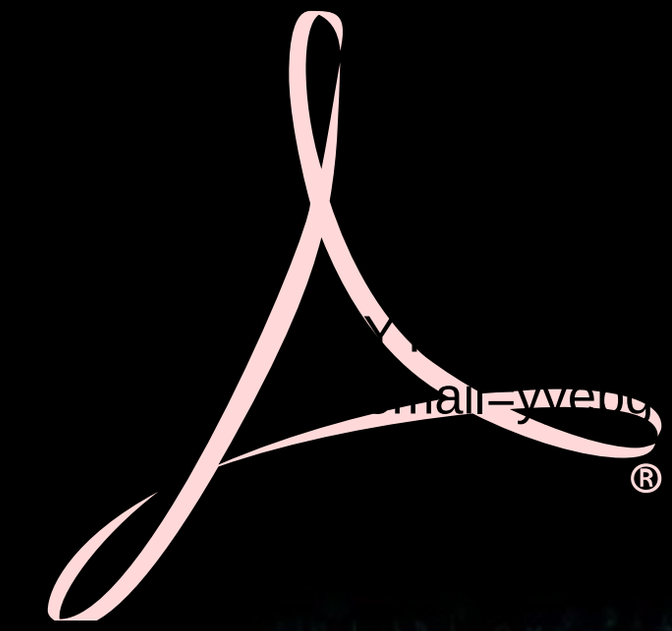

TECHNOLOGY FOR MOTORSPORT

The International Journal

Racecar engineering

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January 2006 · Vol 16 No 01 www.racecar-engineering.com UK £4.60 · USA $9.25

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Herb Fishel
Ex-GM man to spark a revolution in motorsport

McLaren's rig
Visiting top F1 team's test facility

Learning the trade
UK motorsport's new centre of vocational excellence

Understanding tyres
How race rubber really behaves

LAT

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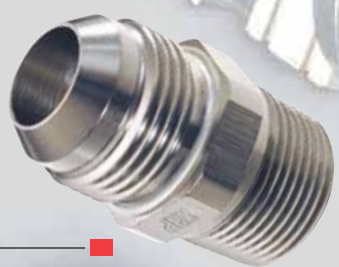

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Write Line

So Adrian Newey has finally skipped Woking for Milton Keynes, although his new team is now called Red Bull Racing instead of Jaguar. The rumour is the story leaked out on a radio station and when Newey got to work the next day his office was locked and Ron Dennis greeted him with 'please clear your personal belongings and leave.'

While I wish Adrian well in his new job after a few months gardening, or more likely 'tinkering with his cars' leave, if the story is true I can't really blame Ron either. Who wouldn't want to avert any risk of your outgoing technical director burning that vital, last CD from his work machine.

To be frank, in the skills-rich world of Formula 1, anybody can build an F1 car. The challenge is in the design. These days grand prix cars exist as data and, as the recent case between Ferrari and two Toyota employees is debating, data is harder to protect that hardware. It can slip out through subcontractors, through network crime and through movement of staff. But, while Adrian has left with little more than his desk ornaments, nobody can erase his brain. One can imagine Ron dreading being faced by a McLaren MP4-20 in Red Bull colours on the 2006 grid. In the late '70s, Tony Southgate left Shadow for the newly-formed Arrows and landed his new team with a court case thanks to their car's similarity to his last Shadow. Arrows lost in court and had to design a replacement. I can't imagine a similar case making it through the courts today though. The cars are so indistinguishable, the charge would never stick.

> **"IT'S NO WONDER TEAM PRINCIPLES FEAR THIS SCENARIO"**

However, all this is not just about a car design. The experience Newey takes with him amounts to much more than how to make a clone of the latest McLaren. It has to do with how to arrive at that design, the techniques and processes for arriving at a direction, and where to assign resources to achieve the greatest progress. Even with modern strategies for knowledge download, this ability to lead a team in the right direction is a rare commodity.

It's no wonder team principles fear this scenario, not just because of what they will lose, but as much for what it will give their competitor. Worse is the prospect of the technical director taking his key engineering staff with him, effectively ripping the creative heart out of the team. This could be a mortal blow and contracts are drafted with many complex clauses to prevent this happening. These days, the only way to acquire a fully-formed design team with current F1 experience is to buy a whole grand prix team. And haven't we seen that happen a lot lately? Renault, Honda, BMW, Midland and Red Bull all bought into F1 by acquiring established outfits. Toyota, on the other hand set up its team from scratch and has had a long and painful growth to its current level of competitiveness. So is constant acquisition the model for teams in the future? Perhaps there will be a group of Formula 1 teams who change their branding regularly on the exchange of vast amounts of money but retain the same staff, the same premises and facilities.

Road cars are becoming increasingly homogenous, distinguished by little more than their badge, but is Formula 1 already way ahead of them?

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Charles Armstrong-Wilson

The International Journal
Racecar engineering

Pit Crew

Vol 16 **No.1**

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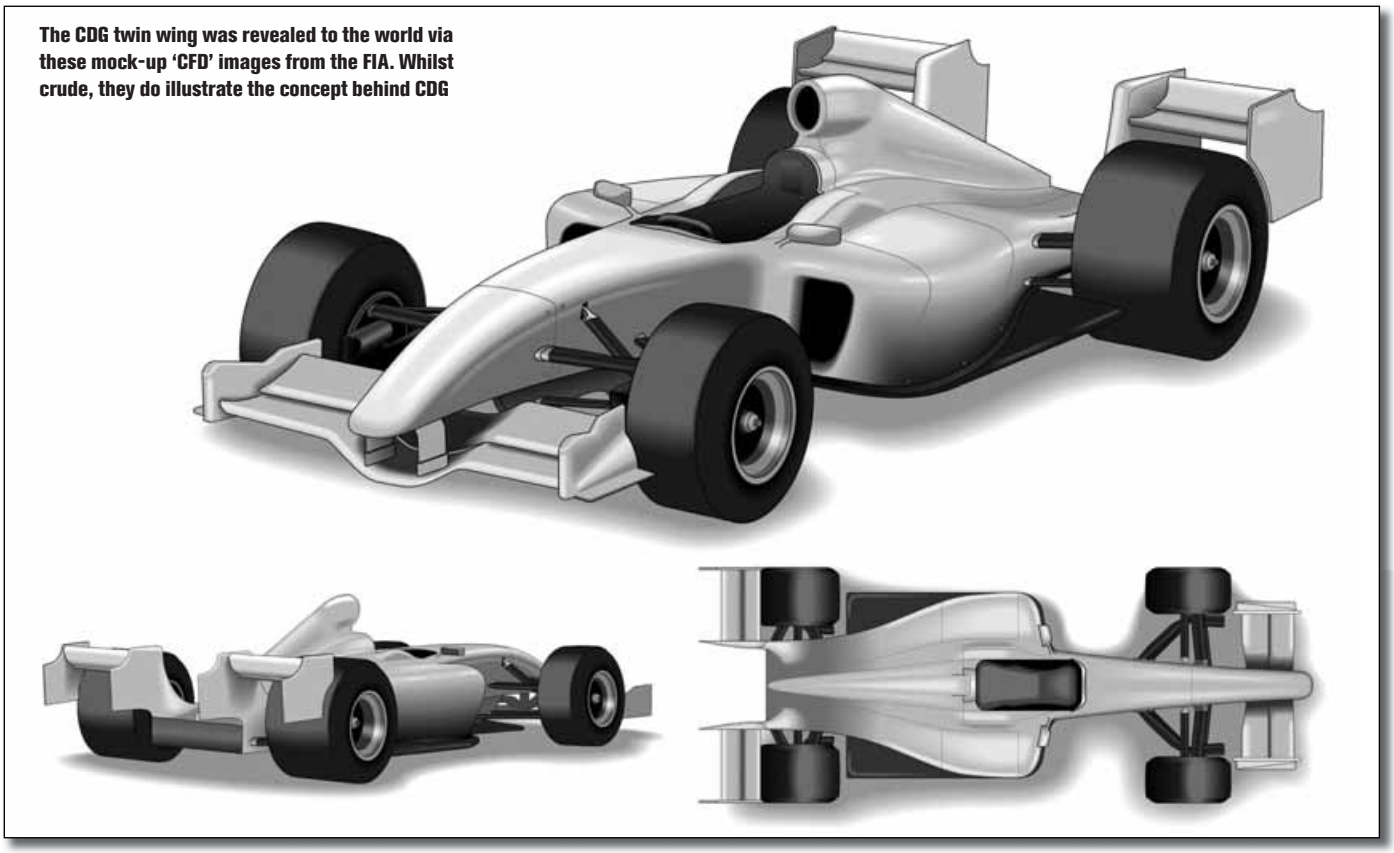
FIA clips Formula 1's wings

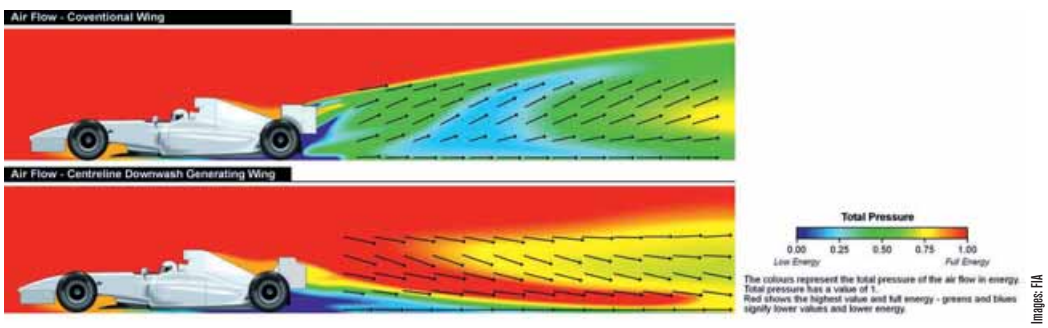


The CDG twin wing was revealed to the world via these mock-up 'CFD' images from the FIA. Whilst crude, they do illustrate the concept behind CDG

Formula 1 is set for a radical new look in 2008, with a new rear wing concept forming part of a package of changes to the series approved by the World Motorsport Council. The wing was revealed to the world shortly before a meeting of the F1 commission and could appear, along with some of the other new measures being proposed, as early as 2007 if 80 per cent of the F1 Technical Working Group agree.

Following the results of the FIA's fan survey, AMD was appointed as 'official technical partner' of the governing body (see debrief V15N7). One of the very first joint projects undertaken was the CFD study into vehicle aerodynamics, aimed at developing aerodynamic regulations that promote overtaking. The centreline downwash generating (CDG) wing is the first result the FIA has revealed from its relationship with AMD.

The new wing aims to reduce so-called 'dirty air', the turbulent flow in a cars' wake. In theory it will also reduce the efficiency of the rear wings as they will now be in the turbulent air of the rear wheels, reducing total downforce.



Images: FIA

However, there has been some negative reaction to the wing concept, notably from Gary Anderson, who commented in the British press that it seems to him that the idea has not been fully thought through.

Sergio Rinland, who designed the Sauber C20 amongst other cars, has a different point of view: 'I like it, because it will have the effect of reducing rear downforce, as I suggested some time ago, and leaving the designers to balance the front without many restrictions. Also it will help cars draft each other (remember what the Handford device did in CART) and that aids overtaking.'

A number of other measures have been taken by the WMC to encourage lower cost and more competitive racing, including larger wheels and a return to full slick tyres supplied by a single company. For 2006 it will also re-introduce tyre changes during races.

Qualifying too has been reworked, with all cars taking to the track in the first quarter of an hour, with the slowest five being knocked out after the first 15 minutes. Five cars will be knocked out every 15 minutes until the fastest five cars are left to compete for pole position in a 20-minute finale.

The FIA has also announced the appointment of the Bernie Ecclestone-owned Paul Ricard High Tech Test Track as the FIA institute's first centre for motorsport excellence. The facility will be used to host safety seminars, for training officials and for testing of new safety features developed by the institute's working groups.

Other centres of excellence for safety will be opened in the future, with the plan being for every continent to have one circuit selected as a hub for improving motorsport safety standards in that region.

Suzuki hits F1 grid with Hondas

A new team will be present on the Formula 1 grid this season, fronted by former grand prix driver Aguri Suzuki. Super Aguri F1 will operate out of the Leafield technology centre in England, former home of Tom Walkinshaw Racing.

Whilst it is known that the new team will use Honda's V8 engine, few details beyond that are known. Honda, who purchased the BAR team late last year, previously stated that it will also be running V8s in the two works cars. However, *Racecar* sources report that both Honda and Toyota have been testing restricted V10 engines in preparation for the season. There have been suggestions that the restricted V10 units will have an initial advantage over the V8s so it is possible the restricted 10s could find a home in the Super Aguris.

One major stumbling block the team must overcome is design and manufacture of an all-new chassis, as F1 rules stipulate that each team designs its own chassis (though its manufacture can be outsourced). Rumours suggest the team will use BAR-Honda chassis from last year but this appears to have been ruled out, leaving Dome the firm favourite to be the chassis manufacturer.

LAT

Mark Preston has been appointed chief technical director of the team. Preston, who previously was head of R&D at Arrows, had been trying to find a way into F1 for his Silverstone -based Preston Motorsport Group.

Suzuki's association with Honda goes back to the 1990s and Formula 1 with Footwork-Honda

LAT

Preston Motorsport's PR material points out that one of the big advantages for potential sponsors getting involved with its Formula 1 project is that the new team is 'perfectly set to exploit the existing FOM championship, or any future breakaway series.'

This could be seen as the entire reason for the team's existence – to allow Honda to have a foot in the door of the F1 championship with Super Aguri/Preston, whilst the works team is committed to the GPMA breakaway series.

Aguri had to get its entry documents to the FIA by 15 November, including engine and chassis data. As *Racecar* closed for press, the Aguri chassis should have been impact tested and certificated, but it appears this has not yet taken place. So, unless a number of rules can be waived, it looks highly unlikely that the team will be on the grid at all this coming year.

Adrian Newey joins rampant Red Bull

Red Bull Racing has scored a huge coup by signing senior F1 technical director Adrian Newey, who is currently at McLaren, to join the team in 2006.

The energy drink market leaders are becoming increasingly prominent on the Formula 1 grid after rounding off a surprisingly competitive debut season in 2005 by buying a second team, Minardi, who will in the future be known as Squadra Toro Rosso.

Red Bull Racing revealed that Newey will join the team in February, which will be too late to really influence the design of this year's (2006) chassis. However, he may be able to develop it and the Squadra Toro Rosso / Minardi chassis.

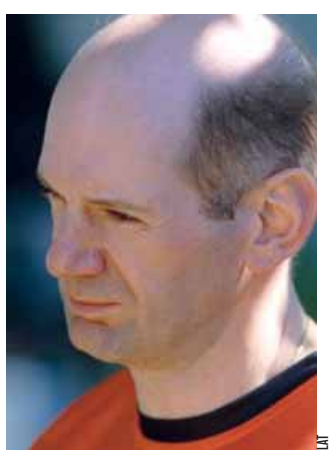
Newey appears to be just the latest achievement in Red Bull's grand prix racing charge, though it had been thought that the English technical director had been keen to leave McLaren for some time. It was announced in 2001 that Newey had joined the then Bobby Rahal-run Jaguar team, but the deal wasn't completed and Newey stayed at McLaren. It is worth noting however that Jaguar then went on to become Red Bull Racing at the end of 2004.

LAT

From 2007 Red Bull Racing's colours will be on a Newey-designed chassis

Red Bull Racing team boss Christian Horner commented: 'It's a massive recruitment for us, we need to make a step forward next year. That has to be focussed on getting into the top five or six in the constructors' championship, then in 2007 the real impact of Adrian's appointment will be seen.'

Newey's illustrious career started in the early 1980s with Fittipaldi Automotive. He then moved to March for whom he went on to design a number of cars including the 1984 Indy 500 winner. In Formula 1 his Williams' chassis defined him as one of the leading designers. The cars were consistently in the top class of the field between 1991 and 1997, during which time they notched up 58 grand prix wins and five constructors' championships. After Williams, Newey joined McLaren where more success followed.



LAT

Willis spills at MIA dinner

Geoff Willis, technical director of BAR Honda, revealed that the team used a seamless shift gearbox throughout the 2005 season. It works on the same basic principles as the Zeroshift and Weismann systems detailed in *Racecar Engineering* [V14N6 and V15N6]. However, it uses the team's own method for accomplishing the changes and is said to be very simple in its operation.

The timing of the shifts and the tolerances are key to its success, Willis confided. To reduce harmonic oscillations in the drivetrain, stiffness in the components – particularly the driveshafts – was said to be very important. Significant improvements in acceleration was an obvious benefit of the system and also the continuous torque during changes apparently unsettled the car less in corners.

The unit was developed jointly between the team and Honda which had first-hand experience of the Weismann Quick Shift when it was tried on a McLaren Honda in 1989.

Geoff Willis, Nick Fry and Chris Aylett were in expansive form at the MIA's recent Networking Dinner

While in expansive mood, Willis also disclosed that the BAR Honda's lack of pace in the early part of the 2005 season was due to an inconsistency in the downforce generated by the front wing causing understeer. 'It took us three months to sort out,' he admitted, 'during which we fell back in other areas of aerodynamic development as we devoted resources to fixing it.' He said the problem was eventually identified and cured and, in the process, opened up a whole new area of aerodynamic research. Willis also noted that both the Ferrari and Toyota appeared to be suffering from the same problem. In contrast, Renault and McLaren showed no signs of the phenomenon but he was unable to say whether it was because they had identified and cured it early on or never encountered it in the first place.

Racecar caught up with Willis at the MIA Networking Dinner at the Belfrey Hotel in Oxford UK, where he was appearing as guest of honour, along with team principal Nick Fry. During an onstage interview conducted by MIA CEO Chris Aylett, Fry admitted that with hindsight the 2.4-litre, V8 F1 engines for 2006 had not been such a good idea. He said they had been expensive to develop and, with the benefit of experience, a rev limit on the previous generation of V10s would have been a simpler solution.

BAR 067 Lakester – the fastest F1 car ever

British American Racing notched up one final achievement at the end of 2005 before morphing into Honda F1 by building the fastest F1 car in history. Its specially adapted 067 Speedster had been trying to set a new record at the Bonneville salt flats in Utah, but rain caused the flats to flood rendering any running impossible. Undeterred, the team decamped to the nearby Mojave airport to go for a high-speed run where the car hit 413.205kph (258mph) on the main runway, making it unofficially the fastest F1 car in history. The team is not content with this though, and plans to return to Bonneville in 2006.

The car has a number of alterations, including a stabilising fin at the rear and different radiator inlets, but still complies with 2005 regulations. It does not comply with current rules though due to the 3.0-litre Honda V10 not being restricted. Whether the next attempt will be made by a 2.4-litre V8 engined car or a restricted 10 is unclear.

BAR

BAR's Bonneville 'Lakester' has already been clocked at an unofficial 258mph

Rockets to the moon

Edwards AFB

The Lockheed F104 Starfighter-based North American Eagle land speed record attempt car tested recently at Edwards Air Force Base in California, USA. The team achieved speeds of up to 400mph and carried out a number of systems checks, including measuring some key systems like the magnetic braking system and 'speed brakes'. The steering and handling characteristics were assessed and data gathered to allow the team to see if the car was generating too much lift for the 800mph record runs on Black Rock Desert.

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NEWS IN BRIEF

- Alfa Romeo is withdrawing from the WTCC after just one season. It had previously been believed that the Italian firm would race a Super 2000 version of its new 159 model.

- BTC spec cars will be allowed to race in the BTCC until 2009 under an equivalency formula. Only privateer teams will be able to run the old spec cars and it is thought they will be not be able to win races. The British series will run to Super 2000 rules in 2006.

- Lada's 2110 WTCC racer was revealed at the Moscow Motorshow in November.

- A1 Team USA hopes to enter this year's Indy 500, though which chassis or engine the team will use is as yet unclear.

- John Barnard's B3 Technologies group has designed and manufactured a Skeleton sled for a British athlete to use in the winter Olympics. The sled is made out of composite materials and the firm is hopeful of a medal.

- Squadra Toro Rosso is considering running a year-old Minardi PS05 chassis in this year's Formula 1 championship – unless the FIA permits the team to use '05-spec Red Bulls.

- Super Aguri F1 is planning to run a team in Formula Nippon using Honda engines in a Lola B06/51 (FN06). It's clear F1 is priority though.

Learn to win students left hungry for more

Some 400 students attend the IMechE's new Formula Student event at Silverstone in late October. 'Learn to win' was a chance for all UK Formula Student teams to get together for a weekend of seminars given by a number of significant motorsport industry figures and a full day of track testing time on the venue's Stowe Circuit.

