger that takes 0-5v input

SENSOR OF PURPOSE

After discovering a gap in the market, Raetech decided to develop a coil spring load sensor. It was a difficult job, but the result opens up endless possibilities

'We are motorsports guys,' explains David Finch, the president of Raetech. 'We were not instrumentation manufacturers, but during our 20 or 30 years of doing racecar development we had to create sensors because we couldn't find what we wanted.'

This comment was made to *Stockcar Engineering* during the PRI Show whilst showing off his firm's new spring-mount load cell, aimed squarely at the NASCAR market. It is designed to allow teams to quantify the results of set up change and identify spring coil binding. Despite the fact the new load cell was designed for Stock Cars, its development can be traced back to the firm's involvement in Sportscar racing, as Finch reveals: 'We started out in road racing doing a programme with Porsche, winning six national championships, then we moved on to do some advanced development on a Dodge programme and we won with that, too. Eventually, we got involved with NASCAR, initially with Trucks, then later with Cup.'

> "a coil spring does not load the unit uniformly"

However, it was when Finch's team started modelling a Cup car that they realised not all the data desired was available. 'We did complete vehicle structural analysis and track performance simulations. We could run them round tracks and understand the loads and compliances but we needed sensors and things, only we couldn't find any we were happy with. That's how we started. We first targeted NASCAR because there were budgets, well, at least there used to be! It was also the area we had most recently been working in and so we created a whole series of load cells. We listened to the guys who said they need this or that and we responded to them by making spring mount, tie rod, panhard bar, steering torque and sway bar drop link sensors. We are also currently developing a front hub axial wheel force tranducer. For many other types of racing, a coil over shock sensor is something I had wanted to do for 10 or 15 years and we have finally figured out how to do it. Nobody has ever produced one of these commercially, and we have spent a long time developing it. We know now why they have not been done before – because it's so difficult. With the coil over sensor we can isolate the spring load from the shock loads and the inertial loads of all the rest of the suspension. This is the only reasonable way to get spring loads or downforce on a MacPherson strut car. It has a 5000lb operating range and a 10,000lb overload. That's a lot for a sensor that weighs just 150g.' Temperature compensation is key to ensuring quality data, as Mike Growdon, the firm's programme manager reveals: 'All strain gage based sensors are affected by temperature induced errors. This can manifest itself in the form of zero drift and changes in sensitivity. Typical errors can easily exceed 5–10 per cent. Just consider that aluminum's modulus of elasticity changes by almost 5 per cent per 100degsF!

> "you can use these to get into spring tuning"

We developed a pc programmable strain gage amplifier to compensate for these phenomena. It is a tiny package that would fit on your fingernail and we thermally bond it to our sensors. An integrated temperature sensor measures the load cell's temperature near the strain gages. Testing is conducted to characterize the temperature dependant behavior of each load cell and this data is used to program each amplifier to compensate for its behavior. The output is compatible with any logger that takes a 0–5v input. It is easy to power it with unregulated 8–36vdc and precision 5vdc is provided for bridge excitation. The amplifier weighs 1.5g and operates over an extreme temperature range. We tried to break it by testing in dry ice on the low end and baking it in an oven, just short of where the solder melts, on the high end. It even survived testing in a vacuum for aerospace applications. Another of the unique features of the Raetech load cell is that it is fully programmable for the desired range, allowing teams to tune the cell to the range they expect to see with the spring and get better resolution (for a bumpy track you simply turn the gain down). Aero testing is also aided as the resolution can be boosted. 'In about a year and a half we have picked up about 70 per cent of the NASCAR grid from nothing. We also have parts going to major European manufacturer racing teams as well now,' smiles Finch.

And to think there are still people out there who think NASCAR only features backwards technology...

RAETECH LOAD CELL RANGE

Raetech's Bump Stop Load Cells are designed to accurately and reliably measure Bump Stop Loads on vehicles that incorporate the bump stop on the shock absorber. Elastomer Bump Stop material properties are loading rate and temperature dependent. Bump Stop characteristics measured in the lab are likely very different than experienced on the track.
The bump stop load cell is designed to allow you to:

- Identify when the Bump Stop makes contact
- Quantify the Wheel Load reacted at the Bump Stop
- Measure the actual Bump Stop Rate during operating conditions

Raetech's Bump Stop Load Cells are designed with interchangeable end caps to accommodate different loading conditions. One cap is profiled for contact with the rigid end of the shock, while another is optimized to interface with the soft elastomer element. Adapters are available to clamp the load cell on the shock housing, keeping it attached to the sprung mass. Our load cells are engineered to operate in the harsh temperature and vibration environment found in motorsports applications.

Meanwhile the 2.25in Coil-Over Spring Mount Load Cell is designed to accurately and consistently measure spring force, that is isolated from shock absorber loads. The load cell has been optimized for spring forces up to 5,000 lbs under all conditions.

Raetech conducted extensive FEA to engineer a load cell that is compact and lightweight, yet is capable of enduring the harsh motorsport environment. High strength 7075 aluminum alloy and a hard anodized finish will provide a long service life.

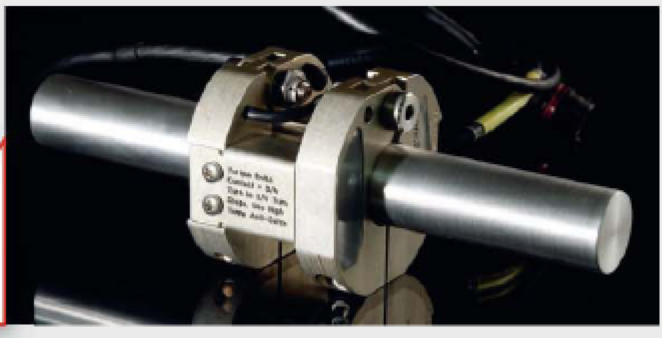
All Raetech load cells incorporate its SG Amplifier to provide a high level amplified output of 0.1-4.9V. This eliminates the need for external signal conditioning and greatly reduces the chances of EMI/RFI noise that can be picked up on low level strain gage signals. The SG Amplifier continuously measures the load cell temperature and compensates for temperature induced drift of the zero and gain. This feature ensures stable and accurate operation over a wide operating range. The zero offset and gain/load range may be customer configured, with an optional SG Amp Programmer and PC.