The event was also an opportunity for universities to introduce new team members to the task of running a racecar in good time for the '06 season.

Event organiser, Brian Robinson, was impressed with the turnout, with over 400 students attending the seminars and 11 of the 12 teams still running by the Sunday afternoon. 'The main reason for this event is to help teams with their preparations for FS 2006. The attendance was more than expected and it was an interesting and exciting experience for all involved,' he said.

Saturday's seminars had some of motorsport's top engineers giving advice on design, cost and testing regimes – Jon Hilton (technical director, engine division at Renault F1), Ian Murphy (track engineer, Williams F1), David Gould (Gould Engineering) and a number of other industry figures.

SAE

Students were given the opportunity to test their cars at Silverstone in October

Of the event Hilton said, 'It was great to see so many of the British teams there. When the seminars took place last December at Kingston University, it was probably a bit late in the day, design and build ideas were most likely decided by then, but this year I think we've caught the teams just in time.'

Ian Murphy of Williams F1 also commented, 'The standard of engineering represented the 'upper class' of the UK 2005 Formula Student entries. The best cars present would be competing for the Design Event win with just a little more design integration, a bit of weight loss and more care applied to load paths through the structure.'

University of Hertforshire's Jon Goddard said, 'I think it's an awesome opportunity to get new team members stuck into FS this year. Also a chance to get together with the rest of the UK teams and run the cars. It should definitely be run again next year!'

That sentiment was echoed by a number of students who also called for a winter series of dynamic-only events during 2006/7. 'It would allow us to train up first and second year students and teach them the skill of developing, running and maintaining an active racecar – something that is really missing in Formula Student and Formula SAE,' explained a senior UK team source.

Continental backs engineering excellence

Continental, the international automotive supplier most famous for its tyres, is backing a new initiative to promote the importance of the engineering sciences in a global economy.

Eight universities from around the world are participating in the initiative to conduct the first worldwide scientific study on 'Global Engineering', starting in October 2005. The group of universities is headed by Germany's TU Darmstadt, and also includes Georgia Tech (USA), Shanghai Jiao Tong University (China), Tingsua University (China), MIT (USA),

Thomas Sattelberger announces the new Global Engineering Study

Escola Politecnica da Universidade de Sao Paulo (Brazil), ETH Zurich (Switzerland) and the University of Tokyo (Japan).

This collaboration aims to study the influence and importance of technological expertise and education on the competitiveness of nations, people and companies.

At the heart of the initiative is a comprehensive study designed to reflect a broad spectrum of topics including competitiveness and technology, career paths of graduates in scientific disciplines, how first-rate engineering and science education are designed and implemented, the development of future trends in these fields and how to promote the successful interchange of knowledge between universities and companies.

'Technology and learning are our passion,' explained Continental's Thomas Sattelberger, 'which is why Continental is supporting the Global Engineering Study. We have actively promoted engineering education and the development of young engineers for many years.

'Continental strongly believes in partnerships with universities and is promoting this initiative as a responsible enterprise in a non-selfish way.'

By participating in this study the universities will analyse engineering profiles worldwide and present the results in autumn 2006.

New prototypes break cover

Giovanni Lavaggi proudly displays the wind tunnel model of his company's new LMP1 contender, the LS1

A new name is set to appear on the prototype racing scene – Lavaggi. The Monaco-based firm set up by former Formula 1 driver Giovanni Lavaggi is already advanced, with designs in place for its new LMP1, the LS1. Lavaggi hopes to be able to achieve the rare feat of designing, building and racing his own car at Le Mans, and to this end the team aims to enter the newly renamed Le Mans Series this year. Selected races in the ALMS and the new Japanese prototype series are also scheduled.

Power is to come from a big block 6.0-litre Ford V8, an unusual engine choice in a class dominated by smaller AER, Judd and Cosworth units. As with every other LMP on the market the chassis is a carbon monocoque, which will have to be crash tested to FIA standards. So far three suppliers have been revealed: Sachs dampers, Brembo brakes and Hella headlights.

Whilst the car is designed primarily for the LMP1 class, Lavaggi also plans to make a LMP2 version to order.

Meanwhile, one of Lavaggi's future rivals, Courage, is advancing with its twin LMP projects. As *Racecar* closed for press the Le Mans-based firm were in the 'final phase' before the LMP2 chassis (initially named C75) goes into production, whilst the LMP1 project (initially named C70) is being developed in the wind tunnel. More from Courage next month.

Elsewhere in France the Ligier name returned to competition with an LMP3 chassis, the JS-49. The car made its competitive debut in a recent VdeV race at Magny-Cours.

While on the other side of the English Channel Radical has been making progress with its SR9 LMP2 chassis – passing the first part of the FIA crash test at Cranfield University.

Racecar safety study

The FIA Institute's Closed Car Research Group has accelerated its work into the aspects of occupant protection during side impact collisions in World Rally Cars.

Following his tragic accident in the Margam stage of the 2005 Wales Rally GB, which caused the death of his friend and co-driver Michael 'Beef' Park, Markko Märtin visited the 2005 Tour of Corsica, where he consulted with FIA Institute president, *RE* technical consultant Peter Wright and relevant members of the research group on the topic.

This particular issue is unique in world motorsport: World Rally Cars travel at the very limit of their tyres at 160km/h between walls comprising buildings, trees and telegraph poles – each offering single-point contact if a problem occurs. The cars accommodate two people, who sit next to each other, their bodies taking up much of the space across the cockpit. The space issue is such that there is just 30-35cm between the outer door skin and the occupants' outer shoulders.

Current FIA rules mandate front side window winding mechanisms and a carbon inner door panel in World Rally Cars. Evidently, such equipment cannot offer the sort of deformation characteristics in absorbing high *g* side impact forces that are available with specifically designed deformable structures.

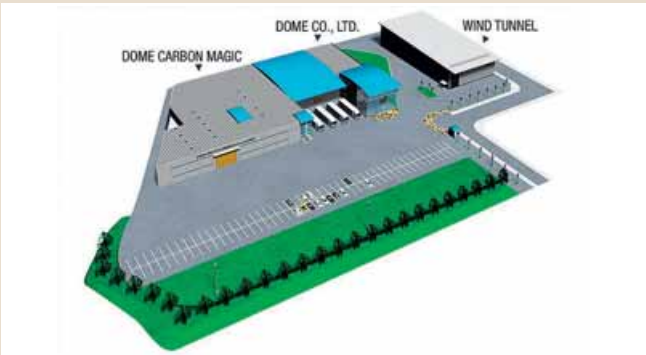
Much can be done to improve the survivability of drivers and co-drivers in side impact situations, and in 2003 Prodrive commissioned Cranfield University to undertake a study into the subject during 2004.

The findings are positive, and *Racecar* is compiling an in-depth report into the subject for future publication. Most observers agree that change is essential to prevent a reoccurance. Read about it first here in *Racecar Engineering*.

Rallying presents a different set of safety issues to other forms of motorsport

Dome expansion

Japanese racecar constructor Dome is expanding into a new, larger factory, possibly to accommodate the chassis construction of the new Super Aguri F1 team. It is also advertising for new engineering staff. Dome is also known to be currently working on a new LMP1 chassis.



Greece is the word for TT

***Racecar's* Tony Tobias opened the Athens Tuning show in late 2005**

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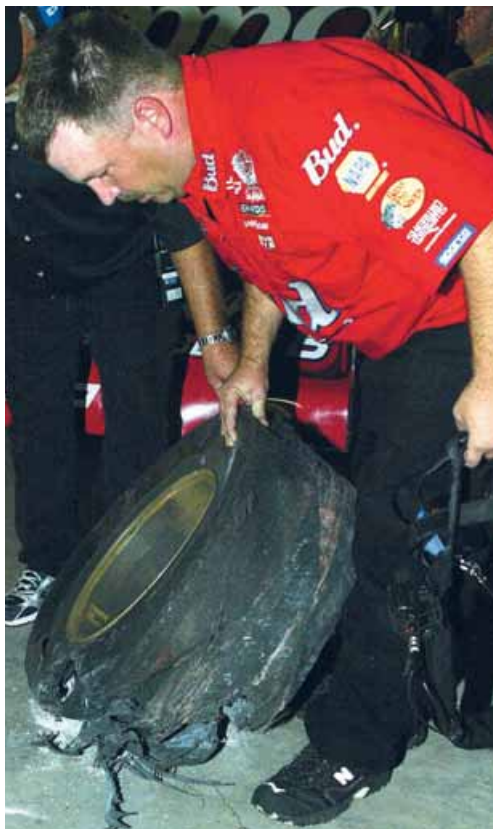
Charlotte still in tyre trouble

Tyres continued to be a problem for Nextel Cup cars at Charlotte in October. Accidents and blow outs were alarmingly frequent, and this on the same track which suffered from similar problems in May 2005 [see V15N8].

Before the October race, tyres were dragged around the track to add some rubber to the surface and improve grip, which it did with speeds way up over last year. Unfortunately, the race was appalling, with no fewer than five drivers hitting the wall with cut tyres whilst leading, including the points chase leader. Tyres were only lasting 20-25 laps before visible blistering could be seen or they blew out though wear. Eight other tyre incidents took cars out of the running. At the end of the race blame was being pitched between Goodyear, the grinding of the track and teams for under inflating right-side tyres.

At one point NASCAR officials enforced the teams' tyre pressures to make sure they were at Goodyear's recommended 50psi and threatened to dock points from those found to be under inflating. 'This is the biggest joke in racing I've ever seen,' remarked Kevin Harvick, who was obviously under a rock during the US Grand Prix. 'It's disgusting and embarrassing for our sport, we should throw the chequered flag and get the hell out of here.' Goodyear's representative at the track had this to say: 'They're running so fast (pole lap was 193.216mph compared with 188.877mph in 2004), so hard, so heavy and they're putting a lot of force on the tyres. There are so many variables involved it will take some time to get a clear picture of the forces on the tyres.'



Tyre problems continue to dog NASCAR, with a succession of crashes at Charlotte. It is not yet clear whether this is a track, a tyre or an inflation pressure issue. The case continues…

Meanwhile, track president, Humpy Wheeler, has promised a re-surface to cover his magic levigating before the May races in 2006, which should give Goodyear engineers time to look at a different compound for the new asphalt, unlike this year.

Jeff Gordon believes that drivers and engineers should give input before tracks are changed in any way, shape or form. 'I don't think anybody wanted to do anything dangerous,' remarked the four time champ, 'they had every intention to do the right thing, but I think you get the right engineers, drivers and people from NASCAR and you're not going to see these things reoccur.'

Goodyear carried out its own tests at the track two weeks after the race with an Evernham Dodge using a variety of compounds, including the one used during the race.

NASCAR mandated a new minimum right front tyre pressure rule in Atlanta that will remain in effect for the foreseeable future in all three of its top divisions. Coupled with new camber restrictions this should help to stop right front tyre blow outs, more often than not caused by wear. NASCAR officials will record the pressure pre-race and before each pit stop (officials have been recording pressures before each race since August in an effort to glean data). The minimum rating will vary each race with Goodyear recommendations. In Atlanta 47psi was used with no issues.

NBC Sports has withdrawn from negotiations with NASCAR to televise the second half of the season once its contract expires in 2006. Disney-owned ABC/ESPN will return to screen NASCAR races after it was booted out by the current Fox/NBC plan, while Fox is expected to continue to televise the first half of the season's events. Time Warner-owned TNT is also expected to become a third party in the mix. The current contracts have the two broadcasting giants paying $200 million (£115 million) each per year, but that is expected to rise in 2007, hence NBC pulling the plug. Whatever the 2007 year contract's sell for it will put between $400-500 million in NASCAR's already swelling swag bag.

NASCAR's car of tomorrow unveiled

NASCAR's car of tomorrow has been revealed to the press in four guises – Dodge, Ford, Chevrolet and what appears to be a Toyota. Few details are known about the COT currently but there will be more in *Racecar* next month.

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WRC calendar revolution

The FIA World Council approved the 2006 World Rally Championship calendar in the now traditional way last October – just two days before the start of the penultimate '05 WRC round, the Catalonia Rally.

The late confirmation of this calendar provides scant time for the teams to make their preparations for the following year, given that the manufacturing lead time of many parts for WRCs is lengthy.

Subaru team principal, David Lapworth, considers that this calendar decision process is 'a joke', and other team bosses express their difficulties with the late timing of the announcement of a schedule of world rallies for the following year.

Not least among these is Mitsubishi rally boss Isao Torii, whose budgets are set annually from April to the end of March. The late timing of the FIA calendar confirmation causes him numerous budget-establishing and logistical headaches, but the edict which also came out of the World Council regarding post-2006 world rallies makes these headaches.

It was also announced that the 2007 season will be 'eight or nine rallies' from just January to May, when the 2007 world champion driver and manufacturer will be decided. Then, the period from August 2007 through to May 2008 is to be known as the 2008 World Rally Championship. The intention is for championships to run over two calendar years after 2008.

Not knowing exactly how many rallies and, in particular, how many long-haul events are in the 2007 World Championship obviously causes a problem for someone in Torii's position when it comes to budgeting. Not to mention in securing a long-term future for the team in the sport, especially considering that Mitsubishi bean counters are currently looking closely at the costs of involvement in the world rallying.

A further complication from the rule makers comes this year in that the 'manufacturer' teams have been split into two categories. Taking into account that 2006 World Rally Cars are devoid of active front and rear differentials, engine water injection and interlinked anti-roll bars, and that there will be a selection of legally homologated 2005 specification cars available with active front and rear diffs and water injection (and Xsara WRCs with passive linked roll bars), without making an official announcement the FIA has decided thus:

Further delineating driver categorisation, there is a 'banned' list of drivers, and these are the stars. This list is so-called because those drivers who have placed in any of the first six places in a World Rally Championship over the past five years will not be allowed to contest world events in a 2005 specification World Rally Car. To score points in the World Rally Championship, a manufacturer must take part with two cars of the same make in all the championship rallies.

Additionally, it has now been decreed that two manufacturer team categories are now to be sanctioned: 'Manufacturer 1' and 'Manufacturer 2'. By implication, the Manufacturer 1 team must field 2006 specification WRCs, while it is understood that Manufacturer 2 teams may run any car, provided it is of the same make.

It seems that this decree comes from the desire to ensure what were known before as 'private' teams (and which now qualify to be named as Manufacturer 2) do not field, say, an '05-spec active Focus WRC on asphalt rallies and an active Impreza WRC of similar vintage on dirt events. However, by dint of their name, it is also understood that manufacturer points scoring opportunities will be available to each of these teams. Which seems to mean that an all-active '05 car can score manufacturer points if driven by a 'non-banned' driver.

It was announced during the Catalonia Rally that Citroën Sport will be retaining the services of its star driver during the teams' sabbatical from the WRC in 2006, to drive the Xsara WRC this year run by Kronos Racing. He will also help with work on the development of the C4 WRC in preparation for the manufacturer's return in 2007. The driver who is reigning World Champion will have to drive a 2006-specification, passive front and rear differential Xsara which will be achieved through applying 'Variant Options' to the 2005 car.

Currently, the only manufacturer to hit the 2006 World Championship running with a brand-new homologation of a new car to the 2006 rules will be Ford with the new Focus. The 2004-specification Focus RS WRC which contested the 2005 World Championship as a works car demonstrated that it remained well on the pace.

LAT

Citröen is one of the few teams who will benefit from rule changes for 2006

Mitsubishi targets Group N performance

Faced with the arrival of cars built to the FIA's Super 2000-Rallies formula, Mitsubishi is staying with its Group N 'showroom' roots with the display of the Concept Sportback at last year's Frankfurt Motor Show (the car first shown as the Concept-X in Tokyo).

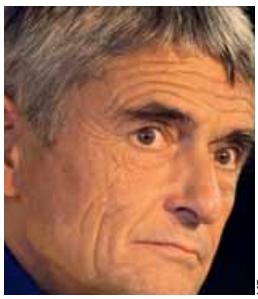
Defining the shape of the new Lancer series, this car is the basis of the Lancer Evo X.

Using aluminium alloy for the bonnet, boot, wings and door panels helps weight reduction, though whether they all make it to production remains to be seen. The Concept-X has active control of its four-wheel-drive system, brakes and steering and anti-roll bars. Power is transmitted via a six-speed gearbox controlled by paddles on the steering wheel.

The Concept-X's turbocharged 2.0-litre, 16-valve, four-cylinder engine is equipped with Mitsubishi's MIVEC variable valve timing technology, which first saw light in a Lancer Evo in the current Evo IX. In Group N trim this MIVEC kit is said to be the main reason for an engine performance increase over its rpm range, offering a better torque curve and more response. A new titanium turbo with a magnesium compressor also helps here, it is claimed.


LAT

Aguri Suzuki


LAT

Pierre Dupasquier


LAT

Max Mosley


LAT

Giovanni Lavaggi

● **Gerald Brussoz**, a former Michelin tyre engineer, has joined Ferrari's Formula 1 team in a new role aimed at optimising the F2006's tyre usage. It is worth noting that Ferrari uses Bridgestone tyres.

● **Pierre Dupasquier** will continue to be involved with Michelin in a consultancy role looking after special projects.

● **Aguri Suzuki**, the Japanese former grand prix driver, has set up his own Formula 1 team. Mark Preston's Preston Motorsport Group is joining him in the venture (see debrief p7 for further details).

● **Max Mosley** has been unanimously re-elected as president of the FIA – his fourth consecutive term in the position.

● A number of other FIA appointments were announced, including **Michel Boeri** as president of the senate, **Marco Piccinini** as deputy president for sport and **Sebastian Salvado** to another senior FIA position. Other members of the senate were also announced, along with vice presidents of the FIA for sport and the World Motorsport Council.

● **Adrian Newey** is set to leave McLaren for Red Bull Racing (see debrief p7 for more details).

● Former grand prix driver **Giovanni Lavaggi** has set up a new LMP manufacturer – Lavaggi. He aims to design, build and race the car at Le Mans.

● **Dietmar Metrich**, chief engineer at Skoda Motorsport, has left the team to spend more time with his family.

● **Franz Tost** has been appointed team principal of Squadra Toro Rosso, Red Bull Racing's 'B' team. Tost had been track operation manager at BMW motorsport.

● **Charles Armstrong-Wilson** became the most prolific editor of *Racecar Engineering* in November when he closed his 65th issue. Previously, the magazine's founder, Quentin Spurring, had overseen the most at 64 issues.

Send your company and personnel news direct to the *Racecar Engineering* team: tel: +44 (0)20 8726 8363; fax: +44 (0)20 8726 8399 or email racecar@ipcmedia.com

ON THE GAS...

CRAIG DAWSON

Post grad researcher, Adam Sharpe Motorsport, amongst others

Dawson, a familiar sight in the pits and paddocks of top-line British motorsport, is a recent graduate from Oxford Brookes University

How did you first get involved in motorsport?

Engineering is in my blood – my grandfather is a former president of the IMechE, and my father has run his own team since long before I was even born. I have seen the highs and lows already and it has taught me a lot.

What's the most interesting project you've ever worked on?

I think it was probably the designing and building of the Westfield SEight GT3 car that my father was in charge of. Trying to make the car strong enough to handle 500bhp and keeping it at 750kg was a huge challenge. When our car pulled alongside the Lanzante McLaren F1 past the pit lane at Snetterton we knew we had it about right.

Formula Student has also been fascinating for many other reasons – it's more of a challenge with 'interesting' experiences.

What achievements are you most proud of?

Winning the skid pan in FSAE 2005 and breaking the world record in the process was fantastic. Driving a car that I and many others had put so much into was a very moving moment and made all the pain of getting there worthwhile.

It showed that we can build fantastic FSAE cars in the UK and, with better budgets, the Americans and Australians are going to have to watch out. We were the first Europeans to win a Dynamic event over there, which made it even sweeter.

Can you name your favourite racing car of all time?

The Audi R8. Only now are people catching up with it. In the modern day I don't feel any other car has had such dominance.

Who do you most admire in racecar engineering and why?

The likes of Patrick Head, Keith Duckworth, and Ross Brawn have all been motivational figures for me. I think it's the dream of most young engineers to replicate these types of people later in life. They have had incredible success. Having worked with Geoff Goddard in the last few years at Brookes has inspired me greatly. He had confidence in some crazy ideas and has let me develop them.

What racing era/formula would you have liked to work in and why?

I think the late '90s in Champ Car. The racing was fantastic – every weekend you could have a different winner. It was so important to chase that last tenth and everyone in the team could really make a difference. It was single seaters at their best.

What tool/instrument could you not work without?

Either a Bosch Automotive Handbook or a Zeus book. As an undergraduate they are never far away, regardless of the subject.

What engineering innovation do you most admire?

Fuel injection, because of the huge step it made in getting the best from a race engine.

Is motorsport about engineering or entertainment?

It has to be a balance. Today there wouldn't be any engineering without the money the entertainment brings in. I guess you could say that entertainment is more important in F1 though – imagine where we would be today if the FIA didn't keep slowing the cars down to try and improve the entertainment.

What new technologies in motorsport are you most excited about?

The use of composites I think. With carbon gearboxes being so successful, how long is it before we see more composites being used in engines?

Is there a future for high technology in motorsport?

Absolutely. The issue is how it is brought into our sport.

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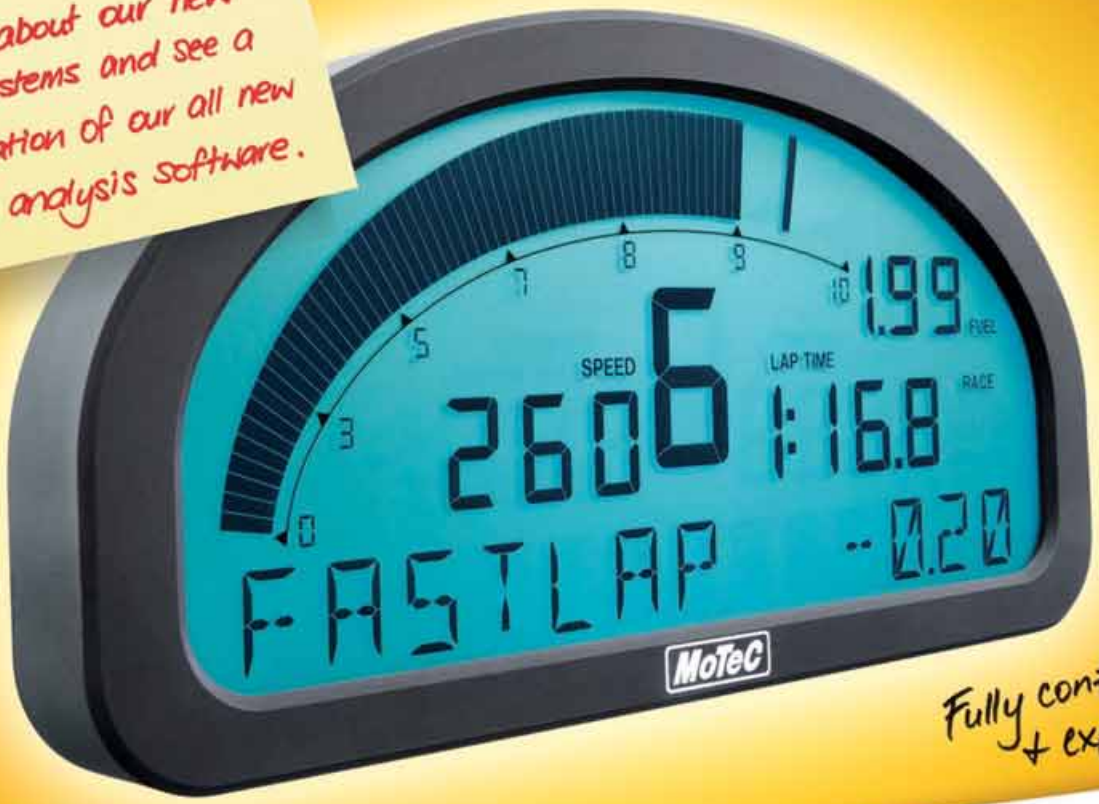

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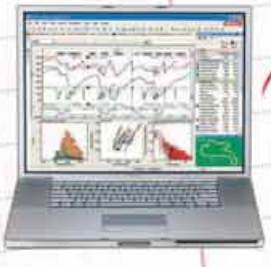

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Autosport International ENGINEERING SHOW
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Autosport INTERNATIONAL ENGINEERING SHOW

News

Many companies are set to use the 2006 Autosport Engineering show as a perfect forum to showcase new products.

German metals specialist, Tennant Metall & Technologie GmbH, will be displaying its new high strength, cold drawn, seamless, stainless steel tube. The company's CRW1000N product is supplied in a heat-treated condition and is entirely suitable for both welding and bending. The tube has been designed for numerous applications, including motorsport, engineering, marine and chemical applications.

Danish company, Ole Buhl Racing, will be distributing a Power Control Module to replace the need for circuit breakers or fuses. It comes with 18 programmable, high-powered channels, 16 low-powered, and runs at a steady 160A power output.

UK specialist component manufacturer, Pace Products, will be displaying its new precision lightweight race fittings. The re-usable anodised alloy hose ends are machined from billet to aerospace standards to provide every application with a secure, leak-free seal.

UK motorsport component manufacturer, SPA Design, will be introducing a new range of 52mm (2.05in) analogue instruments to go alongside its existing range of tachos, while SPA Dynamometer will be showing its latest evolution shock dyno, hosting an increased degree of stability.

To find out what other new products will be available at the show make sure you secure a ticket of your own. To find out more information about the event visit www.autosport-international.com

Talk to TT

If you are thinking of exhibiting at the show and would like to speak to someone about how to go about it, then contact *Racecar's* Tony Tobias. Email: expo@tonytobias.com or call him direct on: 07768 244 880.

Arrow straight

With the ability to design and manufacture custom engine components in house Arrow Precision offers racecar engineers a valuable service

Words | Katie Power

Race engine component manufacturer, Arrow Precision, will be attending next year's Autosport Engineering show to launch its new product range and showcase its design capabilities.

European leaders Arrow Precision produce high quality racecar components from the design stage, right through to manufacture, with a full custom-made service available.

The company was founded in Coventry in 1974 by David Arnold. He saw a market for competition connecting rods and decided to create a small engineering company that provided quality products and service. The company's customer base grew and in 1989 the company moved into its own premises in Hinckley, Leicestershire. There it proceeded to invest time and money into initiating its own manufacturing process for connecting rods. Since this point the company has continued to prosper, becoming a familiar face at many large-scale events.

Arrow Precision actually made its first ever public exhibition at the very first Autosport Engineering show. Many more shows followed and in 2001 it made its first appearance at the PRI show in Indianapolis, now an annual fixture on the company's calendar.

2004 was a key year for Arrow Precision as it successfully branched out into the world of motorbikes. The company now sponsors the Hawk Kawasaki British Superbike Team, opening up new possibilities and increasing public awareness of the company's high quality titanium connecting rods.

David Arnold's son, Ian, took over the position of managing director in 1997 and has been pushing the company progressively forward since. Arrow Precision now has 41 members of staff and has recently increased its production area by 50 per cent. Over the last six years turnover has trebled, and recent investment has seen the introduction of a new CNC grinding machine, a horizontal twin pallet milling machine and a CMM Mitutoyo measuring machine.

As a company, it is mostly renowned for its superior quality connecting rods and cam followers, and is continually developing new products to meet specific customer requirements. Other ranges manufactured include flywheels, valve guides, spring retainers and shims. It is also the main distributor for ARP fasteners in the UK.

Connecting rods are Arrow Precision's main product line but it also manufactures a range of precision engine components

Arrow Precision has never missed a show since the opening of Autosport Engineering and the positive response it receives keeps it returning year after year. It will be using the large-scale event to showcase its established product lines, its design and manufacturing capabilities and to launch a new range of products. As well as this there's also the obvious advantage of being able to interact directly with clients, new and old.

Contact

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Hinckley Fields Industrial Estate
Hinckley, LE10 1YE
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Tel: 01455 234 200
Fax: 01455 235 545
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Sharon Quaife, Quaife Engineering

It was a great opportunity for us to meet with customers, new and existing - and the response following the show has been fantastic. Roll on Autosport 2006!
Andrea Rodney, Hone-all Precision

Autosport International is the ultimate racing show catering to the European markets.
Oscar Romano, Ferrea Racing Components

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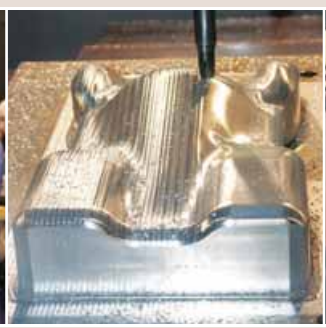
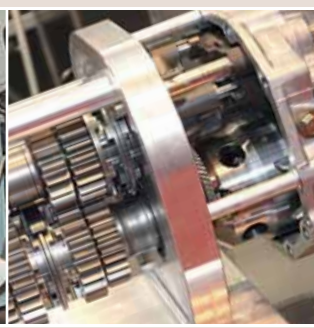
- 54% do not visit any other trade show

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Autosport INTERNATIONAL ENGINEERING SHOW

Birmingham bound

Every year the world motorsport community descends on the Birmingham NEC in the UK for Europe's biggest and best motorsport engineering trade show, Autosport Engineering, which this year takes place on 12-13 January. A close look at the venue reveals why the Birmingham Exhibition Centre is the ideal location – it is next door to an international airport and mainline railway station, serving both London and the Oxfordshire industry cluster.

With over 400 stands this show has become essential for anyone involved in motorsport engineering and everyone of any importance is there. Be prepared for a lot of walking, a lot of talking and even more business cards (both given and received). Once again *Racecar* is the official media partner and will have a strong presence at the show.

Show opening times

The show is open from 0900–1800 hrs daily. Trade days and the essential engineering show are on Thursday 12 and Friday 13 January. The international show, which is open to the general public, continues until Sunday 15 January.

Beat the queues

Trade visitors can avoid queuing to get into the show by pre-registering online at www.autosport-engineering.com for just £22 per day, which includes the trade guide to the show. The ticket gives full access to both the international and engineering portions of the show. Only bona fide trade members and valid competition licence holders will be admitted and must have proof of their status as a competitor, trade buyer, supplier or manufacturer.

Travel

Birmingham's NEC is in the ideal location. Birmingham International railway station, which is part of the NEC complex, is served by fast and frequent trains from central London and Oxfordshire. From the NEC the centre of Birmingham is just 10 minutes away by train. Also in the same complex is Birmingham International Airport, which has scheduled flights from North America and Europe, and is used by as many as 50 international airlines. Road travel is also well catered for, with easy and well signposted access from the M1, M6, M40 and M42 motorways and there is on-site parking for 21,000 cars. For more information on getting there visit www.autosport-international.com

Accommodation

There is a large number of hotels around the NEC catering for most budgets, many within easy walking distance of the show. The on-site Hilton Metropole and Airport Holiday Inn are among the most popular. Early booking is highly recommended.

Public days

Members of the public are admitted to the Autosport International Show on Saturday 15 and Sunday 16 January only, after the engineering section has closed. Ticket prices start at £25 for adults. To pre-book tickets call the ticket hotline on 0870 380 2244 or visit www.autosport-international.com

Pankl makes debut

Austrian drivetrain specialist Pankl will be making its first ever appearance at a motorsport trade show, displaying its whole product range, including gearboxes for LMP2, Formula 3 and touring cars.

At the end of 2004 the tally stood at 50 CART wins, six IRL champions, four Indy 500 wins, nine Le Mans class wins, eight world rally champions, 50 DTM wins and over 100 Formula 1 wins, as well as a plethora of success in other formulae, yet few know much about this Austrian success story.

Pankl is a company firmly rooted in motorsport, and has been since 1920 when Karl Pankl finished on the podium at the Hungarian Grand Prix in a Salmson.

More recently, Pankl has been expanding with flotation on the NASDAQ Europe, and an expansion of the aerospace side of the business. Currently the firm's business is 85 per cent motorsport and 15 per cent aerospace. Of the motorsport business Pankl supplies 84 per cent for actual motorsport and 16 per cent for high performance roadcar applications. Yet the firm has remained highly secretive, only recently allowing journalists from *Racecar Engineering* inside its factory. Pankl will be on stand E318.

If you can't wait until the show there is more on Pankl in the next issue of *Racecar*.

Pankl's PFB006 touring car gearbox will be on display for the first time

French revolution

The Nevers Magny-Cours engineering cluster, in association with CS Consulting, are set to showcase the full spectrum of French motorsport excellence in their own pavilion in the Autosport International section of the show.

As *Racecar* closed for press 11 companies were planning to exhibit in the pavilion. Rapid prototyping specialist, Danielson Engineering, is going to be present, as is ACE Aero Concept Engineering – a firm created by two ex-Prost F1 engineers that supplies a complete aerodynamic consultancy and development service. Texys, Sodemo, Apole, Danielson Equipment, PRM promo racing, LSP and Fibre Active are all planning on exhibiting as well.

The French Pavilion is just one section in the international show of interest to *Racecar Engineering* readers. A number of leading engineering firms will also be exhibiting in the International show.

Visit Racecar Engineering

Racecar Engineering magazine will once again fill its usual spot in the Engineering show, stand number E415. It's the place to take out a subscription or book advertising space in the premier international motorsport journal. Tony Tobias and Andy King will be on hand to answer any enquiries.

Also members of our editorial team including editor, Charles Armstrong-Wilson will be on hand to chat about feature ideas, new products and gather any feedback. Visiting *Racecar* is an essential part of the show as we will be displaying engineering that has caught our eyes over the past 12 months.

Visit stand E415 and meet the *Racecar* team

MIRA to celebrate UK racing success

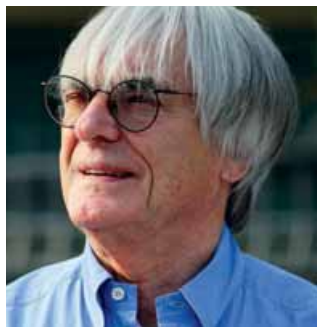
MIRA, the engineering development facility, is planning to celebrate a successful season of racing in the UK on its stand at Autosport International.

MIRA was involved in the design and development of Team Halfords Dynamics' BTCC-winning Honda Integras and assisted the Team West-Tec SCSA stock car team which also took that series' honours. The firm hopes to be able to display some of the spoils of its success on stand 9650.

A MIRA spokesperson said, 'Our stand will be staffed by sales people and also technical experts so people can access our world class engineers.'

MIRA technical experts and engineers will be on hand at stand 9650

Bernie Ecclestone to attend show



The annual Sid Watkins lecture will be given this year by none other than Bernie Ecclestone.

The Formula 1 supremo is a surprise attendee to the show and the lecture is already fully booked.

Left: thermal imagers will be demonstrated on the *Racecar Engineering* stand

New products and latest technology

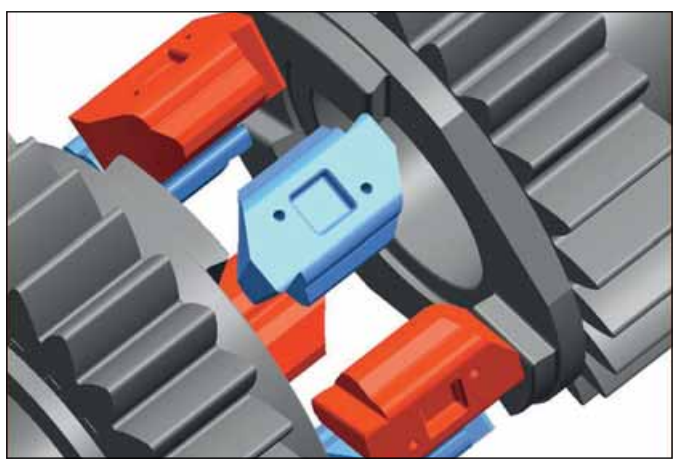
Ole Buhl Racing is planning to launch a number of new products at Autosport Engineering this year, including its Power Control Module which is basically an integrated replacement for circuit breakers and fuses.

The PCM is capable of a continuous 160amp power output and has 18 programmable high-power channels and 16 fixed low-power channels.

The Bournemouth, UK-based firm will also be revealing the all new Euro 4 ECU from EFI Technology. It is a lower cost, high-end unit and will have a range of specifications – more of which will be revealed on the OBR stand (no. E272).

ZF Sachs (E331), ATL (E350), GKN Driveline (E325), Goodridge (E166), Jacquemin Tuning (E168) and ITG (E205) are all also likely to launch new products at the show.

Seamless shifting will be found on stand E415, where the revolutionary Zeroshift gearbox featured in V15N6 and V14N2 will be on display, with its method of operation explained. On the same stand the ISIRYS thermal imagers will be demonstrated.



Right: also on the *Racecar* stand Zeroshift will display its revolutionary seamless shift gearbox

Industry shares technical insight

IMechE, the Institute of Mechanical Engineers, has organised the International Motorsports Engineering Conference which takes place on the 11 and 12 January 2006 at Birmingham's NEC.

This new event is targeted at individuals involved in all aspects of racecar design, development, engineering and technical management.

Attendance at this not to be missed event costs £250+VAT for IMechE, SAE or AMRA members and £340+VAT for all non-members.

Discounted hotel rooms have been arranged by the organisers but are likely to fill well in advance so urgent booking through IMechE is definitely advisable.

Interested parties should contact Stephanie Love at IMechE on +44 (0) 207 973 1312, or by email at s_love@imeche.org.uk

Conference programme*

Updated speaker programme*

Day one – Wednesday 11 January 2006

0930 **Registration and coffee**

0950 Opening address: **Nick Vaughan**, chairman of IMechE's automobile division welcomes delegates to the conference

1000 **Richard Pearson** from Lotus talks about gas dynamic phenomena in the exhaust system of internal combustion engines

1020 Ricardo's **Roland Ermers** on the promotion of alternative fuels and fuel efficiency in motorsport through fuel flow equivalence

1040 **Discussion**

1100 **Coffee break**

1120 Enhancing the design of the valve train of NASCAR Nextel cup engines is **Alex Livadeus** of Menard Competition Technology's topic of choice

1140 Newly crowned BTCC champion **Team Dynamics'** chief engineer discusses the aerodynamic sensitivity of touring cars

1200 Drag racer **David Alexander** on the science behind launching a car from 0–100mph in under one second

1220 **Discussion**

1240 **Lunch**

1340 The Renault F1 engine division's technical director and conference organiser **John Hilton** on driving development with internal competition

1400 University of Durham lecturer **David Sims-Williams** explores wind tunnel model support strut interference and prospects of its elimination through magnetic levitation

1420 Lola man **Julian Cooper** looks at the evolution of the firm's Le Mans class-winning prototype, *Racecar* V15N5 should give you a good background on the B05/40 chassis to be discussed

1440 **Discussion**

1500 **Tea break**

1520 **Rob Dominy** of the University of Durham will speak on tyre surface pressure measurement in the wind tunnel

1540 Xtrac design analyst **Damien Brayshaw** looks at the effects of optimal differential control on the performance of open wheel racecars

1600 **Richard Thomson** of Zeroshift discusses the Zeroshift instant gear shift system. See *Racecar* V15N6 for more information

1640 **Close of day one**

Day two – Thursday 12 January 2006

0930 **Pat Symonds** of Renault F1 gives the keynote speech

0950 Ricardo Motorsport design engineer **Jonathan Hodgson** on value added transmission testing for motorsport applications

1010 **Trevor Dobbins** director of Human Sciences and Engineering Ltd talks about the human limitations of performance

1030 **Discussion**

1050 **Coffee break**

1110 Williams F1 composites chief **Brian O'Rourke** examines impact testing of composite structures.

1130 On board diagnostics using hardware neural networks is **Dr Paul Neil's** topic

1150 **Advantage CFD** looks at design optimisation using CFD and mesh deformation

1210 **Discussion**

1220 **Conference ends – head to the Autosport Engineering Show in Halls 18 and 19**

*** Correct at the time of going to press**

LAT

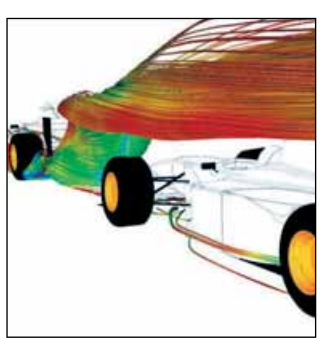
Williams F1's composites chief will talk about impact testing

LAT

Julian Cooper will reveal the evolution of the Lola B05/50

LAT

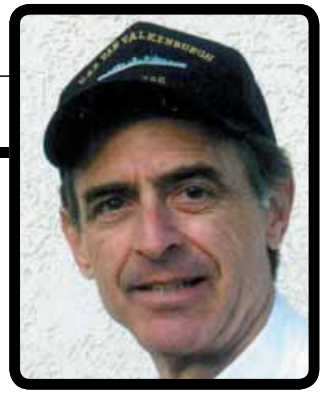
Could magnetic levitation be an alternative to wind tunnel struts?