Finally the firms steering Torque Load Cell provides a quick and simple solution to a historically difficult task, measuring steering wheel effort. The load cell is designed to provide a simple bolt-in installation with no required modifications. The sensor simply clamps over any existing ¾in (19mm) or 20mm steering shaft.

The sensor will fit NASCAR Cup, Truck and Nationwide vehicles as well as any other application with a ¾in (19mm) or 20mm steering shaft. The sensor can be installed and removed with no steering column disassembly. Steering wheel torques up to 35ft-lb are easily measured.

BUMP STOP LOAD CELL
Allows you to identify when the bump stop makes contact

COIL OVER LOAD CELL
2.25" Coil-Over Spring Mount Load Cell measures spring force



STEERING TORQUE SENSOR
Suitable for NASCAR applications and driver development

DYNAMIC MEASURE
The ADI KD-rig allows all geometric changes under dynamic conditions to be accurately measured

A NEW RIG ORDER

How the new KD rig is proving to be an improvement over the older K rigs

LAWRENCE BUTCHER

Kinematics and compliance rigs were first developed in the mid-1990s to accurately measure vehicle suspension movement under road conditions. Unsurprisingly, these machines rapidly found acceptance in motorsport circles, proving an invaluable back up to on-track testing. Rather than modifying road car technology though, Accelerating Developments International (ADI) of Concord, North Carolina developed its K-rigs specifically for motorsport use and NASCAR Cup teams have used them extensively over the past few years. However, there were still some limitations that needed to be addressed, as Jay Drake, general manager at ADI, explains: 'The old K rig was much more of a four-post rig-type of machine with scale pads. We had several teams use the K rigs and over time they ended up generating a hundred extra questions. So we approached this problem by saying, "okay, we have all these scenarios missing and that we don't understand. We know the car is doing x, but *why* is it doing it?" In the end it turned out that most of the problems could be traced back to some sort of geometrical change under loaded or dynamic conditions.'

This led ADI to look at ways of constructing a rig that would allow all of the forces and geometrical changes within a car to be accurately tracked and recorded. This would place the capabilities of the system somewhere between the traditional four post/pull-down rigs and the latest seven-post rigs. The problem being that although traditional seven-post rigs are very good at measuring damping forces and tuning dampers to ensure the tyres stay in contact with the ground, they are not capable of measuring all of the different movements within the suspension and chassis. This meant teams jumping from a four-post programme to a seven-post programme still had large gaps in their knowledge. The system that ADI developed in response to this is the KD-Rig, capable of simulating on-track suspension movement whilst, at the same time, measuring everything from torsional chassis stiffness through to bump steer and toe changes.

> "teams jumping from a four-post programme to a seven-post programme still had large gaps in their knowledge"

MOUNTING METHOD

One of the key decisions taken when designing the rig was to mount vehicles by their hubs without fitting wheels or tyres, and Drake reveals the reasoning behind this: 'We hub mount because very few teams get any tyres that represent actual race tyres. When we do testing on the K rigs or the pull-down rigs the tyre has to be inflated to a real high pressure and the dynamics of that tyre don't really match up to what you run on track. So we take that unknown out of the equation.' The towers the hubs are mounted to on the KD rig float along two axes, allowing accurate tracking of several key chassis variables, including hub movement and rear steer angles.

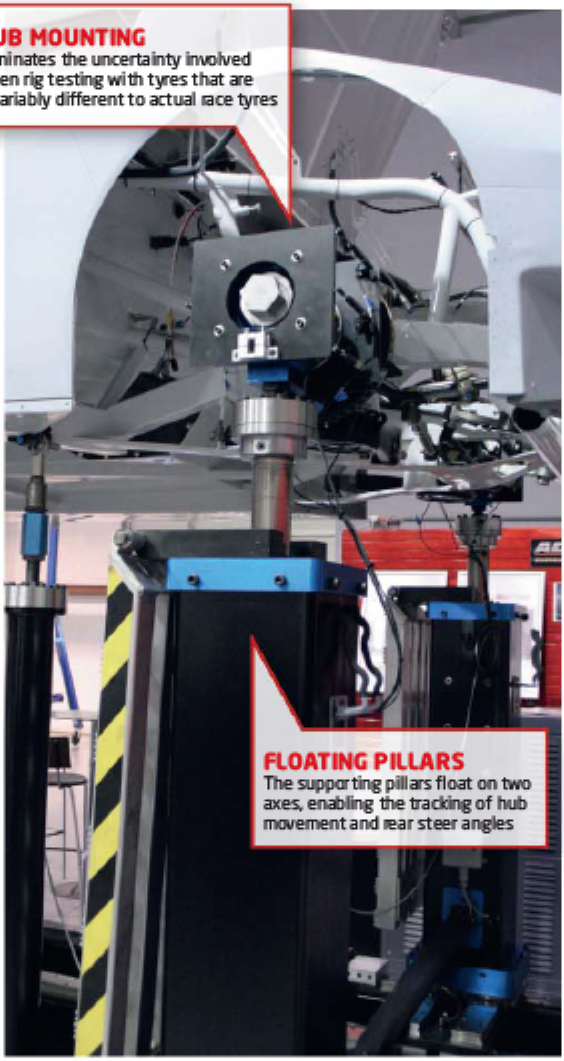
Once teams started to test on the new rig answers began to appear to the many questions generated by their K rig tests, with the rig also bringing some further unforeseen problems to light. 'We have found an interesting scenario here recently,' explains Drake. 'Teams

Lawrence Butcher

ON-TRACK MOVEMENT
the KD rig enables full simulation of on-track movement, allowing everything from torsional stiffness to toe changes to be measured

Lawrence Butcher

THE OLD RIG ORDER
The previous K rig was a far simpler affair – a four-post rig with scale pads



HUB MOUNTING
Eliminates the uncertainty involved when rig testing with tyres that are invariably different to actual race tyres

FLOATING PILLARS
The supporting pillars float on two axes, enabling the tracking of hub movement and rear steer angles

who were doing back-to-back testing from the KD rig to the conventional K and C rigs, which are very good at fine measurements under different load scenarios, found that the actual chassis deflections, movements and bump numbers were higher on the KD rig than they were on the K and C machine. We traced that to tyre absorption on the K and C machine. This is interesting because the teams thought there was something else going on as when they tested on the rig and then tested on the track the numbers weren't correlating.'