Advantage CFD

Advantage CFD will look at design optimisation using CFD

By Paul Van Valkenburgh



Gravity power

Far more than just some kids having fun, gravity racing has become a serious sport, and presents engineers with just as many interesting challenges

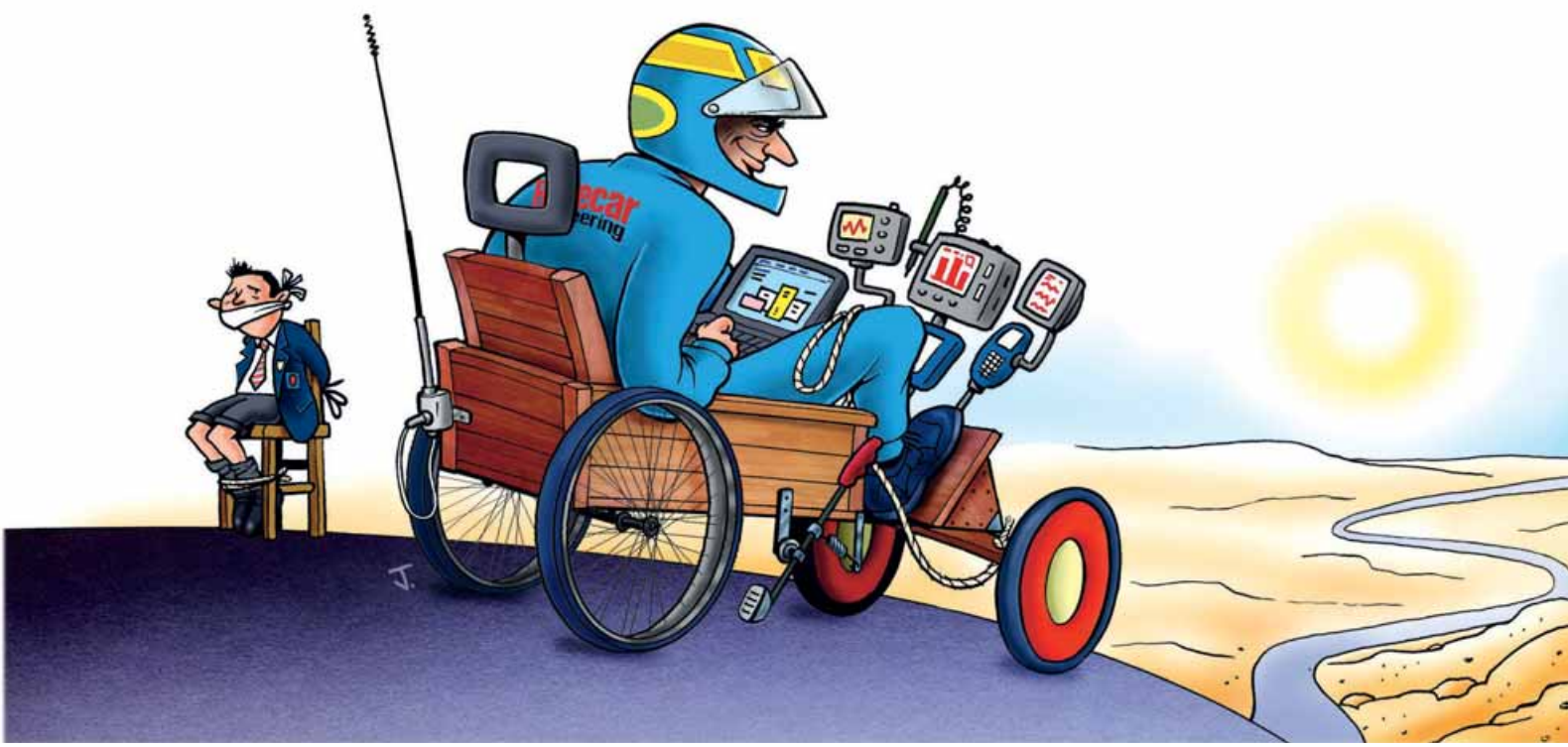
What could be simpler than gravity power? Does it sound too trivial to be interesting to a racecar engineer? Maybe not. Last week I went back to my roots, near my hometown in Topeka, Kansas, partly to see my nephew, Roman, race on Sam Ingo's Soapbox Derby team. Coincidentally, the 1000ft downhill track is just a few miles from the quarter-mile track where I ran my first drag race, 48 years ago. In fact, this coasting event is a lot like a quarter-mile drag race. They're 'pulled' off the line at one g – but pulled downward – and the acceleration rate is proportional to the grade.

By further coincidence, Topeka is also the home of current Soapbox Derby champion car builder, Jerry Pearson, who I interviewed about the technology involved. He's a former soapbox driver, who became an engineer also, so he had more than just experiential knowledge. He assured me that the same engineering principles apply, just on a much smaller scale.

The All-American Soap Box Derby began in 1934, which may make it the second oldest race series behind the Indy 500. But in 1972, there was a little cheating scandal, when a magnet was found in the nose of one car, which would pull it forward as the steel restraining paddle dropped, and AASBD lost credibility and sponsors. Subsequently, the racing became more tightly restricted, and cars slower. Until recently, bodies were hand built from wood strips. But bodies are now spec – either vacuum formed, blow moulded (to allow rolled-under sides), or glass fibre, depending on the class – but still with tiller steering and skid brakes.

Over time there have been various other less restricted attempts at gravity-powered racing. In the late '70s, downhill skateboarders built enclosed streamlined shells over reclining boards, until they had a few 60mph accidents. Recently, ESPN has promoted its X-Games Street Luge – which doesn't allow aerodynamic shells, but does have cornering challenges. The Goodwood coasting event, which →

> "DITHERING THE INITIAL STICTION OUT OF THE WHEEL BEARINGS BY VIBRATIONS"



> "THE RACE IS WON OR LOST AT THE TOP OF THE HILL"

you must have read about here already [RE V10 N8], started in 2000, but was cancelled this year following uncontrollable costs and alarming crashes. And there is also a German sanctioning organisation. The 'Extreme Gravity' series is a recent attempt to get the big auto manufacturers' engineers and designers involved. But my observation of their vehicles at one event was that some were built by very non-technical stylists, some builders were aerodynamically clueless, and only a couple really had their engineering down.

NASCAR joined forces with AASBD a few years ago, with the encouragement of president Mike Helton, who started out as a soapbox racer himself. Now it has added an 'Ultimate Gravity' category, with more open rules, to try and raise the speed record every year. This class pays $3000 (£1700) to win, and, significantly, also $1000 (£565) for the best innovation.

The latest coasting technology can be picked up from numerous website references, such as http://207.242.75.40/derbtech/derbtech.htm or a book by aircraft mechanic David Fulton, called Winning ingredients (www.geocities.com/winningingredients/).

I talked to Fulton, and I think his most valuable tip was: 'The race is won or lost at the top of the hill.' Or, as I've said about drag racing, the first few feet – when everyone is travelling relatively slowly – are by far the most important. In a website photo of the Akron Championships, Pearson's car can be seen to have a one-foot lead less than 20ft out of the starting blocks. And yet some finishes are so close that dead heats are not that rare.

Fulton's book has seven chapters: 1 – aerodynamics, which has some interesting stuff on axle fairings and fillets, and wind tunnel tests, but is mostly theory since bodies are fairly standard; 2 – potential, kinetic, and wasted energy, demonstrating the importance of weight placement and rotational wheel inertia; 3 – suspension and its energy absorption, including solid/rubber mounting, tight/loose suspensions and body stiffness; 4 – design and construction of wooden bodies, floorboards, and brakes; 5 – alignment, via spindle bending, steering precision, and toe out from steering cable tension; 6 – driver education and practice, and track analysis; 7 – race day considerations. There are also many suggested experiments, which is a good way of introducing kids to science and technology. There's also a company that specialises in precision spindle alignment tools – although many innovators design their own.

There are many racing classes, with different restrictions and with increasing levels of sophistication. But keep in mind that in amateur events they often 'level the playing field' by swapping lanes and the spec wheels, so that may not be a productive area for development. Here are my thoughts about what I would focus on:

Data acquisition – to start with, I'd love to use a precise speed recorder on a test vehicle. In fact, I've long advocated carefully controlled coasting as a substitute for the wind tunnel. And you'd probably be amazed at the importance of the first small fraction of a second.

Aero – like NASCAR, there's a lot you can do with a common body, especially if it's flexible. This would be a good place to use wind tunnels and CFD, especially since the tunnel power requirements are so much less, and I'd focus particularly on the drag of exposed spinning wheels.

Rolling – in spite of the spec wheels with their one-inch solid rubber tyres, racers concentrate on alignment, steering, and sideways bearing walk [For 'Ultimate' racing, where wheels are open, Pearson obtained some high-pressure custom pneumatic tyres and wheels from the German coastdown competition, which seem to be a significant advantage, despite an obviously greater frontal area handicap. My guess is that they have much lower hysteresis rubber, to recover speed lost over surface imperfections.]

Weight distribution – calculate what the vertical drop in feet (potential energy), would convert into in mph of kinetic energy – in the total absence of air and rolling drag – and use that as a theoretical goal.

Possible 'unfair advantages' – I would also consider nose shape where it contacts the starting paddle, imperceptible shifting of body weight, laser alignment sighting down the course in the starting blocks, exploiting the slightest breeze at the start by blocking or exposing to the wind, and dithering the initial stiction out of the wheel bearings by vibrations from humming.

Factor analysis, or what I call the 'sensitivity of parameter variations,' is a way to determine which factors are most cost-effective to focus on, and which are a waste of time. Either you can do real-world tests, in which you make large negative changes, like adding lots of ballast or a drag plate to see how much effect it has on times. Or you can eliminate the uncontrollable variables like weather and pavement roughness, by creating an accurate computer simulation and varying the coefficients. As with any scientific research, you start with theory, run simulations, test to validate, and keep detailed records.

But wait – is this for kids, or their parents? Pearson said that depending on the class, from 10 to 70 per cent of the kids are heavily involved in the mechanics of it and you can see it in their performance, and in what they go on to become. I guess it depends how fanatical you can get about winning a simple trophy, or about beating another dad and his kid. On the other hand, it can be a golden opportunity to teach your kid your more positive values about competition.

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By Vinit Patel

From the inside

Many engineering graduates entertain the idea of working for a race team. But it's not a given, you have to put in the legwork if you want to succeed

Just over two years ago, *Racecar Engineering* asked me to write an article from my then perspective. At the time I was, as many of us are/have been/want to be, a recent graduate aching to break into racing (see V13N11). I had chosen to try and get into front line race engineering as I had always preferred the cut and thrust on the track and in the pit lane to more design-based opportunities. This time round, *Racecar* has asked me to follow up with my experiences in the intervening period, and my views now with my feet on the inside of the sanctum that is our industry.

Soon after I wrote my article in 2003, I got busy networking as much as possible. Through people I knew, and by cold-calling those I didn't, most of the single-seater race teams in the UK and beyond had been contacted by me. I also scraped enough money together to broaden my knowledge by attending the Claude Rouelle Vehicle Dynamics seminars – which was justified as it allowed me access to other course delegates that again expanded the network. This was while also applying for those advertised positions in the back of the popular weekly comic, which were much more formalised with the usual covering letter and CV. I deliberately made this approach very systematic, making sure I knew the names of HR staff in big companies, team managers or directors in smaller ones and always following up calls or applications after a week. None of this was revolutionary, but I made getting the right job my full-time occupation in the winter of '03/'04.

The timing of the Racing Car Show at the NEC in Birmingham was good for this, and I was able to meet people that had been responsive by telephone so that they could put a face to the name. This approach worked for me, and I was installed as a junior race engineer for T-Sport in British F3 for 2004. I would say that my persistence and dedication to the task were the bedrock of this success but, looking back, it was 50 per cent luck to call the team at the right time, 20 per cent down to coming across well at the interview and 30 per cent allocated to a reference from my boss at my previous team where I had been assisting during my last year at university.

James Bearne

Vinit (right), now works as a race engineer for T-Sport, here discussing details with driver Barton Mawer

For the past two seasons I have been attempting to establish myself as a race engineer. This was no easy task, and I was on a steep learning curve from my first test day with my first driver. I had no previous real experience of this situation except as an observer and contributor in my previous team, but this time the responsibility and the decisions to be made were mine. To say it was daunting was an understatement. The team was extremely supportive, and as much as I made my own decisions, they were always analysed and discussed with the senior engineer and team manager and it was quickly apparent we all worked on the same wavelength. Our first season was successful, winning the Scholarship Class of British F3. Our second season was unfortunately budget limited, but →

"I MADE GETTING THE RIGHT JOB MY FULL-TIME OCCUPATION IN THE WINTER OF '03/'04"

Aim as high as you dare, go for teams with good reputations and above all, get yourself out there. Experience is everything

LAT

bearing in mind we did 10 test days less than our rivals, we secured second in the championship, only missing out in the last race of the year.

It's been an interesting time to see how my academic background, which is different to that of the rest of the team, could work in F3. Like most teams our size, budget is minimal and every spare penny goes on making the cars better prepared and even more reliable – the driver brings the money so there is zero acceptance of mechanical failures. Nonetheless, any spare moment at the workshop was spent investigating things we could do – ranging from improving the mechanism to use the gear cut to basic suspension and damper component modifications/improvements to full suspension analyses to fully quantify changes between wishbone positions. I relished this challenge, as did the team. It was all-encompassing to do the most we could with what little we had using the best knowledge available to us.

> "WITH LIMITED RESOURCES AND CUSTOMERS TO DEPEND ON RISKS HAD TO BE QUANTIFIED"

Using a few spreadsheets and calculations here and there I was able to apply a certain level of academic knowledge to real world situations, and when we had the chance we'd try these concepts at test days. I think we got a lot out of better understanding our car and its reaction through this applied knowledge – which is grossly rewarding. There was frustration along the way, with limited resources and two customers to depend on, risks had to be quantified, and the old adage about not fixing things that are not broke always applies. So some of the more sweeping ideas, such as the wings I wanted to run at low downforce circuits, had to be reined in without being given enough of a trial. It would also have been nice to try and get a little investment into basic FEA or CFD packages that I am trained on and capable of using, but unfortunately this is a low priority over wholesale commodities such as lighter-weight bits or kits.

The past two seasons have also been interesting to see people try and break through in a similar manner to myself a little over 24 months ago. Our team is small, with seven staff, from team manager to no.2 mechanic through two engineers, two no.1 mechanics and the truckie. Between us we run two cars to a good level of professionalism for our pit lane. This is only achieved through all of the team members being adaptable to all roles, from making the tea to being the spare pair of hands when you have to bolt on three corners in an hour before qualifying. With this in mind, it surprises me to see the volume of CVs and covering letters I have read over two years that begin 'Dear Sir/Madam' or are addressed to the 'HR Dept.'

The fact is this – positions are rare at the best of times for engineers, especially those without experience. For anyone serious about entering motorsport at this level, you need to do your research more thoroughly. To even be considered, or filed in our 'note for the future' file, a certain level of aptitude, desire and dedication has to be demonstrated. And that also applies to people seeking experience over summers etc. Most don't follow up speculative communications at all – something I don't understand if you're serious about applying in the first place. Those who introduce themselves face to face at a race track with a CV in hand will stand a better chance than those communicating by Royal Mail or disturbing a few electrons. This approach shows a certain level of the above mentioned characteristics, and you have a five-minute soapbox from which to tell us how great you are. Plus you get to see racecars on circuit!

It's easy to say but everyone has a good degree in engineering and everyone's final year project is wondrous and revolutionary. You need to distinguish yourself as different – for positive reasons. If you've still got a year or so to study, get some experience – even if it's washing wheels. Aim for teams in formulae as high as you dare and with good reputations as these are the ones from which you can learn the most. Name dropping will stand you in good stead if you can back it up with a reference.

As my boss often says, 'Trust Me'. All of the above worked for me, so why aren't more of you doing it? RE

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Fuelled student

I am a second year Motorsport Engineering student at Brunel University in England and I am planning to design a racing engine to run on biofuel diesel or bioethanol fuel for my major project. I would like to ask *Racecar Engineering* readers what their experiences are (if any) with alternative fuel engines.

My intention for this engine is to use a turbine in a case with an injector and jet nozzle similar to that found at the end of a jet engine. Fuel supply will be at high pressure onto the turbine blade which then compresses the fuel against the case and the spark, roughly at 15 degrees, ignites the fuel. Once the turbine spins at full speed, the exhaust goes through an exhaust manifold with 45 per cent of the gas getting re-supplied to the injector for the new fuel/air mix. I hope to pre-heat the new fuel/air mix and burn off the unburnt fuel.

The idea is for the turbine to be connected to a generator which supplies electrical current to motors at the car's wheels. This project is currently just at the design and research stage.

Samuel Bennett,
Taken for the forum section of racecar-engineering.com

Vive La France!

So Britain's motorsport valley is the heart of world motorsport is it? Well I would most heartily like to disagree with that sentiment, whilst referencing the Le Mans report in V15N8, and suggest that perhaps France is more the heart of the industry these days. After all it was a French car that won the F1 World Championship, a French car that won the WRC and a French car that was fastest at the last Le Mans 24 hours. French cars made up most of the LMP grid, and even the name grand prix is French! The FIA are a Paris-based, French-named organisation, who will celebrate 100 years of grand prix racing this year in France.

Motorsport is a French sport in origin and France produces a huge number of racecars for the world market. So with Mygale, Courage, Ligier, PSA competition departments, Norma, Tatuus and more, why is it that we in France are so often overlooked?

I also see there is to be a French Pavillion at the Autosport International Show in Birmingham this year. I urge you all to attend and find out about the real home of the world motorsport industry.

Georges Boullion
Nancy, France

Legal aero?

Something has just occurred to me – by designing a set LMP floor configuration, where the objective was to prevent cars from taking off in forward and sideways motion, could the FIA have stumbled into a legal grey area? What would happen if any of the cars were to have an aerodynamically-induced accident whilst using the current regulated aero configurations?

Accidents such as these have claimed the lives of several drivers, so could teams sue the regulatory body for negligence?

As the FIA demand that all LMPs racing in its events must use the set floor configuration for safety reasons, should the rules be a legally binding document that guarantees the aerodynamic safety of the cars?

I hope someone in Paris realises the implications of imposed aero regulations. Wouldn't it be simpler, and legally safer and non restrictive, to demand a maximum level of aero sensitivity for forward and sideways motion as the only aero rule requirement?

This should be the point where the cars shouldn't create enough lift to lose traction at the speeds commonly reached, then let the aerodynamicists do the job they are paid for.

Ado Sigal, by email

Email the Editor: racecar@ipcmedia.com
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Visit www.racecar-engineering.com and submit your project for a feature online

LAT

Pescarolo – fast and very much French

One down

Words	Charles Armstrong-Wilson
Photos	LAT

GP2 has had a mixed reception, so following its first season we talked to someone with first hand experience of the series, Sergio Rinland

Last year saw the introduction of a brand new series to international single-seater racing, GP2. Brought in with a great fanfare to replace the ailing Formula 3000 series it has had a mixed first season. Fans have raved about the improved action on the track, with close battles being fought throughout the field and considerably more overtaking than the premier series it supports. Behind the scenes though, there have been problems. The cars have suffered reliability, durability and overheating problems that many feel are unacceptable in a controlled formula. It is said that without the need to compete on design, the cars should not be pushing their limits in any areas so shouldn't be found wanting.

To understand what these issues were and how they came about, *Racecar Engineering* spoke to ex-Formula 1 designer Sergio Rinland who experienced the new series first hand when he worked with the Coloni team as a consultant when GP2 first started.

GP2 is organised by GP2 Series and led by Bruno Michel who invited suppliers to tender for the various areas of the car. Dallara was awarded the contract for the chassis and Rinland is very complimentary of the result: 'Technically they have a very competent chassis. There was only one reliability problem with the chassis itself – that was when a rear wing end plate came off in testing. It was a one off and Dallara solved that within 24 hours and it didn't occur again. These things happen. In terms of aerodynamics I was surprised how well balanced the car was.'

Rinland also feels this contributed to the action on the track. 'You saw a lot of overtaking manoeuvres on the outside in GP2 as the car can go in a couple of different lines because of the aero characteristics.' He is unsure whether this was a conscious objective on the part of Dallara but he points out where it comes from. 'The way the aerodynamics was done was similar to the World Series by Nissan cars with tunnels.' Both the GP2 and the World

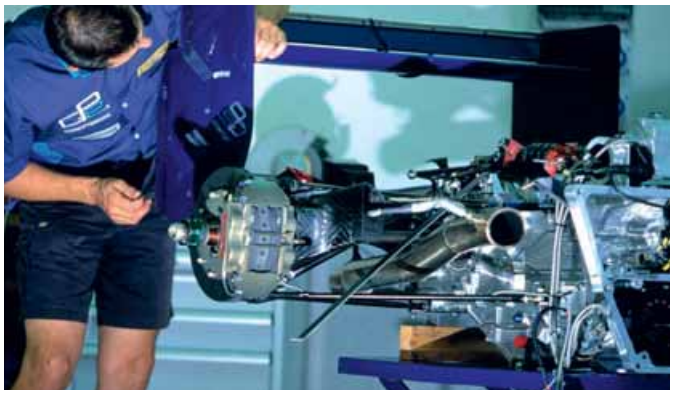
Series car have bigger venturis than are currently allowed in Formula 1. 'They are a good way of getting downforce. Just put tunnels in a car with a couple of skirts and you have downforce. Easy, cheap.'