BETTER PREPARED

The sanctioned track-testing ban imposed by NASCAR has also changed the way teams utilise ADI's services. Initially, the company envisaged the new rig as a pure R&D tool, where teams could assess week to week and month to month set-up changes in order to formulate their car set-up 'recipes'. However, ADI have found that more and more teams are using the data gained from the KD rig as an input for their simulation programmes and to allow them to prepare better for other activities, such as wind tunnel testing. 'Because we have a very controlled environment it is accurate in terms of the plane and position and how we fix the car in position. We are able to extract a lot of data that influences splitter heights, frame heights and other factors that are critical to the car on track and to the car's attitude on track. Particularly if they are going to go aero testing and need to know where forces are going to be acting at a particular car attitude, giving them better input for the run in the tunnel.'

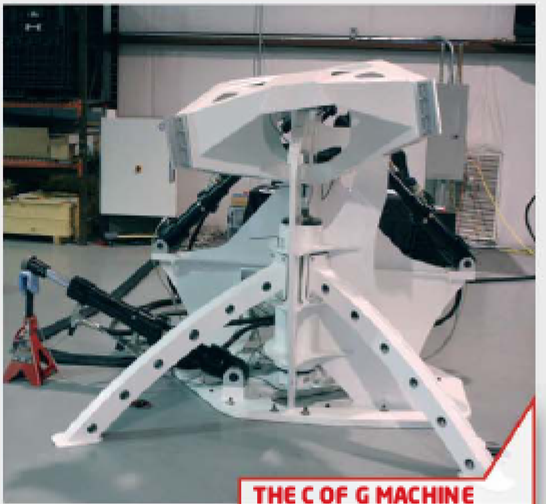
> "teams are using the data gained from the KD rig... to prepare better for other activities"

There's no doubt the new system from ADI is proving an invaluable tool for Cup teams racing to gain an understanding of the CoT. However, whilst it is able to answer many questions, as with all such technologies it is simultaneously generating just as many more as the CoT chassis slowly but steadily reveals its secrets.

THE VIMM

ADI is a big advocate of teams having the right tools to successfully set up a car. One of those tools, it feels, is the KD rig and another is a good simulation package. However, the company identified a weak link in the simulation process stemming from an inaccurate c of g calculation and set out to remove the problem. Its solution was a totally new concept in c of g measurement.

The VIMM machine (Vehicle Inertia Measurement Machine) is a device that was developed at the university of Aachen in Germany and has about six years of development work behind it, mainly on the algorithm used for accuracy. Jay Drake explains: 'We have been working with CFM Schiller in Germany to develop this technology in the North American Automotive market for accurate three-dimensional c of g measurement. It's a completely different approach from the pendulum-type machines, which have some drawbacks, including the time they take to set up and their accuracy being +/- about half an inch. The accuracy of this machine is +/- 1mm, which allows for very accurate sim inputs, with even things as inignificant as drinks bottle position affecting the set up!'



THE C OF G MACHINE
The VIMM will soon become the new standard in vehicle inertial measurement.

LAT

THE CAR OF TOMORROW TODAY

Perhaps the greatest change in NASCAR history has been the introduction of the CoT. We talk to engineers past and present to see how they are dealing with the change

LAWRENCE BUTCHER

The last decade has seen a paradigm shift in top-level Stock Car racing in the US. Whilst the 'good ole boy' crew chief is by no means dead and buried, without the back up of cutting-edge engineering he's not going to win anything these days. Areas that previously used to be the preserve of the top Cup teams, such as data logging and rig testing, are now essential and are even beginning to filter down to the series below NASCAR's three flagship championships. Regulatory changes over the past two years, notably the Car of Tomorrow (CoT) and a ban on testing at NASCAR-sanctioned tracks, have further accelerated the technology race. *Stockcar Engineering* spoke to a range of engineering personnel who represent the face of Stock Car racing past and present to see how teams are coping with this shift and the challenges it presents.

> "Areas such as data logging and rig testing are now essential"

Larry McReynolds is one of NASCAR's most successful crew chiefs, with over 22 Cup wins and 122 top-five finishes to his name and, with this experience behind him, is well placed to put the recent changes into perspective: 'In the mid- to late '90s we had two deaths, Tony Roper killed in a truck in Texas, then Adam Petty and Kenny Irvine get killed a year later. They were kind of the little knocks on the door, maybe saying our sport is not as safe as it should be. Then, in 2001, we all got the wake up call to say we really need to improve the safety because the icon of our sport, Dale Earnhardt snr, got killed. That knocked the doors clean off the hinges.'

The second concern addressed was one of cost containment for teams. Whilst it was perfectly feasible for teams like Hendrick and Penske to build tens of different chassis for individual tracks it was becoming impossible for the little guy to compete. The CoT itself has been well documented in these pages before but to summarise, its key design concept was to improve driver safety and to prevent teams being able to simply spend their way to the forefront of the grid.

However, the end product was not necessarily to everyone's liking. 'The big thing the NASCAR fan, and in fact myself, had a hard time getting our head around was the fact that we were used to having a conventional spoiler on the car and now we have this wing. I think we are starting to embrace it a bit more than we once did, but that was probably the biggest thing that people struggled with – the fact that we don't like a car with a wing on it that is supposed to be called a Stock Car.'