Rinland is clearer on why Dallara decided to rely so heavily on tunnels. 'The motivation to put tunnels was not so much to balance the car or help overtaking but to achieve more overall downforce. With more downforce you can go faster. How do you get more downforce more easily? Put tunnels and skirts on the cars.' However he has a strong view on the latter. 'The skirts in my view shouldn't be there.' His main objection is durability and consistency when they touch the ground. 'You get wear on them. You have to keep changing them and setting them up. It wastes a lot of time and is a huge performance factor. You shouldn't have anything on the car that wears on the ground apart from the floor. So I'm against the skirts.'

On the whole he has praise for the car's aero: 'The information that Dallara give the teams on aerodynamics is quite repeatable at the racetrack, I found.' But there was one area that did not work so well. 'The problem the car had was cooling this year and depending on which side you talk to they blame each other. When you have a car that is not cooling it is because there

> "TECHNICALLY THEY HAVE A VERY COMPETENT CHASSIS"

is not enough air going though the radiators and/or the radiators are too small. The only way people like Dallara would design a car with these characteristics, with all the knowledge and experience they have, is because they didn't have the right information, which is what I believe happened.' The organisers tackled the problem two ways. Firstly during pre-season testing the engine revs were reduced by 500rpm and later by another 500rpm from 10,000rpm to 9000rpm. Then a new radiator and bodywork package was introduced. Some of this cost was passed on to the teams, plus some had already suffered engine failures which could be attributed to overheating. Obviously performance suffered but, being a controlled formula, it was not a big issue. To Rinland however this was unnecessary and unacceptable. 'Teams have to pay for their own testing obviously; they have to pay their own hotels, restaurants, salaries of the mechanics and hire of the racetracks. So if you go on the racetrack for two days and you lose one day because they cannot get a new kit for radiators or bodywork, that's one day you could have spent at your workshop for no extra cost. So that does not speak very well about the organisation initially.' →



One rear wing end plate came loose in early tests but this was quickly fixed

With less reliance on aero, chassis set-up is critical and can pay real dividends

Original brakes were unsatisfactory, so were changed to Brembo for race two

Nosecone and gearbox undergoing crash testing at CSI. After initial reliability problems, Mecachrome gearbox is now sorted, though is still considered too heavy

The engine is an area Rinland has mixed feelings about. Descended from a Mecachrome sportscar engine the GP2 unit is built by Heini Mader. 'The engine is conceptually a nice idea – four litres, lots of torque, fun to drive. But it has gone completely the opposite direction to Formula 1 so whatever a driver learns, he has to forget when he goes and drives an F1 car. The braking points are different, the turning points are different, the way you put the power down is different. It's a different animal altogether. When you drive a car with torque you drive with your throttle. In an F1 car you can't drive with the throttle, there is nothing there.'

The aim with GP2 was to produce a car that could compete on lap times with cars on the back of the F1 grid, making it the natural step toward Formula 1. 'There is no right or wrong, it is just a different technique,' says Rinland. 'But it's a nice concept. It's a way of getting power without the expense of high-revving engines. So in a way it's good because it is giving them an engine that is durable, delivers the power, has got the speed and has high torque. What I don't agree with is that it is too heavy for a single seater.

'So if I have a criticism of the engine it is only the weight. They had the opportunity to put a more purposely designed racing engine from three or four English manufacturers who tendered, but unfortunately for the British industry they didn't get the contract and the company who won the contract have less experience of designing and building an engine from scratch. They have a lot of experience tuning engines as they were engine tuners, not engine manufacturers. Now they are engine manufacturers. The teams were unhappy as they don't want to pay for engine development.

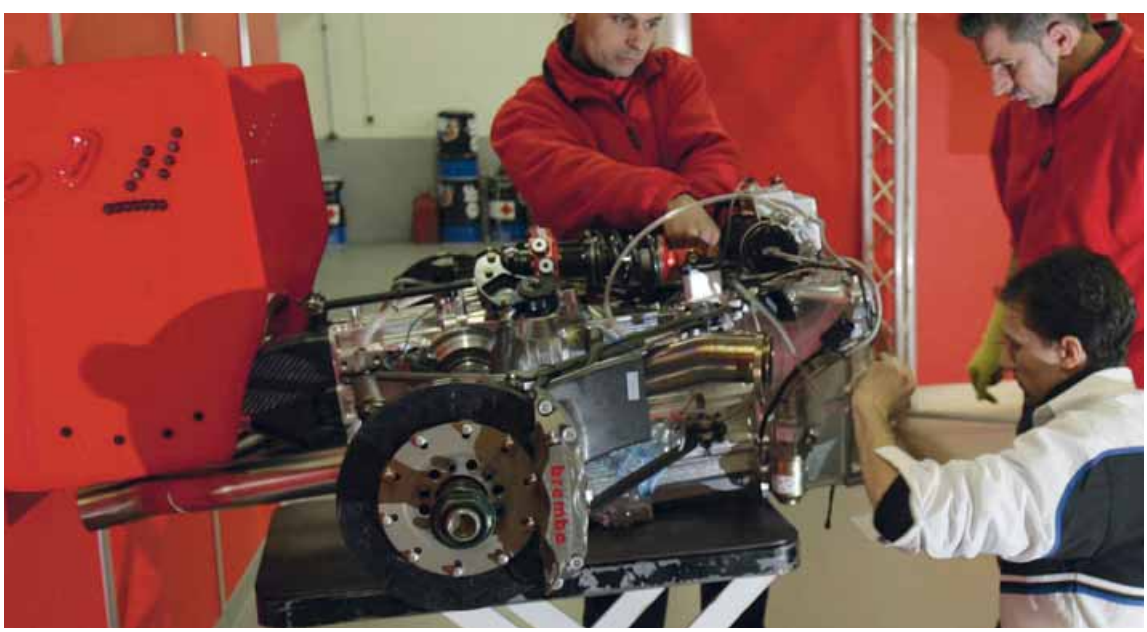
'As far as weight is concerned, in a sportscar you could afford a heavier engine – you want 24hr reliability – because you are talking about a 800-900kg car, but when you are taking about a 600kg car you can't put in a road car-derived engine that weighs that much.

"IF I HAVE A CRITICISM OF THE ENGINE IT IS ONLY THE WEIGHT"

'You could drive it to go to the supermarket or to go racing, it is a fantastic engine. My only criticism was that it was a little bit unreliable at the beginning and it is too heavy for a single seater.'

Like the engine, the gearbox also came from Mecachrome and Rinland believes the company's lack of experience in racing transmissions was evident here, too. 'It is too heavy for that particular single seater, although everyone is running the same so everyone has the same problem. It was unreliable in the beginning and again the organisers chose a gearbox

Some teams have objected to the apparent on-going development of the car's drivetrain which they feel has been done at their expense



The Dallara chassis has proved itself very competent in the first year of competition. Rinland suspects initial overheating problems were due to Dallara being supplied the wrong information regarding radiators

manufacturer with no experience of manufacturing gearboxes. This company has a lot of expertise in manufacturing individual components but the gearbox is more than just the components bolted together. It's a system. There were a lot of teething problems which the teams had to endure in the winter testing and the first few races. Now it's all sorted, I think, so we have a reliable gearbox, but it is still too heavy for a single seater.'

However, this is a situation Rinland regards as not ideal rather than a fatal flaw. 'If Dallara can tune the aerodynamics and the tyres are tuned to the weight distribution it is not a big problem.'

The tyres are one area in which Rinland is unreservedly complimentary. 'Even though they are grooved tyres and I don't like grooved tyres, they were very, very good. They needed tender loving care, from an engineer and a driver who know how to read tyres. That was one of the few things that an engineer could do is to read and manage the tyres. About the only thing you could manage on the cars.' He felt they had a good, even performance, and worked well from brand new to when they were quite old without a big drop in performance, which is important for a cost-conscious formula.

Where the tyres suffered most was on the front due to an inherent understeer tendency in the chassis. 'They use F1 derived tyres designed for a car that has a weight distribution 47-48 per cent in the front,' explains Rinland. 'Because this car has such a heavy engine and gearbox it doesn't have as much weight in front. That is the initial culprit of the understeer. You are not working the tyres as hard as you should to get the grip. You can't substitute that with aerodynamics because then it becomes an unstable car. Your centre of pressure has to be behind the centre of gravity, not in front, so it's a limitation.'

> **"[FRONT] TYRES SUFFERED MOST DUE TO INHERENT UNDERSTEER"**

He also feels the type of power delivery the tyres were designed for has a bearing on the relationship between the fronts and the rears. Being designed for a 3.0-litre engine with lower torque than the GP2 engine, they were not worked as hard. 'A 4.0-litre engine warms the tyres much faster because of the higher torque so you have much more grip on the rear than the front and so you end up with understeer. If you understeer once with a new set of tyres, they carry on understeering. If you ruin a tyre when it's new it is very difficult with the same set of tyres to get rid of the understeer and to clean the tyre in a way that it will pick up grip later on. The graining, the heat cycle, how fast and slow you heat them all have an influence on the future behaviour of the tyre. Comparing the front and the rear, they can be of different hardness because the rears heat up faster than the front. The compound changes differently from the rear because of the heat cycle. Bridgestone have done a lot of work because they have changed the tyres during the year and solved this problem. I'm sure they have changed the compound to be able to compensate for the different heat cycles in the front and rear tyres because they really worked well.'

Another area that caused problems in early tests was the brakes. 'They were a very experienced aircraft brake manufacturer which I never heard of before,' recalls Rinland. 'Brakes are a very driver preference thing. Some drivers prefer a brake that is like a switch, some prefer to modulate the brakes and different materials have different characteristics. When you do a single-make formula with carbon brakes you are on very dangerous ground and these people didn't have the experience on these high powered, high downforce, fast cars and the teams eventually sort of stamped their feet in Imola and said we are not racing unless we have Brembo. Funnily enough, being in Italy Brembo had a truck loaded with discs and pads and the second race was done with Brembo brakes. That evening every team had to change its brakes. Again, this could have been done at a lower cost with less controversy if they had listened to the teams' opinions in the first and second tests in the winter.' →

Bridgestone-supplied grooved tyres were deemed an unqualified success

A combination of tunnels and skirts ensure high levels of downforce, though the skirts have been prone to damage incurring extra costs in replacement

The electronics too experienced difficulties. 'It was to do with the link between the gearbox and the electronic management,' notes Rinland. 'I don't think they were using the best quality plugs in the steering wheel.'

However, he is keen to stress that GP2 has had some notable successes. 'I am talking about the negatives. There were a lot of positives about GP2, don't get me wrong.

'The marketing is flawless. They have done a fantastic job because they have a lot of experience of it. That is what they have done all their life. They are driver promoters and series promoters. They have a hell of a lot of experience and have done a fantastic job. If you are a sponsor in GP2, you are treated as well as in F1.

'Apart from F1, it is the most widely seen Formula. Why? Because it is promoted properly. So hats off to these people for doing a fine job.

'The website is very professional: if you are interested in the lap times you can get there in no time; if you are interested in the gossip you get there in no time; if you want to see pictures of your favourite driver, they are there. The marketing is really good and the commercial side is really good. They have the best teams, the best drivers and a pool of good global sponsors making good economic sense.

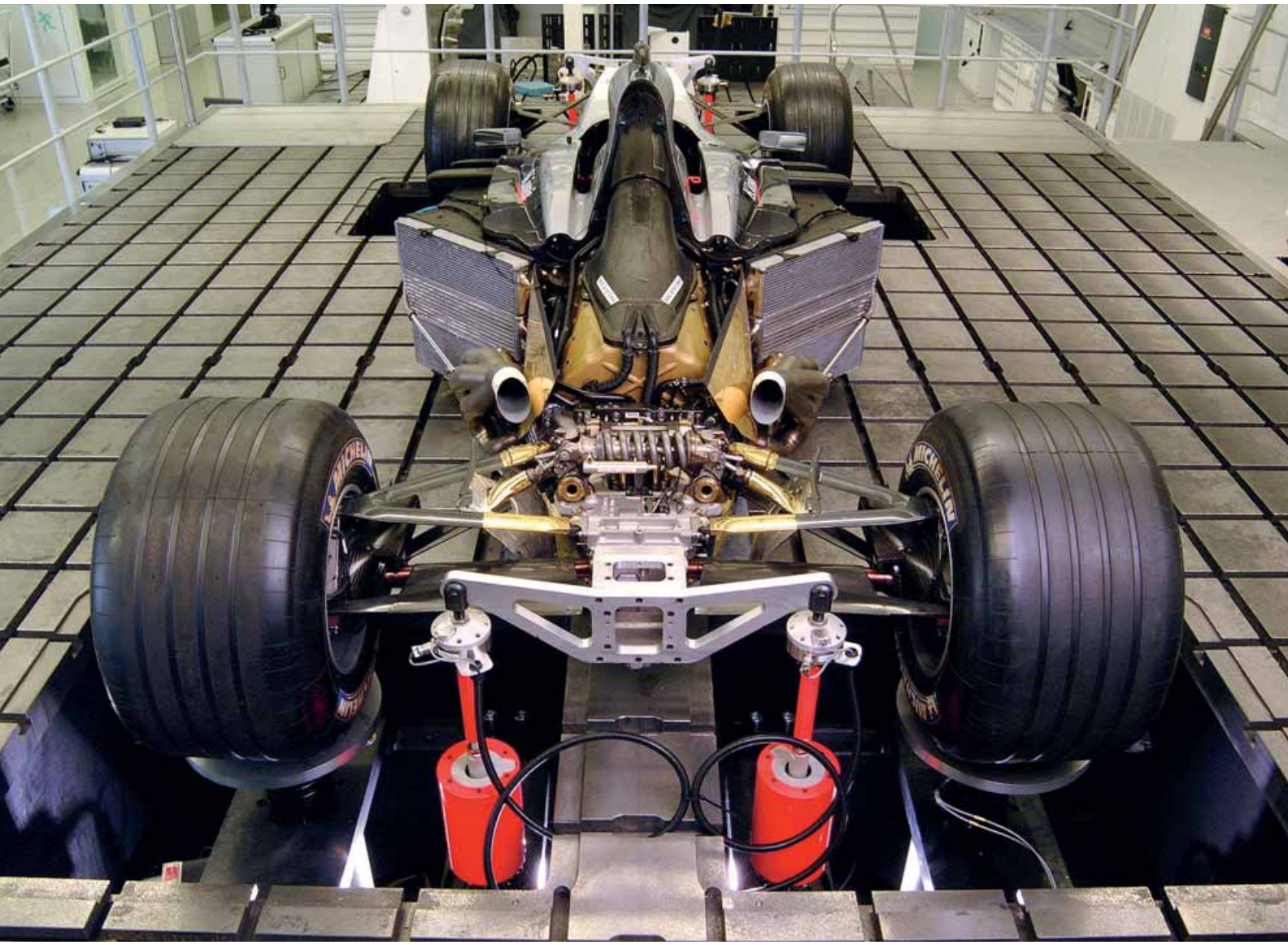
"THE MARKETING IS FLAWLESS AND THE COMMERCIAL SIDE IS REALLY GOOD"

'I believe the teams have spent more money than they should have but I think it has more to do with the initial development of the car than anything else. But they ended up spending more money than they thought. GP2 is more expensive than F3000, I am not sure by how much, but it is more expensive. All the teams will tell you this.' In spite of this Rinland feels it will be easier to raise funding: 'It will because it is much better promoted than F3000 has ever been, because that was not the job of the FIA.'

'The show is very good because the characteristics of the car allow closer racing and overtaking. Also they have more torque so you can overtake.

'With the aerodynamics not relying that much on the front wing, and with the weight distribution they have less need of the front wing so you can come a lot closer to another car without damaging your aerodynamics. That helps overtaking and makes the show better. By design or sheer chance I don't know but they've got it. They probably thought about this and that's what makes it a good formula. Talk to the drivers and they love it – it's fun to drive and they can overtake. If their engineer has a better set-up and they can come out a corner slightly faster than the car in front they can catch him and overtake. As you don't rely as much on aerodynamics you can brake here or there, all these are pluses. RE

Aerodynamics do not rely on the front wing as much as in F1 so closer racing and overtaking are much more prevalent



Testing partnership

Instron's state-of-the-art test equipment provides McLaren Racing with the accuracy its engineers require. But can it match reality?

Words	Dave Hancock
Photos	McLaren; LAT

In Formula 1, speed and precision are vital to success. These values also underpin the relationship between the Instron Corporation and the McLaren Technology Centre, the headquarters of the McLaren Group. Instron and McLaren first conducted an engineering exchange in the 1980s. The resulting collaboration has blossomed into a mutual drive to push back the boundaries of structural and material testing.

Established in 1946 to investigate the properties of parachute materials, Instron has grown into a global leader in the materials and structural testing field and has pioneered testing machines in more than 50 countries. Instron and IST, its structural testing division, is an official supplier of test equipment to the McLaren Technology Centre, the production facility for the Team McLaren Mercedes Formula 1 team and McLaren Automotive, which is currently manufacturing the Mercedes-Benz SLR McLaren sports car.

The McLaren Technology Centre, an award-winning building in its own right, was opened in 2004 and accommodates two state-of-the-art

IST eight-post racetrack rig at McLaren Racing sits at eye level, supported by an 80 tonne seismic base on isolation mounts

Data from the racetrack is fed back to the factory to be run on an identical car by the hydraulic test rig

Instron test rigs – an end-of-the-line hybrid system and an F1 racetrack eight-post rig – as well as other materials testing machines.

Moving through the McLaren Technology Centre, we come to McLaren Racing's test department for the Team McLaren Mercedes Formula 1 operation. This houses an IST racetrack rig – commonly referred to as an eight-post rig. The first impression is striking, stunning even. Usually, such rigs are sunk into the ground so that the racecar can be rolled onto it. The McLaren Racing rig sits on an 80 tonne seismic base with the racecar at eye level – the visual impact reflecting the importance of the rig. It is disconnected from the building by vibration isolation mounts so that loads are not transferred to the structure. Equally, the building must not influence the rig, as this would affect its accuracy.

> "CONSIDERABLE EMPHASIS WAS GIVEN TO QUICK TURNAROUND TIMES"

The eight Instron Hydropuls actuators at the heart of the rig sit beneath a 10x8m T-slotted bed plate. The Team McLaren Mercedes racecar is craned on to the rig and its tyres sit on wheelpans on top of these actuators. Potential variations in track or wheelbase dimensions arising from rule changes can be accommodated easily. Four further actuators – used to replicate the motion of the chassis – are connected to the racecar via rig-specific (ie not racecar specific) brackets.

When designing the rig, considerable emphasis was given to quick turnaround times. This is reflected in the design of the attachments to the downforce actuators and the use of quick release electrical connectors for the on-car transducers. The rig control software also recognises the various sensors quickly. As a result, turnaround time is less than one hour.

This is important, as during the course of a year up to three racecars can alternate on the rig. Last season's car is generally used for validation of current and on-going developments. The current season's car is used to collect and validate data compared to on-track testing and may be used to investigate race set-up options and problems. Next season's car is tested to assess and measure performance enhancements.

Put simply, this (and similar test rigs) attempt to accurately mimic the motion of the racecar on the racetrack – many different racetracks in fact. Vertical forces are applied to each wheel through the wheelpans to replicate the track surface. More vertical forces are applied to the chassis (at four points in this case) to reproduce the effects of aerodynamic downforce and the motions resulting from lateral and longitudinal acceleration (positive and negative). To illustrate the aerodynamic forces involved, typical Formula 1 racecar ground clearances of 40mm (front) and 80mm (rear) can be reduced to virtually zero at maximum speed (about 220mph).

It would be possible to user fewer than four actuators for the chassis and, on the McLaren Racing rig, actuators can be linked and paired. →

Controlling downforce simulation is critical. The IST rig delivered figures three times more accurate than the target figures it was asked to produce

However, using four chassis actuators means that chassis twist can be measured and thus taken into account. Given the accumulated expertise that goes into the design of an F1 racecar chassis and the inherent strength of the carbon fibre materials used, chassis twist is a surprising phenomenon. McLaren Racing will not disclose the measured figures, merely stating that it is 'very small'.