> "we have never had a wing and a splitter to play with [before]"

The addition of these new aerodynamic elements has not just been challenging fans' opinions of NASCAR it has also presented engineers with a steep learning curve. Tiff Daniels, support engineer with Earnhardt Ganassi Racing with Felix Sabates, summarises the challenge this produced: 'We have had to learn a whole new way of dealing with the aero because we have never had a wing

SPLITTING HEADACHE?
Front splitters were new territory for Cup teams. Gone are the days of coil binding to control ride height

ON A WING AND A PRAYER
Rear wings allow cars to run closer than the old spoilers but struggled to find acceptance with Stock Car diehards

BIOGRAPHY

Larry McReynolds
- 23 NASCAR Winston Cup wins as crew chief
- 20 NASCAR Winston Cup pole positions as crew chief
- Two Daytona 500 wins as crew chief (1992, 1998)
- Two consecutive wins in NASCAR All Star race – The Winston as crew chief (1991, 1992)
- 1998 UAW-GM Teamwork Award of Excellence winner
- Named Copenhagen/Skoal All Pro Crew Chief for five consecutive years (1991-1995)
- Founding member of the Crew Chief Club

BIOGRAPHY

Tiff Daniels
- 2007-present, support engineer at Earnhardt Ganassi Racing with Felix Sabates. Also driving no 94 Dodge for Hamilton Racing in the NASCAR Camping World East Series
- 2007 graduated University of North Carolina at Charlotte, Batchelor of Science in Mechanical Engineering
- 2002-2006 competed in Limited Late Models and National Legends. 2003 Womens National Legends Champion

BIOGRAPHY

Pat Suhey
- 2003-present, group manager oval track racing, GM Racing
- 1998-2003 design engineer, General Motors
- 1985-1990 Michigan Technological University

and a splitter to play with [before]. Once we started to understand these there were some considerable gains made. However, with the rest of the car, because we work within such a tight box, any gains have been very gradual, which you can see over the past year and a half… There has not been one week where we have returned from an aero test and been like "ah, we've figured it out", it's just little tweaks.'

Of these, ride height control has become increasingly important due to the constraints of the aero package. McReynolds: 'What has been a real challenge for the teams is the splitter on the front. NASCAR mandates not just a minimum height to the ground but also a maximum height. So what that has done is limit the amount of travel teams can run, so you cannot run the splitter hitting the ground, you need an ideal height and none of the tracks we go to are completely smooth. One of the biggest challenges facing the teams is having that splitter and a car that travels down but does not bottom out.'

So how has this rapid advance in engineering approaches meshed with the more hands-on approach previously prevalent in NASCAR? Daniels has been on both sides of the fence, having grown up in her father's Stock Car team before gaining her degree in mechanical engineering. 'They [the mechanics] are really adapting to it now. Since I have grown up around it I have a lot of experience of the traditional way of doing things, working from purely driver feedback and very simple set ups such as shock travel. Combining that with what I learnt when I went to college gives me a good perspective on the different approaches. I think at first when engineering started becoming bigger there was a lot of distrust from the mechanics, thinking 'where are they coming up with these numbers, why can't I see what they are telling me?' So we just had to bring them along to show them where we were coming from. They [the mechanics] are coming from a point of 20-years worth of experience, so we really had to prove it to them. They are definitely more comfortable with it now though, especially now the testing ban has come in they have to accept it.'

TECHNOLOGY DRIVEN
Data engineering has played a vital role in the rapid development and understanding of the CoT

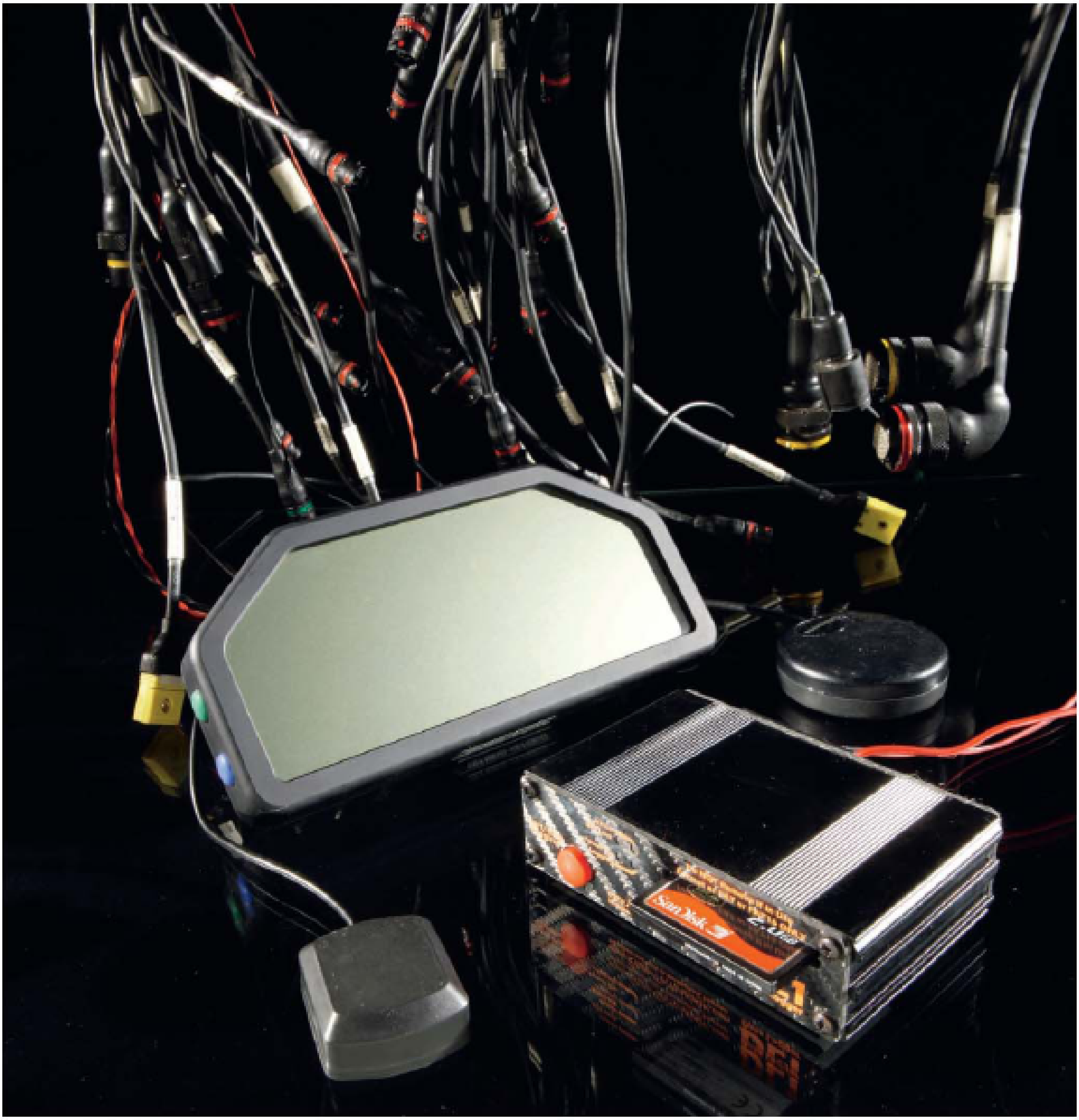
As if dealing with an entirely new car was not enough for teams, starting in 2009 the testing ban has meant teams are relying on off-track testing more than ever before, with the supporting manufacturers also changing the way they work. Patrick Suhey, general manager oval racing at GM Racing: 'We have had to start paying much more attention to our off-track testing. We were talking the other day to someone about tyre tests, saying it's made any track time you get much more important than it was. Tyre tests are now a really big deal. We didn't send people to tyre tests before, now we have one that goes along to every one so we can understand more about the tyre. So with the increased off-track testing the duty cycle gets much higher on our seven-post [rig] and all the aero tools too because they are getting much more use than they used to. Now, instead of just going out to a test, we are having to use those resources to achieve the same results and we have a lot more engineers working behind the scenes and with the teams on things like aero to achieve those results.'

> "ride height control has become increasingly important"

It is this manufacturer back up that has helped the teams keep up the pace of their off-track development. Suhey described their support role as being like the 'Intel inside' for the teams, providing the back up for their simulation packages and resources to allow them to rapidly progress with development.

So has the raft of changes introduced since 2007 meant teams are still struggling to understand the CoT or have they got it sussed?

The general consensus seems to be that by the start of the 2009 season all the teams were pretty close to having it worked out. Larry McReynolds: 'Where the teams are at now compared to where they were at the start of 2008 is light years ahead. I think we saw in 2007 that Hendrick were the only team to have this car figured out, but when we got to 2008 a lot more teams had it figured out. The only thing I would really like to see is for NASCAR to open the performance window back up a little bit more, so the teams have a bit more of a gap between a good driving car and a bad driving car.' And Daniels echoes these thoughts: 'It's getting better, but with everything changing we are not quite to the point we were at with the old car, but it has come on a huge amount from where we were a year and a half ago. There are still some things being developed, such as bump stops, which we never used to run on the old car, but I think in a year or so, whilst still not completely understanding the car, we will be in similar place to where we were with the old car.'



DATA CAPTURE

We show you how easy it is to get started in Stock Car data analysis by testing two of the most capable and affordable systems currently on the market

GPS data loggers were something of a paddock rumour a decade ago, little more than whispers of military spy technology and star wars. They were practically unheard of in Late Model racing. These days there are many different ones on the market, but the uptake in oval racing remains low, despite the fact that in such close racing they can often be the difference between victory and going a lap down. Some of them are so small and discreet they could even be used without your rivals or the tech inspectors knowing…

GPS loggers use the same satellite network as the navigation system you will find in most new road cars, and this is the only real difference to conventional systems. However, it's an important difference. The vehicle speed is calculated using GPS rather than wheel-speed sensors, making them far more compact and quicker to install.

We took two very different GPS loggers and a high end conventional logger and fitted them to some Late Models which race in the European Championship. Loggers are, as a rule, banned in Stock Car races but the series bosses in Europe gave us a special dispensation to run them at two meetings, one at the picturesque Lydden Hill Speedway in England, the other at the steeply banked Warneton Speedway across the Channel in Belgium.

Cosworth supplied us with a Pi Omega D2 GPS – its latest dash logger combined with a GPS receiver. Like the Race Technology package, the Cosworth system was easy to install. Out of the box there is just the dash, a CD with the required software and a wiring loom with rpm trigger, power lead and GPS receiver.

Racing on a short track with a digital dash seemed too much of a distraction for our drivers so the Omega D2 dash was fitted behind the drivers' seat. This is something that even Cup

TECH SPEC

RACE TECHNOLOGY DL1

Price: from $800

Dash: optional extra

Processor: 24MHz RISC

Memory: compact flash 32Mb–2Gb

Analogue inputs: 8

Frequency inputs: 4

Communications: 2 serial ports

Max sample rate: 100Hz

Operational temperature range: -20degC-70degC

GPS logging rate: 5Hz

Power requirements: 12v nominal input, minimum of 10v, maximum of 15v

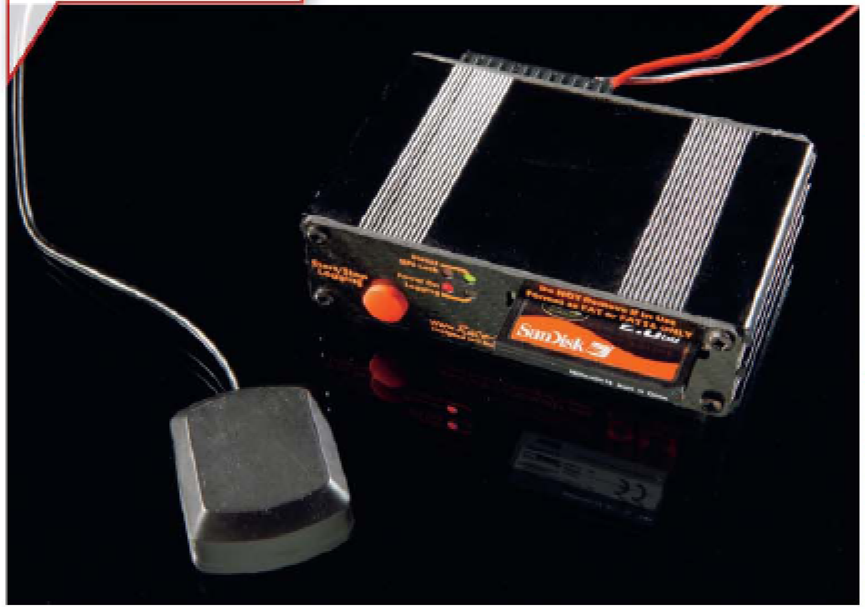


EXHIBIT A
The Race Technology DL1

EXHIBIT B
The Pi Omega D2

TECH SPEC

PI OMEGA D2

Price: from $1500

Dash: yes

Processor: Freescale MPC 5553 (32bit, 128MHz)