Still keeping it simple for the moment, having simulated track conditions, which areas of the racecar can be developed? Essentially, suspension components. Wheels, hubs, uprights, wishbones and so on can be assessed for flexing – using strain gauges. Friction and 'stiction' of joints can also be considered. Springs, dampers and anti-roll bars (both the parts themselves and various configurations) can be developed to minimise variations in tyre contact patch loads – maximal and consistent tyre loading is the ultimate quest of racecar designers.

Aficionados of F1 test rigs will know that some subject the wheels and/or chassis to horizontal inputs rather than just vertical ones. Richard Felton, team leader, Hardware in the Loop Simulation, McLaren Racing says: 'Some rigs have more axes, loading the cars laterally and longitudinally as well as vertically. The headline figures of how many posts you have look impressive but the extra inputs just introduce imperfections that would outweigh the very small increments we are looking for in terms of suspension design. The accuracy we are able to achieve is of an order of magnitude better than anything else currently available.'

This gives a clue to the excellence of IST. The contract with McLaren specified target levels of accuracy across a range of parameters. Controlling downforce simulation is the critical factor and this is expressed as the RMS (root mean square) and the phase shift accuracy of the rig. In practice, IST produced a rig that was three times more accurate than the target figures. This was achieved by changes to the mechanics and hydraulics of the actuators, reductions in friction, improved compliant links (rubber bushes) between the actuators and the chassis and an advanced closed loop control technique.

Instron's director of sales and service, Phil Vere, says: 'Both companies are very engineering driven. We want to be the best by as big a margin as we can be. McLaren Racing wanted precision and fidelity of data rather than sheer volume of numbers. That's what we have achieved together.'

> **"WHILE ON TEST, THE RACECAR IS FITTED WITH IN EXCESS OF 60 SENSORS"**

While on test, the racecar is fitted with over 60 sensors – load transducers, displacement sensors and accelerometers. It is these that provide data to the RS LabSite(r) analysis software. The accuracy of the rig means that even the performance of sensors can be assessed and McLaren Racing is able to use this data to drive the development of sensors from the suppliers.

In this world of simulation, where cars can be 'raced' without turning a wheel, has the driver been forgotten? Not really, after doing tests with a driver sat in the racecar while on the rig, McLaren Racing has been able to replicate the influence of its drivers using an equivalent mass. Moreover, the rig is sometimes used to investigate chassis or set-up anomalies reported by drivers. Invariably the drivers are proved correct – they are able to detect surprisingly small changes in the performance of a racecar.

The wheels do not rotate and the environment in which the rig is operated cannot be altered to mimic race circuit temperature and humidity. Instead, the tyre pressures are adjusted to compensate. Using the simulator, the effect of changes to the racecar can be very accurately measured and track testing validates the resulting performance differences. Indeed, validation of the accuracy of the rig is a key component of its success. 'Race engineers are a very sceptical bunch,' laughs Felton. 'It's not until you reach a certain threshold of accuracy that they say, "Yes, I'm going to go with your suggestion." Now, with this rig, we are really in the loop.'

For the operation of the racetrack simulator, IST's RS LabSite control software is used with a Labtronic digital controller. This control package offers levels of simulation accuracy and automation not available with other systems. From the range of RS LabSite software modules, the racetrack simulator uses RS BasLab (the operating environment), RS Block (for cyclic block programmes), RS Replay (for track data replay) and RS SigEdit (for signal editing). Results from test runs can be displayed, edited and printed or exported to other software packages.

Is there one line that sums up the expertise and effort that went into building the racetrack simulator and is still going in to its operation? Richard Felton: 'Yes – 0.2 seconds a lap...' RE

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Diamonds are forever

LAT

Top: Darrian T90 GT, with Millington Diamond engine, is a formidable competitor on UK rallies

Main pic: although originally based on the Ford Cosworth YB, all the major castings of the Diamond engine are now made to Millington Racing Engines' own designs

Undoubtedly one of the smallest race engine manufacturers in the world, Millington has one product – its durable and adaptable Diamond all-aluminium four

Words	Simon McBeath
Photos	LAT; McBeath

Durability is one of the foremost qualities of any gem. It's also a key selling point of the Millington Diamond competition engine. Add in usability and competitiveness, and it's no surprise that Colin McRae is running one in his 'out of hours' Ford Escort Mk2 rally car. It could just be one of the best four-cylinder competition engines you've never heard of. Yet over 250 have competed in categories ranging from the American Le Mans LMP675 to UK hillclimbs, and numerous race and rally categories in between. But the Millington approach is dissimilar to most. There are many companies that modify and uprate production engines for competition use, but there are very few smaller companies that *manufacture* competition engines. Yet that is effectively what Millington Racing Engines does, for it has also designed – and manufactured – its own castings.

Diamond formation

It hasn't always been totally this way though; the ancestry of the Millington Diamond can be traced to the Cosworth YB. Ford originally produced the YB for the turbocharged Sierra Cosworth, with design input from Keith Duckworth. After the first roadgoing variants – YBA and YBB – there followed two competition variants: YBC, a Group A rally engine developing 280-300bhp; and YBD, which powered the Sierra Cosworth RS500 and, in Touring Car specification, turned out a rude 500bhp. So the basic engine had a good pedigree.

Roy Millington: 'Around 1988 BDA parts had become harder to find and the YB engine became

"DURABILITY WAS ALWAYS THE WATCHWORD, AND THIS QUALITY HAS BEEN WELL PROVEN"

popular for modifying. But it had a heavy [cast iron] block. I thought a lightweight version might work well, so I initiated an aluminium block project with Richard Jenvey, who cast the first 30 or 40 blocks in 1989; we then jointly machined them. With modified production cylinder heads these became the first 'Diamond' engines. Then, in the early 1990s, Holbay Racing asked us to do a 30-off block project, and the profit from that enabled an upgrade from a Moog Hydropath 3000 to a state-of-the-art four-axis CNC machine.

'I wanted to do the heads and porting by machine. There were not many people doing that then. It took three months to make up the jigs and fixings but it was worth it because we're still doing those jobs on that machine (and another machine we now have). We use a production casting but the porting, the contact facing on the inlets and lots of other little things are different. It takes about an hour and 20 minutes to machine what used to take a week to do by hand. A whole head can be prepared in half a day now, so it's been a good investment.'

Thus the Diamond was effectively a YB with an aluminium alloy block designed for competition – a Millington-modified head, plus Millington specified internals, induction system and exhaust. Among the alloy block's key features is a sump with integral bearing caps, and a shape designed to minimise windage. The block itself is said to be very rigid, with good cooling and long bearing life. Durability was always the watchword, and this quality has been well proven. Ready to run, the engine weighs 85-86kg (set to reduce with developments, as we'll see), excellent when it first appeared and still impressive when compared to competition modified production units today (see table 1). As Roy Millington modestly asserted, 'the Diamond was a good combination with the original YB head – light, durable and effective.'

Millington also believes in providing a good spread of usable power: 'you can put the car in its highest gear, put your foot flat on the throttle from 2500rpm and it will pull. This is one of the pluses of modern engine management systems of course [Weber Alpha is used typically]. The engine may not be running efficiently, and it'll be off cam, but it will pull.' In 2.0-litre guise, peak power is around 290bhp at 8100rpm, with peak torque in excess of 180lb.ft at 6800rpm. That torque figure rises to nearly 200lb.ft on methanol, where permitted, with a significant boost to torque and power between 5000 and 7000rpm. Maximum rpm is well over 9000rpm, but although good power is still being made it tails off at these speeds. With 'softer' camshaft profiles, rally variants produce slightly less peak power at the lower speed of 7700rpm, with a broader spread of power. In 2.5-litre guise, as fitted to Colin McRae's Mk 2 Escort, peak power is 315bhp at 7750rpm with peak torque of 242lb.ft at 5500rpm, and there are a few 2.7-litre versions that generate the same peak power but a hearty 250lb.ft of torque.

Table 1

ENGINE	Capacity	Weight
Vauxhall	2.0 litre	112kg
Ford Duratec	2.0 litre	92kg
Rover K2000	2.0 litre	75kg
Millington Diamond	2.0 litre	85kg (decreasing to 80kg)

Table 2

ENGINE	Bore	Stroke
Vauxhall 2.0	86.0mm	86.0mm
Duratec 2.0	87.5mm	83.0mm
K Series 1.8	80.0mm	87.5mm
K2000 2.0	82.5mm	93.3mm
Millington 2.0	95.0mm	70.5mm
Millington 2.5	95.0mm	88.0mm

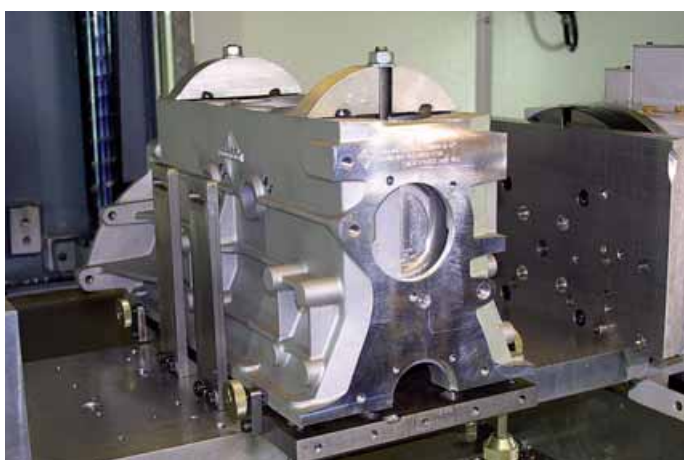
Table 2 shows bore and stroke figures for the Millington Diamond in two variations, compared to the previously mentioned competition-modified production engines. The differences are immediately apparent: the Millington, even in 2.5-litre form, is very over-square with a large bore offering a big valve area, key to attaining high power. It seems likely that this, in part at least, is why the Diamond can make 290bhp at just 8100rpm where other engines require at least another 400rpm to achieve peak power values that are not all this high. It should also be stated that Roy Millington has tested engines other than his own that were reputed to produce in excess of 300bhp but which were measured at around 290bhp on his dynamometer. This might suggest that the Millington dyno reads conservatively...

"THE LATEST DIAMOND VARIANT WILL BE AROUND 80KG READY TO RUN"

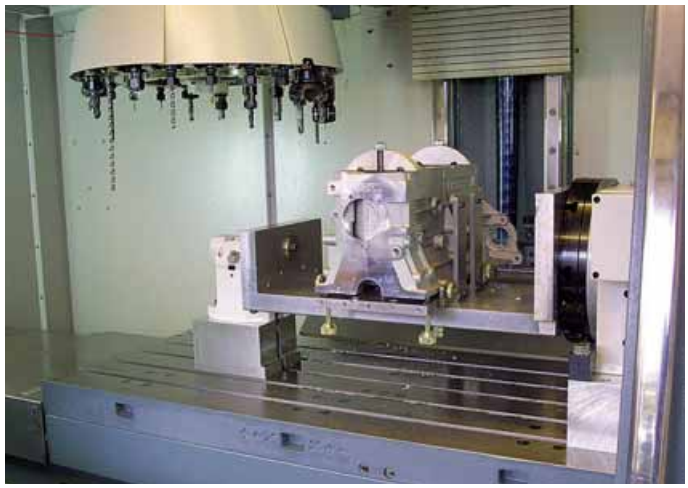
All new head

But Roy Millington was not content for development to stagnate, and supplies of YB head castings ebbed and flowed unpredictably. So Millington decided to design and manufacture his own head, based not unnaturally on the YB but with features he wanted to incorporate. Principal among these were the included valve angle, which at 45 degrees on the YB was thought to be too wide for efficient combustion; the exhaust port shape (designed for a turbocharged road car application so 'pointing the wrong way'); reduced weight, but retaining plenty of material around the combustion chamber; and incorporating good cooling for turbocharged applications. →

The build process starts with the X-rayed, certified castings



Preparing a block starts with machining the front and rear faces, and centres at each end. This is followed by a water and oil pressure test



The Cincinnati Arrow 1250C is equipped with a comprehensive set of tools

Unique, traceable reference numbers are engraved on each casting, and records kept throughout every engine's life

Following the second machining phase, oil pressure testing is again performed, and then the block goes into stock

Line boring is done on a modified lathe. This is a QED/Millington Vauxhall alloy block

Millington remarked that 'the YB head was very good in its day [and for its application] but we wanted more efficient combustion.'

So a spell welding up and machining a number of YB heads ensued in what was described as 'home development, playing around to make it work better. It will produce more power because of better flow and better combustion – there are no 'dead' areas now – and we've saved 2kg because it is smaller. We were also struggling to get a high compression ratio with the old head, and had to use a large 'intruder' [extra metal intruding into the combustion chamber to reduce its capacity and raise the C/R]. This compromised the combustion chamber shape, so this will also improve with the new head.' Other details still being researched include inlet tract length, barrel versus butterfly throttles, trumpets and air filters. The aim is to make a more compact package for installation reasons, although Millington realises this will lose some torque.

Having settled on the new head's layout, significant capital investment was required to produce the complex set of patterns needed to make the castings. Fortunately, Grainger and Worrell, described as one of Europe's leading

> "THE EXPECTATION [WITH THE NEW HEAD] MUST BE COMFORTABLY IN EXCESS OF 300BHP"

rapid prototyping and small volume aluminium and iron casting companies, is just a few miles from Millington in Bridgnorth, Shropshire. The company had been casting Millington's blocks and sumps for over seven years, and now the new heads are being made there, too.

With the weight saved on the head, and a 'few other lightweight parts' the latest Diamond variant will be around 80kg ready to run. 'We're using lighter internals to compete with the bike engines,' remarked Millington, 'which means reducing the weight of the crankshaft. Stronger steels and better heat treatments are now available, but we're going to have to monitor life – crack testing at regular intervals because we don't have the resources to do full endurance testing. They should be fine though.'

At the time of writing the new head had not yet run, although some of Millington's many loyal customers already had them on order. But with a bottom end that can withstand well over 9000rpm, and a head that should flow and combust better, once camshaft profiles and mapping have been sorted, the expectation must be comfortably in excess of 300bhp.

Cutting diamonds

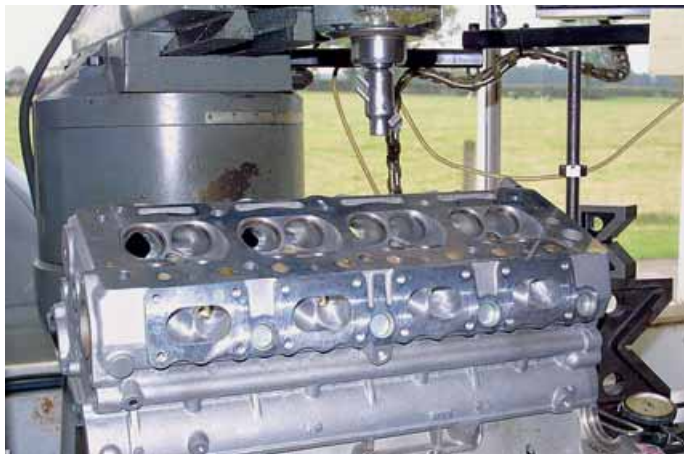
The well-organised engine building process at Millington starts with deliveries of X-rayed, certified castings that then require machining. Each new block is placed onto a Cincinnati Arrow 1250C four-axis CNC centre and located with bespoke jigs and fixings so that the two ends can be machined and centres located. The bore cores are also centred to specification, and unique reference numbers engraved on the front block face. This step takes around 25 minutes.

The oil galleries are then drilled, and the oil and water jackets are pressure tested. Providing this test is passed, the block is transferred to a Cincinnati Arrow 1000 four-axis CNC centre, jigged in place, and the two sides, the top and bottom are then machined. The main bearing surfaces are roughed out to within 15thou (0.38mm) and the bores are machined to the smallest that will be used. The oil galleries are once again pressure tested and, once passed, the block is put into stock. This second machining phase takes about one hour 10 minutes. Engines that are destined for turbocharged applications use through-bolt assembly that requires different machining. Sumps and cylinder heads are machined along much the same lines before they are put into stock.

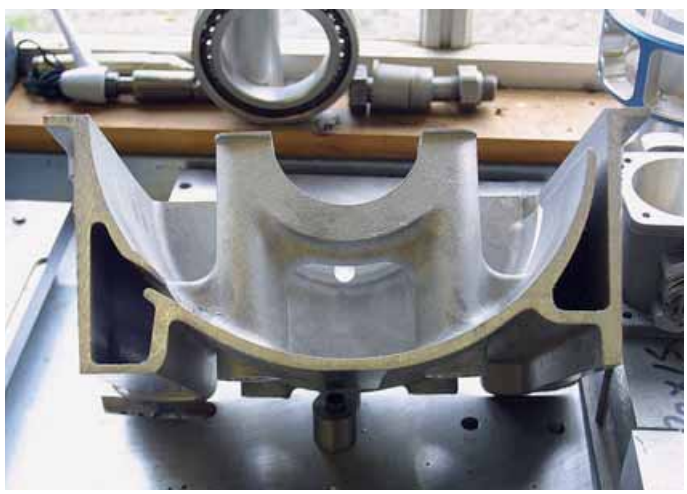
> "CNC MACHINES ARE THE KEY TO THE VIABILITY OF THIS BUSINESS"

Roy wrote his own CNC programs in 1996 using 'text document G codes', which he described as 'a bit old fashioned but very easy to change – for example to a different valve spring platform or in some other detail.' Clearly these CNC machines are the key to the viability of this business, given that just three of the company's complement of four work on engine build.

Blocks and sumps are then clamped together and line bored on an in-house modified lathe. 'It's very difficult to get accurate line boring done outside,' remarked Millington, 'and our cold clearances are tight so we can use off-the-shelf competition bearings.' So sumps and blocks are paired up and numbered as matched sets. Then the blocks are split again so thin wall cast iron liners can be inserted. 'These are to our own specification and fit. They move with the block's expansion and contraction, and it works well if you get the thickness exactly right. We've been doing it this way for 14 years now. Nikasil bores would theoretically be better, but there is more cost and potential aggravation, and we can't do that in-house.'



Valve seats are part machined on a manual mill. This is the YB cylinder head originally used on the Millington Diamond



This sectioned sump shows the integral bearing caps as well as the clever shaping of the sump and scavenge rails

In the foreground is a section through a YB cylinder head, behind is Millington's new head, with shallower valve angle, and different port face angles. Just visible on the inlet side (left) is the barrel throttle option

Stocks of engine internals and ancillaries await orders for new, complete engines

The castings then join the internals in the assembly shop, managed by Wayne Mitchell who, says Roy Millington, helps maintain the company's high standards. Pistons come part-machined from Omega or Accralite and Millington machines the valve pockets and piston tops to suit the application, so just one piston variety needs stocking for the three different engine types (2.0 and 2.5-litre normally aspirated, plus turbocharged). Well-known suppliers are used for all major internal components, like DKE (crankshafts) Kent (cams), Arrow Precision (followers, conrods), Paul Ivey (valves), Richard Jenvey (inlet assembly parts) and Webcon or DTA for management systems. To ensure all is well prior to delivery, the company's dynamometer is used to map or check each engine.

Millington is distinct in another key respect. Whereas many engine preparation companies offer a staged approach to modifying a production engine, Roy Millington says 'there aren't cheaper parts available for our engines so we supply the customer with the best engine we can make. The only real option is milder cams to give more torque spread.' Thus the current price range of £18,500 to £25,000+VAT ($33,300 to $45,000)

> "WELL-KNOWN SUPPLIERS ARE USED FOR ALL MAJOR INTERNAL COMPONENTS"

represents the price of a top specification Millington Diamond engine. But take into account this comment from one happy customer: 'rebuilds cost half what they did on our previous engine, the rebuild interval is twice as long, and it's just so reliable.' Add to this the fact that the second hand value for a Millington-serviced unit is around £14,000 to £15,000 and through-life costs seem relatively modest. Customer service is on a very personal level, and Roy Millington retains records of every engine he's ever built. But candidly he remarks, 'we do get problems. It's how you deal with them that matters.'

Millington Racing Engines has not sought a high profile, yet the combination of its engines' qualities, together with personal service, has seen steady business growth, largely through referrals. So as Roy Millington juggles his daily priorities to keep on top of the demands of the business, at least he doesn't have to worry about marketing...

Contact

Millington Racing Engines (Roy Millington)
Tel +44 (0)1746 789 268

Background

Roy Millington personally deals with customers as well as running the whole engine building operation

Roy Millington began working on engines in 1971, fixing agricultural diesel units on the family farm near Bridgnorth, Shropshire, progressing to re-boring BMC A-series engines, and then modifying Ford crossflow cylinder heads for Autograss competitors. He and his wife shared a car in that category, establishing a name and reputation, and this led to preparing rally engines for Opel Manta 400s and Ford Escorts. In turn this created a client base running Ford BDA engines, and ultimately it was the scarcity of BDA parts that led to the development of the original Millington Diamond.