Memory: 128Mb

Analogue inputs: 14 (+2 thermocouples)

Digital inputs: 4

Communications: 2 × CAN, 2 × RS232, 1 × ethernet

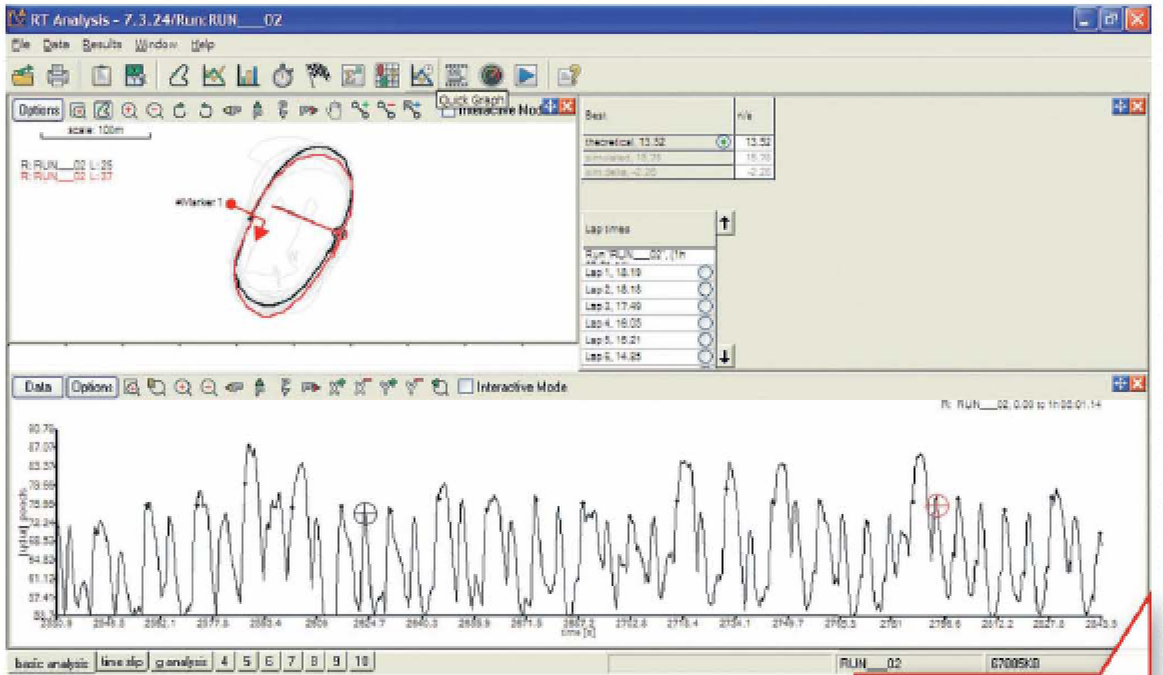
Max sample rate: 200Hz

Operational temperature range: 10degC-70degC

Weight: 440g

GPS Logging rate: 5Hz

Power requirements: nominal +12V and +28V



FULL RACE
The Race Technology software showing the full race at Warneton Speedway in Belgium

teams report, with some drivers wanting all the data in the world on the dash, others not wanting to see it at all.

Getting the D2 up and running was as simple as the system itself – fit it, power it up and off you go. Normally, to get good lap data the driver would press a couple of buttons on his first lap to set the beacon but, with the dash-mounted unit out of the way, this was not possible, though lap splits can still be added later using the analysis software.

Time spent ensuring the system is correctly set up is time saved at the track, with a couple of issues being encountered with the rpm sensor and interference from other electrical noise taking up valuable time on race day, a problem solved by adjusting the sensor sensitivity.

This logger was fitted to the Profil + Ford Taurus driven by former champion Jean Vassuer at both tracks. We also fitted a Pi Omega D3 to the 4 Roots V8 Racing Ford Taurus, complete with shock pots, though we will discuss this in more detail in a future issue of *Stockcar Engineering*.

Setting up and connecting the Race technology DL1 data logger was just as easy. It is supplied from the factory with a 12V cigarette lighter connection, but this can easily be adapted to any fused 12V supply (1A fuse). The logger features 13 configurable inputs, allowing one to log from a range of sensors, including shock pots and temperatures, which can all be attached through the supplied connector. Another useful function, although not strictly relevant to use in a Stock Car, is the ability to connect the logger through the serial port to any OBDII-compliant diagnostic port to record engine data directly.

At Lydden the DL1 was fitted to the Race Car Direct Pontiac, a former ASCAR, and at Warneton it ran on Kelvin Hassell's Roots V8 Racing Chevrolet.

Due to time constrains the DL1 was only set up to record basic acceleration and positional data. This involved attaching a power supply and mounting the GPS receiver so it could clearly see the sky. Operation of the logger is equally simple, with one button to start and stop logging and a clear visual indicator to show the unit is operational. The logger unit is supplied with both heavy-duty hook and loop fasteners and aluminium fixing brackets, however for out purposes good old racer tape was used. It is recommended that the logger be mounted with the front of the unit facing the rear of the car, due to the orientation of the onboard accelerometers, but the logging software does allow the unit orientation to be changed. Once the unit is mounted and powered up all that was left to do was position the GPS aerial with its magnetic mounting. Obviously, this is not a problem on a steel-bodied car, but on the Late Models, which have glass fibre bodies the old, faithful racer tape once again came into play.