While the normally aspirated Diamond is Millington's bread and butter, other fascinating projects intersperse the company's history. A customer's Ford Puma project, built to (non-homologated) World Rally Car specification, involved designing a through-bolt engine assembly. Thus, turbocharged Diamond engines became available, and Marshall Cooke Racing set about tackling the ALMS LMP675 category in 2002/03 using a turbocharged 2.0-litre Millington in its Lola B2K40s. Roy Millington recalls, 'it was a restricted, high compression, through-bolt engine. It produced around 485bhp when the MGs were said to have 500bhp, though we couldn't verify their numbers. The Lola was fast but it was a heavier chassis than the MG. Nevertheless, Marshall Cooke was class runner-up in 2003. The engines ran for 38 hours and the customer was pleased with performance and durability.'

A spin-off from this project was the turbocharged engine in the UK hillclimbing Pilbeam MP88 of father and son Barry and Josh Goodyear. This started at 2.5 litres, but 'we originally had problems with too much power! Reverting back to 2.0 litres, and using a Pectel EMS with boost control, it became very driveable. It took time to develop, but now the engine has three different maps for different track and weather conditions. Torque from using methanol helped this programme, and this converted me to the benefits of methanol.'

Millington also flirted with a five-cylinder concept to achieve 2.5 litres when the original four cylinder block patterns were wearing out, and he had to review how to re-tool. But potential torsional vibration problems ultimately deterred him, given limited development resources. Ultimately, longer strokes allowed 2.5 and even 2.7-litre versions, but a 98mm Nikasil bore, 82mm 'short stroke' 2.5-litre engine is under consideration.

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Conversations

The retired boss of GM's North American racing operations has an enlightened vision of motorsport's future

Words	Paul Lane Jnr
Photos	LAT; GM

After 40 years inside the auto industry, Herb Fishel has his own view of how mot orsport should work with it

Retirement for a successful executive once meant a gold watch or carriage clock, a testimonial dinner and a life of leisure on the golf links. But that is no longer the lot for the likes the of Herb Fishel.

Replacing it is the freedom to define one's view of what is important, and injecting new life into the tangled web that is motorsport has been Fishel's target: 'When I retired from GM in August 2003, I decided to take a couple of years to see where industry fits with the motorsports business and, more importantly, within the automotive industry itself.'

Fishel also spent time in the UK learning how the rapidly developing Motorsports Industry Association (MIA) operated as a focal point for the multi billion-pound British motorsports community. 'Retirement allowed me to get away from a company point of view and the politics that involves,' Fishel continues. 'In 40 years of working, my views of the automotive industry were limited to an in-company experience. I accepted the chairmanship of SAE's 2004 Motorsports Engineering Conference to help gain a broader understanding of how international motorsports and SAE functioned.'

Influences such as the native North Carolinian's early enthusiasm for NASCAR and stock car racing in general left him open to the necessity for a close and enduring bond between the automotive industry and the sport. A critical tool to revising his opinion was expanding his network of contacts within the industry worldwide.

It didn't take Fishel too long to realise that the size and complexity of motorsport required a narrowing of focus to primary views, past and present, and that there should be a strong, two-way relationship between motorsport and the automotive industry.

> **"THE MAJOR AUTO INDUSTRY COMPANIES NEED TO BE EDUCATED"**

Globally, the tie between the two is not a strong one, he says, believing each industry operates in isolation of the other, with a significant technical and bottom line loss to both.

In response to this he has begun working with industry clients to develop a framework within motorsport that will bring about healthy exchange at the major company levels. Central to this line of thinking is justification of investment – the total cost and the added value of showcasing an automotive or automotive-related company in competition.

As Fishel talks, it becomes evident he is encouraging revolution, a complete overthrow of the hype and excess evident in motorsport today. To that end he has come up with seven points that summarise (admittedly with a degree of idealism) his feeling about what needs to be achieved in the next couple of decades.

At the time of writing, revolution may be what is needed to salvage the integrity of top-level motorsports. Feuding, poor judgement, safety issues, runaway costs and sponsors viability have cast long and dark shadows over the sport.

Fishel is ready to bend the ear of all who will listen to what he calls his deliverables, justifying industry investment in motorsports.

with Herb Fishel

A native of North Carolina, Fishel was enthused by stock car racing but realised early on the importance of a strong bond between the sport and the auto industry

Looking to the future, Fishel suggests 'sportscar racing offers the best fit with OEM and tier-one manufacturers, the category could rise to exceed the sportscar glory days of the '50s, '60s and '70s.'

Reaction to the ongoing power struggles in F1 and among track owners and US oval track sanctioning bodies/promoters are among the worldwide instabilities that could offer the chance for revolution, though it all depends upon what fans will want or will tolerate.

The major auto industry companies need to be educated on the lost opportunities to derive bottom line profits from motorsport. The motorsport business model has got to change to provide a better cost/value proposition, or a better return on their investment, says Fishel.

Dynamics in the workforce

As Fishel works with industry, he sees its dynamic technical workforce questioning itself about its size and organisation, such as is the case in Formula 1. Also in NASCAR where the team staff are increasingly degreed professionals. He also sees an interchange of assignments between motorsport activity and general automotive production in industry.

A number of visits to student groups at university level have left Fishel enthused: 'I found there is a high level of interest and enthusiasm in creating a curriculum that is motorsport driven,' he said. 'The faculties are trying hard to connect the curriculum to where motorsport and the industry currently are.'

> **"CHANGES IN MOTORSPORT RULES WILL REDUCE JOBS"**

But he only actually observed mixed success – motorsport is fast moving and eager to use new technology and tools, whereas educational establishments typically are not. Even though a curriculum that dwells on theory will lose relevance and leave the new graduate at a competitive disadvantage. Fishel also witnessed some faculty members uncomfortable with the practical problem of meeting racing's demands.

'The type of skills developed in Formula SAE/Formula Student are an essential part of any curriculum,' he says. That recommendation is echoed by many in industry and motorsport in general, and alumni will attest that a Formula SAE graduate will show up on recruiters' preferred hire lists time and again.

Developing a programme that cycles promising industry personnel though a motorsport assignment was pioneered by Honda in the mid-'60s, but Fishel gives mixed marks to emulating companies. Where a structured programme is supported by top and middle management it →

Fishel believes sportscar racing provides the best fit with the big OEMs and sees a return to the glory days of the '50s, '60s and '70s ahead. He feels this type of racing offers manufacturers the best value for money

usually produces commendable results, but without complete support there can be a significant loss of benefits.

Fishel also suggests that continual changes in motorsport rules will ultimately reduce the number of jobs available, and those seeking a career exclusively in motorsport will find the competition stiff. A combination of in-depth education and experience, starting at the earliest age, is necessary.

Changes in technical approach

Fishel goes on to suggest that design and simulation software has now matured to a point where it can support an assortment of power plants such as reciprocating, hybrid or fuel cell, to achieve parity and run competitively in cars of the same class.

Le Mans organiser, the ACO, has historically been open to such innovation at Le Mans, and certainly this would be an opportunity to develop data and establish merit for future production vehicle applications.

In this instance he sees a need for a neutral party to develop the technical standards, perform evaluations, and/or act as ombudsman in development of race series or special events. With such a history of politics and bickering within motorsport in general, this would be a vital role. In Fishel's opinion, the Society of Automotive Engineers International is the best fit to carry out this role.

When challenged to compare the past with present and future approaches to racecar technology, Fishel characterises racecar development in the age of the Donohue/Penske 'Unfair Advantage' as a limited, fundamental, mechanical approach, whereas today's analytical methods provide a means of generating a large amount of data and rapidly laying out options.

He points out that today many tools within racing are state of the art, and the automobile industry is turning out engineers able to sift data and gain experience that is useful across the board. The trick is to be able to apply the rapid out-pouring of information into an optimum integrated solution. Adding some old-fashioned, hands-on experience is often something that closes the decision loop.

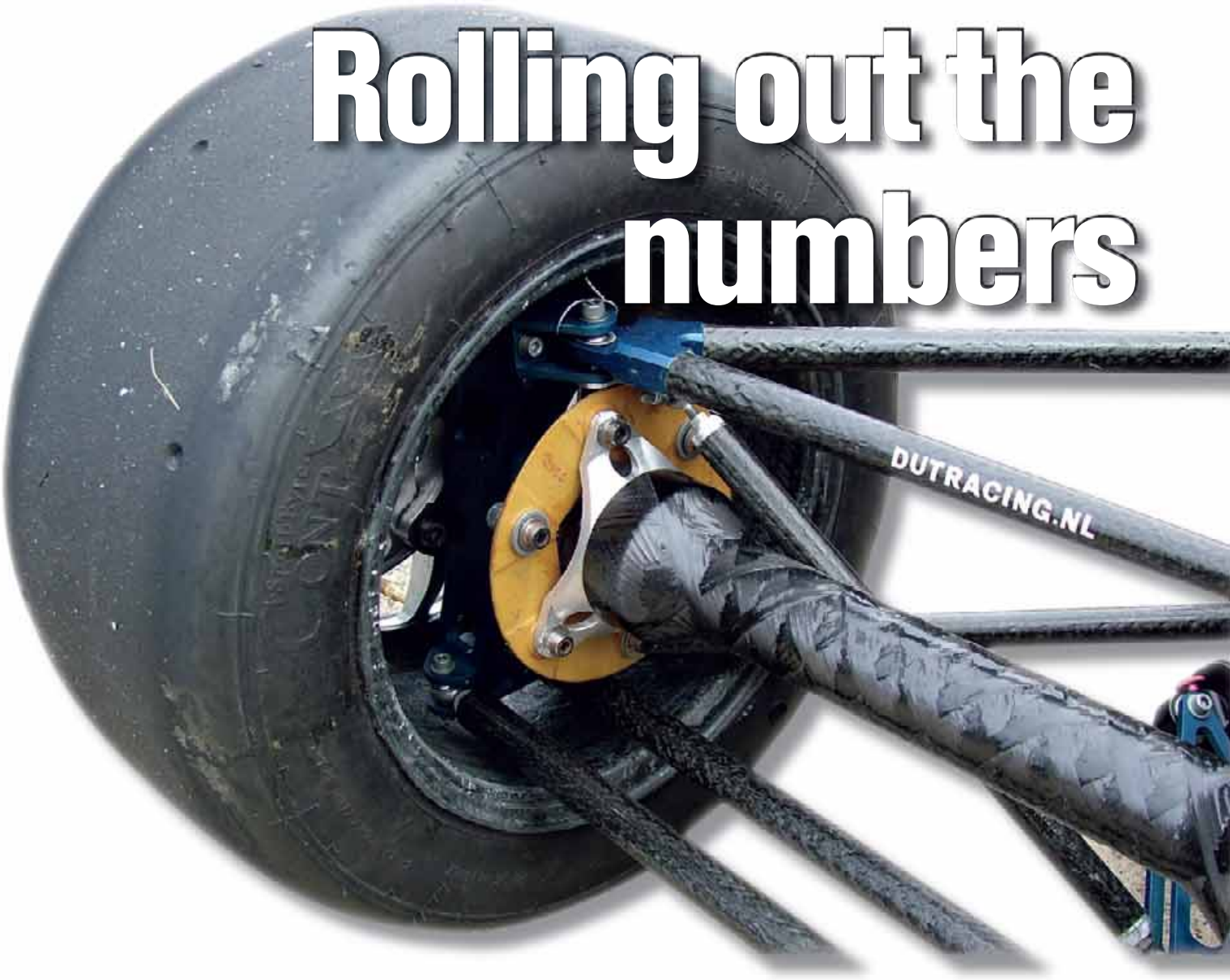
> "SPORTSCARS OFFER THE BEST FIT TO LARGE MANUFACTURERS"

The escalating cost of racing has always been a hotly debated topic throughout the motorsport community. Fishel applauds the current effort to reverse the pervasive trend to over-engineer, citing an alternative experience with the Chevrolet LS1 production-based engine utilised in the now defunct ASA stock car series (though still racing in Europe as SCSA). The bottom line is today's near-stock production engine, enabled by current design techniques and tools, can be a season-long reliable race engine.

There are other proposals, too, such as the proposed rule changes in Formula 1. Anything aimed at reducing cost also has to satisfy critics, particularly those suggesting loss of image and entertainment value.

Fishel has a challenge ahead in developing pathways for potential clients to invest in motorsport programmes in an era of change. His vision is bound to stir controversy and discussion, yet his championing the elevation of sportscar racing, as Aston Martin, Porsche, Peugeot, Audi and other rumoured factory-backed teams surface, adds credibility to his vision for the future. Besides the half-dozen automotive manufacturers pouring tens of millions of pounds into F1 and new programmes starting in the sportscar series, the report card on Fishel's efforts – and that of other notable movers and shakers – will be the increase in industry interactive programmes. The price to world motorsports is maintaining enough stability to allow a return on industry's investment.

Rolling out the numbers



Corporate support and a small group of willing individuals have provided Formula SAE competitors with essential tyre data that until now was simply out of reach

Words	Edward M Kasprzak
Photos	Sam Collins; Kasprzak

Tyres are one of the most important elements of any racecar and the design and tuning of a chassis and suspension are aimed at optimising tyre performance. At the same time, tyres are one of the most difficult elements of the car to quantify in engineering terms. Professional motorsport teams spend large sums of money each year conducting tyre tests in an attempt to understand, characterise and model them but traditionally such tyre data has been beyond the reach of today's engineering students. Until now.

Formula SAE and companion events in the United States, England, Italy, Brazil, Australia and Japan draw entries from well over 300 colleges and universities each year. The competitions are unique in that, along with the performance-based competitions common across all areas of motorsport, they are also design and engineering contests. Students trying to design, fabricate and race their own car face the same issues, questions and limitations as professional motorsport teams, including the need for tyre data.

The Formula SAE Tyre Test Consortium (FSAE TTC) was established in 2005 to meet this need, by measuring Formula SAE tyre data and making it available to students at a reasonable cost.

The Calspan Tyre Research Facility (TIRF) staffed a display booth at the 2004 Motorsports Engineering Conference and Exhibition in Dearborn, Michigan. A number of students and Formula SAE faculty advisors in attendance approached the booth to ask if there was any Formula SAE tyre data available. An idea was born and the FSAE TTC was established.

Three co-directors oversee the all-volunteer FSAE TTC. Edward Kasprzak (yours truly), a PhD candidate at the University at Buffalo and 10-year associate at Milliken Research Associates,

spearheaded the effort. Dr Bob Woods, founding member of Formula SAE from the University of Texas-Arlington, provided his considerable wisdom and experience and Denny Trimble, a student at the University at Washington, completed the trio.

At the time of writing, over 40 teams had paid the US$500 (£290) registration fee. 100 per cent of this fee goes toward tyre testing and data distribution costs. Doug Milliken, vice president of Milliken Research Associates and respected FSAE design judge, volunteered his time to oversee the finances and consult directly to the FSAE TTC directors.

The Goodyear Tyre and Rubber Company and Hoosier Racing Tyre donated tyres. All tyres were new racing slicks between 6 and 7.5in width mounted on 10 or 13in diameter wheels. Reduction of the data to mathematical tyre models was donated by Stackpole Engineering Services (Pacejka-based tyre model) and Milliken Research Associates (non-dimensional tyre model). The corporate support provided for these tyre tests

> **"THE NUMBER OF POSSIBLE VARIABLES FAR OUTWEIGHS THE NUMBER OF TESTS THAT CAN BE RUN"**

speaks of the stature of Formula SAE and the willingness of companies to support the education of young engineers.

In that same spirit, Calspan's Sam Pugliese and George Tapia offered to conduct the tests below cost – a significant contribution considering the cost of tyre testing. Seven tyre constructions were to be tested over the course of three full days at Calspan TIRF and the first tyre tests took place at the end of July 2005.

Calspan TIRF

The Calspan Tyre Research Facility, located in Buffalo, New York, was constructed in 1972 and remains one of the world's most capable tyre testing machines. Clients from the car, truck and motorsport worlds keep the machine running two shifts per day all year round. In motorsport, Calspan tests tyres for race teams, constructors and tyre manufacturers from F1 to NASCAR, to pro drag racing. Virtually every type of professional race tyre has passed through the facility.

The tyre-testing machine resembles a large belt sander that acts as a 28in wide roadway. A tyre is mounted on a head which can provide steer and inclination angles of 30 degrees and apply up to 12,000lb of normal load. Test speeds over 200mph can be obtained. Underneath the contact patch the belt is supported by an air bearing, assuring accurate recreation of the correct pressure distribution in the tyre footprint.

The Formula SAE tyre test was designed by Dave Gentz, principal mechanical engineer at Calspan TIRF, in cooperation with the FSAE TTC and based on a general test philosophy at Calspan. The test was designed to produce curves of tyre performance as a function of tyre normal load, slip angle, inclination angle, slip ratio and inflation pressure. While the tests were fairly

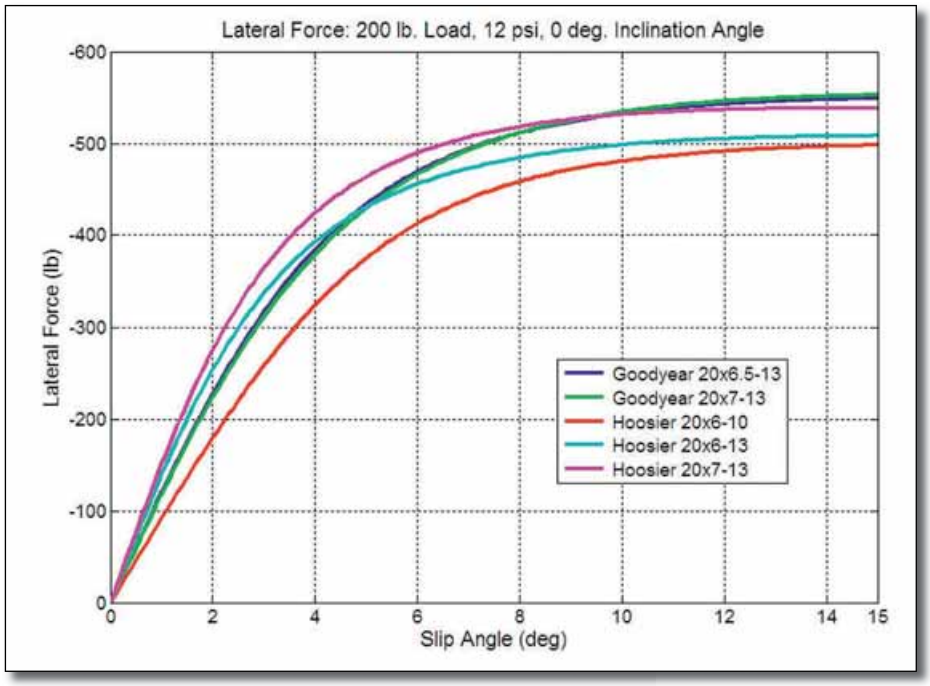


Figure 1: The lateral force plotted against slip angle for the five different tyre constructions tested

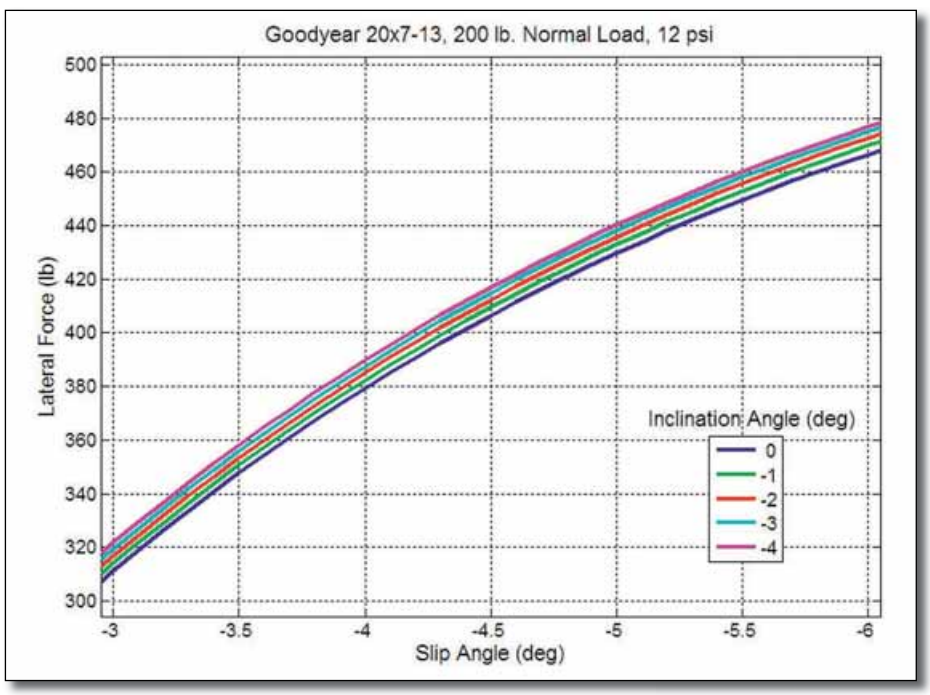


Figure 2: Trace showing how increased tyre inclination angle provides more lateral force on tyres

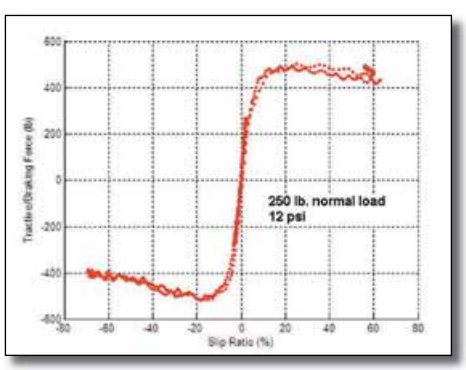


Figure 3: longitudinal data was collected to show tyre force changes in accordance with slip ratio

extensive, the number of possible variables (including thermal cycles, tyre wear, rim widths/constructions, tyre dynamics, temperature effects etc) far outweighs the number of tests that can effectively be run.