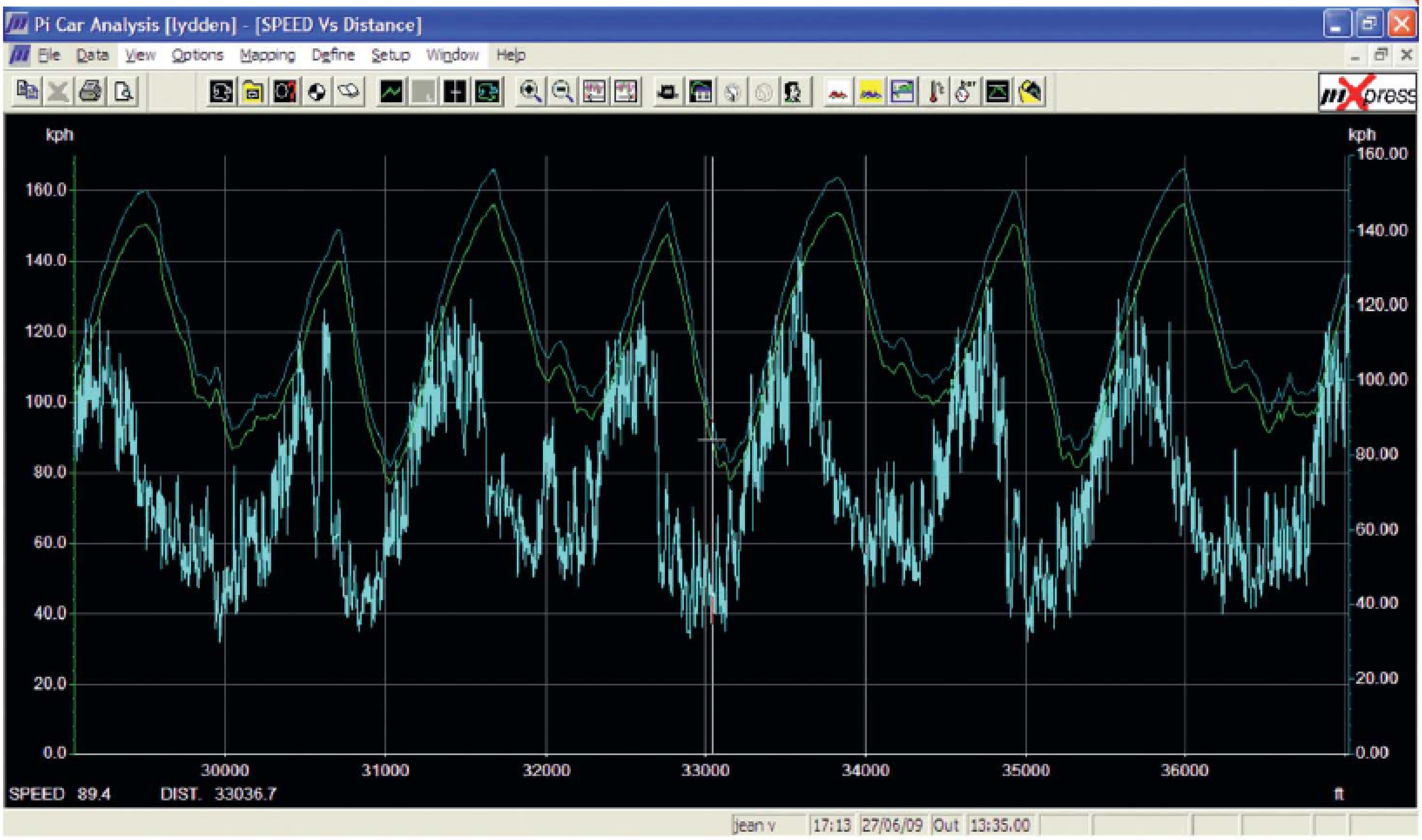
SAM THINKS...

"I was staggered at just how easy it was to call up useful data on both GPS loggers. After two very long days at the track the *Stockcar Engineering* team sat down in the plush surroundings of the Club Lounge on a P&O cross-channel ferry and got to work. We called up all the data on a Samsung NC10 Netbook and, within 30 seconds, were looking at clear data. The Race Technology software is ideal for novices as it's well designed, incredibly intuitive and extremely easy to use. You can have a look at it yourself by downloading a version from www.racecar-engineering.com.

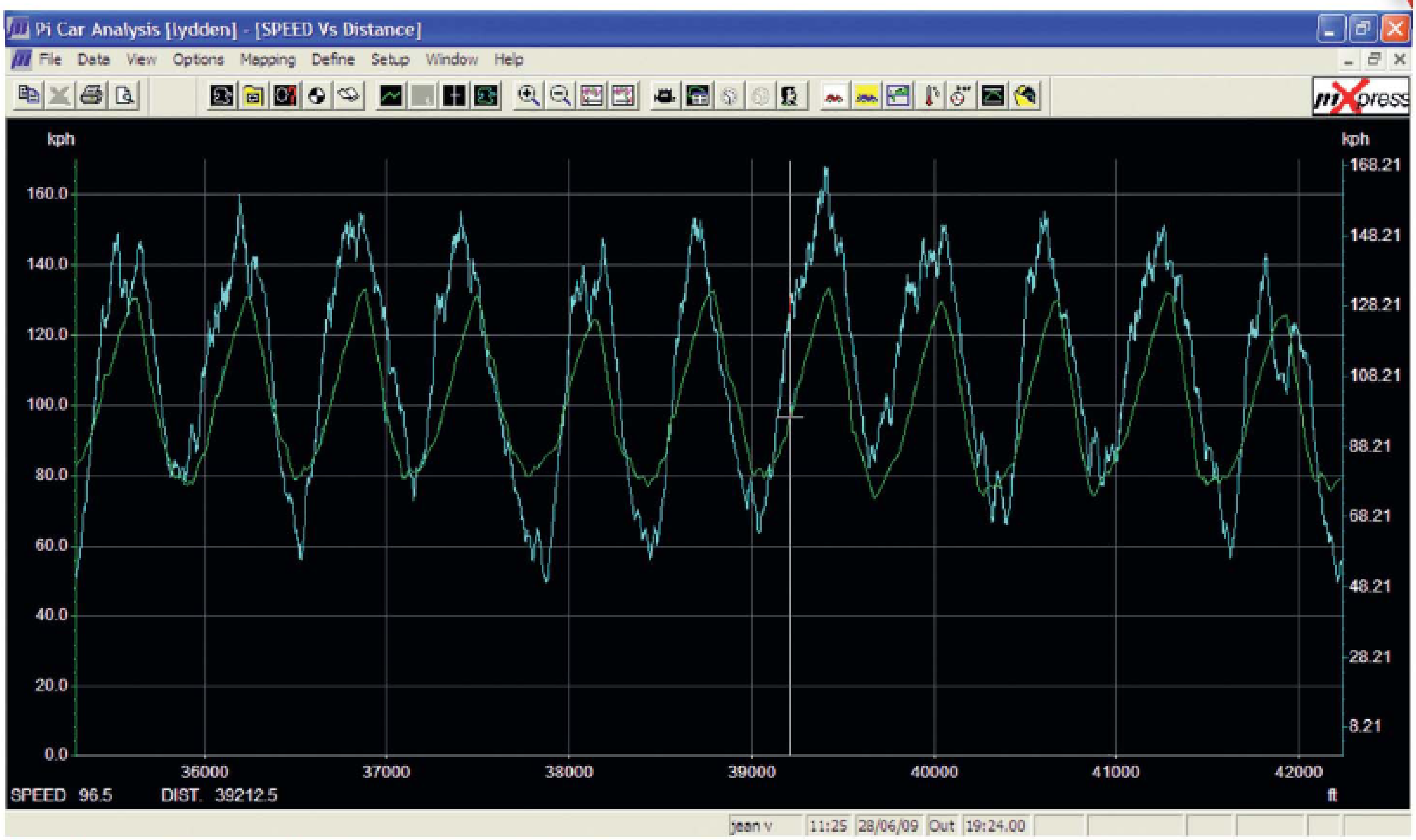
Cosworth's logger is a more capable device, as you would expect from its higher price tag, and is capable of logging rates of up to 200Hz. It also works with Pi Toolbox, a Formula 1-spec analysis package. Whilst this does not come as standard with the D2 GPS it is well worth upgrading.

Personally, what I would like on my car is the Omega D2 GPS with shock pots, along with a video camera, which is all very possible with this system. Dear Santa..."

PI OMEGA D2 AT LYDDEN HILL
This output trace shows three and a bit laps of Lydden Hill Speedway in England. You can see the uneven and undulating nature of the track from the green speed trace, whilst noise is distorting the light blue rpm trace. This was rectified by adjusting the filter settings on the Pi Omega GPS



PI OMEGA AT WARNETON SPEEDWAY
This outing shows five and a bit laps of Warneton Speedway – a high-banked oval racetrack in Belgium where the speeds are notably lower than at Lydden Hill. Note the rpm trace is much cleaner due to the filter now being applied



MATT BROWN

THE DEVELOPMENTAL EDGE

The difference between cheating and *Cheating*

Richard Petty once said 'There is no doubt about precisely when folks started racing each other in automobiles. It was the day they built the second automobile.' It could also be said that there is no doubt about precisely when folks started cheating in automobile races - it was the day the first rulebook was released. Racecars may be incremental in their evolution, with small advancements made that make it seem as though development is sometimes stagnant, but you only have to look at the fines handed out for rule violations after every event to see that teams are constantly looking for that extra developmental edge. An edge - we'll call it cheating - that is always a dependable source of entertainment. As a result, the column 'Caught' is the first thing I read when the new copy of *RE* shows up in my mailbox. There should probably be a distinction here between cheating and *Cheating*, with the former being more of a clever interpretation of the rules, but I still use the word cheating because the rules are usually written to make these exploits and plausible deniability mutually exclusive. That is to say, once you start cleverly interpreting the rules you are usually far enough into the grey area to know you're far into the grey area.

Cheating is prevalent enough, especially in Stock Car racing, where most of the teams' fines come from exploits that could be described as laughably shortsighted. Things like suspension modifications that result in on-track ride height changes practically guarantee a fine in post-race inspection. I'm hesitant to use the phrase laughably shortsighted, as this is likely just evidence that everyone is doing it and getting away with it most of the time, making the occasional fine acceptable. I expect some of the better teams might have even taken the time to do a cost / benefit analysis of the situation…

Also on the *Cheating* side we get the occasional very clever cheat, like the 1995 Toyota World Rally Car air restrictor design that resulted in a 12-month ban for Toyota. Max Mosley called it 'the most ingenious thing I have seen in 30 years of motorsport.' From the man himself, the most ingenious thing to come from motor racing in all that time was a cheat.

> "I want to win within the rules, almost as much as I want to win"

The grey areas are fun to work in because some of them practically beg to be exploited. Certain engine component surfaces must be flat, but what is flat? Nothing can really be flat, there must be a tolerance, a number. You may not be able to have moveable aero, but everything moves, and in ways hanging a weight off the rear wing can't accurately duplicate. Sometimes it's hard to know where the grey area ends and the black area begins, and sometimes there's only one way to find out… The simple fact is that the rules do not define the development area, but the policing and enforcement of the rules do. To be competitive, teams must work within the enforced rules and up to the limit that they are enforced.

People talk about cheating like it's detrimental to the sport, but I don't think it is. I'm not saying it should be accepted by the governing body (in which case it would no longer be cheating) or that the teams shouldn't be handed appropriate fines when caught, what I'm saying is that it is entertaining and interesting, and that it is undeniably part of the sport.

Cheating and winning in motor racing is not a hollow victory like it is in the Olympics or baseball, it's just the way things are done here. I think most people, most fans, are okay with their favourite team 'bending the rules' or 'exploiting the grey areas' to gain an advantage, considering the nature of the sport precludes sufficient policing to prevent everyone else from doing it. This fact, coupled with the constant pressure to win, I suspect leaves most professional racecar engineers sharing my opinion: I want to win within the rules, almost as much as I want to win.

CLEVER CHEATING
A prime example of *Cheating* was the brilliantly engineered air restrictor on the 1995 Toyota WRC

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