Even with the use of DOE techniques, the size of a test becomes large, time-consuming and expensive very quickly as variables are added. As Gentz put it, 'that's something very few new customers understand when they first approach us. For the newcomer it's almost always a shock unless they've actually sat down and multiplied the numbers out. You could double a test size simply by having two rim widths, and so on.' The large number of variables, the need for a sizeable test machine and the cost of performing such tyre tests mean there are very few tyre-testing facilities operational worldwide. Consequently, tyre data has until now remained the domain of the highest levels of motorsport and passenger car development.

> "FSAE TESTS INCLUDED SEVERAL INTERESTING TYRE SPRING RATE TESTS"

Formula SAE tyres

Because of his position, Gentz has possibly seen more tyre data on more types of race tyres than anyone else in the world. And fortunately for Formula SAE students, many of the trends seen in full-size race tyres were also seen in the Formula SAE tyre data. 'The testing went like a normal race test. In general, they act like little race tyres.'

The first notable feature of the Formula SAE tyres is the amount of grip they provide. Peak friction values ranged between 2.5 and 3.0, meaning that a tyre operating at 200lb normal load could produce between 500 and 600lb of lateral or longitudinal force. Few tyres tested at Calspan have shown such performance, as Gentz explained: 'That says they're similar to an F1 tyre with very high coefficients. F1 tyres normally run between 1.5 and 2.5.

The tyres were also remarkably sticky at operating temperatures – fingerprints could be left on the tread and more than one person made the mistake of brushing against a warm tyre only to wear some of the rubber home. The soft compounds were similar to rain racing tyres tested at Calspan. During the tests the belt stayed fairly clean, although at the end of each test some build-up accumulated on the tread. Carcass pyrometer readings immediately after each test reported temperatures between 120-170degF, depending on the tyre and the test. Formula SAE students in attendance confirmed that this was consistent with what they see on their cars during on-track testing.

One of the Goodyear Formula SAE tyres on the tyre test machine, post-test. Note the build-up on the tyre

Students will be interested in comparing the performance of different tyre constructions. For example, figure 1 plots lateral force against slip angle for five different tyre constructions. The two Hoosier 13in tyres exhibit higher cornering stiffnesses (initial slope of lateral force versus slip angle), but the Goodyear 13in tyres ultimately have higher peak lateral forces. The Hoosier 10in tyre produces less lateral force, likely because of its smaller footprint, but the tyre/wheel assembly is also lighter. So which one is the best? Keep in mind that this is only a single load, a single inflation pressure and a single inclination angle. Change the inflation pressure or the load and you may see different results. If tyres could be understood and optimised from a single graph motorsport would not be as challenging as it is.

Besides, while the optimum is a very important operating point, in practice it is difficult to achieve. A racecar has four tyres, not one, and all four need to work together in conjunction with the vehicle's weight, load transfer, suspension, aerodynamics, engine etc – a very complex system to optimise. For tuning purposes it's just as important to understand the sensitivity of the tyres to changes in load, inflation pressure or inclination angle as it is to know the conditions of the peak performance.

For example, the Formula SAE tyres proved to be less camber sensitive than most racing tyres, mainly due to the low normal loads. Representative data in fig 2 at 200lb normal load shows that an increase in tyre inclination angle from zero to -4 degrees provides about 15lb more lateral force, or about eight per cent of the load on the tyre. In the plot shown, this effect is nearly the same at all slip angles. The tyre tests allow these sensitivities to be determined at various operating conditions, along with the sensitivity to other variables such as inflation pressure.

The Formula SAE tyre tests included several interesting tyre spring rate tests and the test segment was repeated four times during the life of the tyre. When a brand new tyre was placed on the test machine, a range of normal loads was applied and the loaded radius measured, from which vertical spring rate was determined. This was done first with the tyre stationary and then with the tyre rolling. Warm up and conditioning cycles were then performed for several minutes, and the spring rate test (rolling) was repeated. The main segment of the tyre test was then performed, after which a final spring rate test (rolling) was conducted on the worn tyre.

Results showed that the tyre's vertical spring rate was different in each of the four tests. For example, the Hoosier 20x6-13 produced vertical spring rates of 735lb/in (new, non-rolling), 926lb/in (new, rolling), 810lb/in (intermediate, rolling) and 700lb/in (used, rolling). This shows that tyre spring rates measured with the tyre rolling are different from a stationary tyre. It also shows that as a tyre is used it loses vertical stiffness. Analysis

> "THERE ARE MANY OPEN-ENDED QUESTIONS IN TYRE DATA ANALYSIS"

of the data during the slip angle and slip ratio sweeps shows that non-free-rolling conditions reduce the vertical stiffness of the tyre even further. Therefore, because of the lateral sidewall deflections, a tyre has a lower vertical spring rate while cornering than while running straight. This has implications on the tyre's contribution to roll stiffness and chassis ride height.

Longitudinal data was also collected on all the Formula SAE tyres. Typically, Calspan tests just past the peak slip ratio which, on these tyres, occurs around 10-20 per cent slip ratio. At the request of Josh Callaway, Formula SAE student from the University of Illinois, a final slip ratio sweep at 250lb normal load was taken to almost +/-100 per cent, from spinning at twice the roadway speed to near lock-up. At the peak, the optimal percentage of the print is operating at the static friction limit. Past the peak, the tyre force approaches the lower sliding friction value as less and less of the footprint is stuck to the roadway (see fig 3 for the results).

As with other racing tyres, the Formula SAE tyres show basic inflation pressure trends. Within a reasonable range, increasing inflation pressure increases lateral force but decreases longitudinal force. The optimal inflation pressures for lateral and longitudinal forces do not coincide. This is one of many trade-offs FSAE students will have the opportunity to discover, study and ponder.

Nicholas Fishbein, Formula SAE student at Cornell University, taking notes during the test at Calspan

In all, over 20 channels of data were recorded on the tyres, including lateral and longitudinal forces, aligning and overturning moments, three infrared tread surface temperatures and all the tyre operating conditions. FSAE TTC members received a DVD containing the raw data, Pacejka and non-dimensional models of the data, and video recordings of all the tests.

On-track performance

It's one step to realise you have a need for tyre data, it's a second step to collect that data. Understanding and making engineering judgements based on the data however is a third, significant step. It is a challenge for well-funded professional motorsports teams, and will be a challenge for Formula SAE students as well. There are many open-ended questions in tyre data analysis. The Formula SAE forums will be filled with discussions and debates over the data for years to come.

Perhaps the first question to ask though is how tyre data collected on a tyre testing machine correlates with tyre behaviour on track. Calspan's controlled environment allows for repeatable test conditions on a known surface, but the belt is not paved like a typical roadway. For racing or high performance tests, 120grit 3M-ite is the only surface Calspan has ever used.

Fortunately, this question has a scientific answer, as Gentz explained: 'We can run a test here called ASTM E501. It uses a laboratory tyre with straight grooves in it. It looks like an aircraft

tyre with a flat top. Those are one of the tyres run on outdoor skid trailer testers that the highway departments use periodically to measure roadway friction. We replicate the ASTM E501 procedure here, including water depth (if desired), velocity and load on that tyre.' The result of the test is a measure of surface friction known as the 'skid number', based on a locked wheel. The nominal skid number for dry 120grit 3M-ite is 85, or a friction coefficient of 0.85.

'Then you can look in accident reconstruction handbooks for different surface types and friction numbers. It's a wide range – from polished concrete to coarse concrete to some of the blacktops. The low end of the range is around 50 and the upper end is around 90. It's a huge spread depending on the type of surface and the condition of the surface.' Simulations used in professional motorsport often have two surface friction modifier coefficients. One describes the friction at each location around the track as the surface changes paving material, age etc. The second is a global modifier, which can be adjusted as track temperature, rubber build-up, sun/clouds or other factors affect the entire track. In this way, engineers can adjust the simulation for varying track conditions and grip levels.

> "STUDENTS WILL USE THIS DATA FOR YEARS TO COME"

The Formula SAE Tyre Test Consortium plans to conduct another round of tests before the 2006 competitions, and may continue to test tyres in future years based on funds available. The goal of providing extensive tyre data from a top-notch test facility to students for use in Formula SAE has been achieved. Many students will use this data for years to come, and several students made the trip to Calspan to witness the tests in person.

Gentz put the student involvement in the programme into perspective: 'They asked reasonably intuitive engineering questions. Clearly they're not the kinds of questions you'd get from an engineer who's worked in the field for a few years, just because they don't have the experience yet. But I think they saw basic engineering trends in the data. I'm sure that a number of students, once exposed to the data for a while, will come up with a whole bunch of useful questions. Some of them will have very good ideas about something else to do or some imaginative way to look at the data.'

And that, in a nutshell, is what Formula SAE is all about. RE

Calspan Corporation

The Calspan Tyre Research Facility is located in Buffalo, New York, USA, across the street from the Buffalo Niagara International Airport and about 30 minutes from Niagara Falls. The company's roots date back to 1943 when it was founded as the research arm of Curtiss-Wright Airplane Division. In 1946 it became Cornell Aeronautical Laboratories (CAL), a not-for-profit research lab affiliated with Cornell University. In addition to an advanced 10ft diameter (test section) transonic wind tunnel, early work focused on in-flight measurement of aeronautical stability derivatives and the invention of the first variable-stability aircraft.

In 1952, aircraft and automobile research were united as CAL began applying its considerable expertise to the dynamics of automobiles on contract to General Motors. Flight research expanded into transportation research and beyond. In 1972 CAL became a public company, Calspan Corporation. That same year the Tyre Research Facility (TIRF) was constructed.

Calspan's accomplishments through the years are impressive and too numerous to list. Several

> "ONE OF THE MOST CAPABLE TYRE-TESTING MACHINES IN THE WORLD"

in-flight simulators – aircraft modified via variable-stability technology to fly like other aircraft – have been developed and used for aircraft handling evaluation, handling standards establishment, pilot training and the development of 'fly-by-wire' technology. Calspan's transonic and hypersonic wind tunnels have been used in the development of the space shuttle, advanced military aircraft and have even been used by members of the US Olympic skiing team.

The Calspan Tyre Research Facility tyre tester

Calspan developed the first fully automated aircraft carrier landing system, terrain-following radar, worked on the 'Star Wars' space-based laser defence system and developed numerous still-classified projects for the US government.

On the ground, the fundamental equations of motion of the automobile were developed at Calspan and are the basis for many automobile simulations worldwide. The same dynamicists, apparently enjoying their work, developed the 'spiral jump' – made famous by James Bond in *The Man with the Golden Gun*.

Calspan performed pioneering work on seat belts (for which it holds the patent), the box beam guardrail and has been performing crash sled testing for over 30 years. The Tyre Research Facility continues to be one of the most capable and most used tyre-testing machines in the world.

Since the early 1970s Calspan has had various owners including Arvin Industries, Veridian and General Dynamics. Calspan Corporation is now once again independently owned. Over 20 spin-off companies have been fathered by Calspan over the past 60 years, and Calspan has cooperative ties with the University at Buffalo.

Today, the company's many focuses are divided into crash data research, flight research, systems engineering, wind tunnel and transportation sciences.

School for the skilled

Words | Ian Wagstaff
Photos | NC4M

A shortage of suitable engineers coming into motorsport has led to the launch of a bespoke facility offering courses and apprenticeships in motorsport engineering

During the last two or three decades the concept of the apprentice has been largely forgotten in the UK. This could be one of the reasons why the trade bodies MIA (Motorsport Industry Association) and AMRA (Automotive Manufacturers' Racing Association) found themselves complaining to Patricia Hewitt, then minister at the Department of Trade and Industry, that they were having difficulty finding the right skills from traditional recruiting areas such as aerospace, military and railways. The supply chain was struggling to find suitable workforces, particularly with the leading teams 'cherry picking' the best candidates. The industry seemed to have sufficient graduates, but what it could not find were the technicians.

Ms Hewitt formed the Motorsport Competitive Panel. One result of this was the establishment of a CoVE (Centre of Vocational Education) aimed specifically at training technicians – people who want to enter the motorsport industry – from potential car constructors to mechanics. This was publicly launched at Autosport International in 2004, initially with three existing colleges: Tresham Institute, the lead partner with a motorsport facility already operational close to Rockingham Speedway; the Oxford & Cherwell Valley College that has recently moved from Rycotewood, Thame to Bicester (also being re-named in the process) and Milton Keynes College in Bletchley.

> "THE GEOGRAPHICAL LINKS WITH 'MOTORSPORT VALLEY' ARE OBVIOUS"

All three can deliver the core engineering skills that are the foundation basis of the course. On top of this they have their own specialist fields. Tresham's specialist area is the training of race mechanics, with many of its apprentices working full time within the motorsport industry. Some are already with high level racing teams, as well as a cohort of full time learners training to reach a level of competence that will take them onto a race team. Oxford & Cherwell, for example, operates a composite facility. That college's engineering head, Evers Pearce, points out that it does not just provide race mechanics but also serves other parts of the industry. On its new,

The 6000ft² Silverstone facility gives students direct access to the circuit for testing and among the racecars available for them to work on are FFords, FRenaults, F3 cars, karts and a Honda race bike. As well as foundation courses in general hand skills, apprentices can specialise in all areas of racecar manufacture and preparation, from electronics to model making, composites and fabrication

On the inside

Those lecturing and working within the NC4M come from the industry itself. At least four – Jim Harrod, Justin Downard, Mark Savage and Dave Juniper – have been Formula 1 technicians with the likes of Williams, Lotus and Arrows, while two have worked within Formula Palmer Audi. Another, Chris Hodgins comes from Jordan's composites department, while Derek Ashby was a machinist with Benetton and Andy Thomas worked in Switzerland as a welder fabricator with Sauber.

Other companies whose former staff members now work at the NC4M include Parallel Motion, Hewland, Xtrac and Rockingham Speedway, as well as the touring car teams of Vauxhall, Nissan and Renault.

20,000ft² premises are to be found a welding and fabrication workshop, composites facilities with clean room, autoclave and trim room, a machine shop and an electric and electronic room. Milton Keynes is currently reorganising its engineering department to gain more space for its chosen specialisation, race engine building in Bletchley.

The geographical links with 'motorsport valley' are obvious. The Oxford & Cherwell is based next to the former Reynard operation, while Tresham has the Rockingham-based SCSA oval racing teams on its doorstep. However, it was also the intention to have a racetrack-based centre, and this came to fruition at Silverstone – among the multitude of racing teams that reside there – in April 2005. This enables the National College for Motorsport, NC4M as it is collectively known, to make use of the facility's self-contained Southern circuit on a regular basis. Up to four hours track time can be used twice a week. The new unit features an industry standard workshop with five vehicle bays and a small sub-assembly area, lecture room, student study area, two industry meeting rooms and offices.

Twelve students were initially recruited, mid-academic year, for the 6000ft² Silverstone unit. Within 10 days all had been placed as apprentices with companies within a 25-mile radius. Students are also brought in from the other colleges.

> **"FOR THE APPRENTICES A PARTICULAR PATHWAY IS MAPPED OUT"**

AMRA, which has close links with the British Racing Drivers Club, the owner of Silverstone, was closely involved in the setting up of the operation. The industry has been supportive, particularly SPA, which assisted with the purchase of a damper dynamometer, Lista which has installed extensive storage facilities and the workshop race bays and Würth, which has been responsible for the consumables used in the workshop. Brian James Trailers has assisted in the purchase of a race shuttle, while Demon Tweeks, which helped with racecar set-up equipment and Ford, which assisted with a fleet of minibuses, have also supported the college. The college also owns a race trailer unit built by J S Fraser with a tractor unit supported by Mercedes-Benz. [At →

the time of writing the trailer, which enables courses to be run anywhere, was being used at MIRA.] Other potential deals are in the pipeline.

The Silverstone facility is also spoilt for racecars, with a number of Formula Firsts having come from the BRDC driving academy. The students can also work on a collection of Formula Fords, a Formula 3 car and two Formula Renaults, as well as a Honda CBR600 racing bike.

There is also one full-time member of the educational staff based at Silverstone – former Williams Renault touring car chief mechanic Justin Downard – while the centre is managed by Jim Harrod, lately chief mechanic with Williams F1. Other staff used at Silverstone may be full time at the other colleges. The NC4M prefers to employ people who have come direct from industry, rather than an education background. 'It's easier to take somebody who knows about motorsport and teach them a bit about education than take someone who has been in teaching for years and teach them about motorsport,' observes Pearce.

The facility gives students access to all areas of relevant practical experience in a real-world environment

NC4M's own smart trailer unit. Other companies have assisted with consumables and set-up equipment

Bespoke qualifications

Prior to the launch of the NC4M, there had been no bespoke qualifications at the craft or technician grade level. This was, therefore, 'one of the first things to make happen.' The result has even attracted the attention of NASCAR.

Full time courses and apprenticeships are now offered in motorsport engineering and the NC4M has worked with the Motorsport Development UK in creating courses at what are known as Levels 1 and 2. A foundation course is also offered in the general hand and machining skills such as turning, milling and grinding – 'the skill sets that you need before you can do anything,' says Pearce. For the apprentices a particular pathway is mapped out, sometimes even bespoke for companies involved.

The apprenticeship contains a technical certificate that concerns the theory side of engineering. The course then moves on to an NVQ (National Vocational Qualification) that proves competence. The full timers complete their technical certificate requirement in year one and will also have intensive time in the workshops developing their practical skills. If they stay on for the second year they can have these assessed with an NVQ and can add on units that will prepare them for going to university.

Beyond that, apprentices can specialise in areas such as race/rally technician, composites, fabrications, electrical and electronics, pattern and model making (it has been estimated that the industry will require 45 new model makers this year) and manufacturing.

Overall, around 4–500 students may start each year at the NC4M and candidates are expected to have at least four GCSEs at grade C or above, especially, indeed crucially, maths.

Not all graduates necessarily stay in motorsport, as the skills learnt can be applicable elsewhere. Pearce refers to one former student now working in the bio-medical field. However, there are plenty of opportunities for the NC4M former student. 'The need is out there at the moment,' he says.

> "THERE IS A NEED FOR SPECIALIST ENGINEERS IN EVERY COMPANY"

Most companies, on taking on an apprentice, will give them a tour of the firm in the first year, spending some time in each department. The company will look at its own needs and what the skills of the apprentice are. These will help to determine the path of the student through college. Pearce points out that this is made possible by the bespoke nature of the courses. MIA surveys have identified that there is a need for specialist engineers in every company and it is hard for other colleges to accommodate this. Presently 38 different companies have apprentices studying at the NC4M.

The whole NC4M process is run by a board comprising the Learning & Skills Councils of Northamptonshire and of Milton Keynes, Oxfordshire and Buckinghamshire, the Northamptonshire Partnership and the East Midlands Development Agency, SEEDA, senior management from the three partner colleges and representatives of the Motorsport Development UK and the Motorsport Academy. The chair is Caroline Wilkinson, deputy principal of Tresham Institute, the lead partner.

The industry is already responding well to what the NC4M is offering. Prodrive normally takes up to 10 students a year from the three colleges. BAR has said that it will take nine apprentices this year, Williams three. The span of interested companies is wide and is now likely to expand into the motorcycle sector, too. 'NC4M tries to cultivate the right mindset, the cleanliness, and presentation that are expected by this industry; the 'can-do' attitude,' concludes Wilkinson. RE

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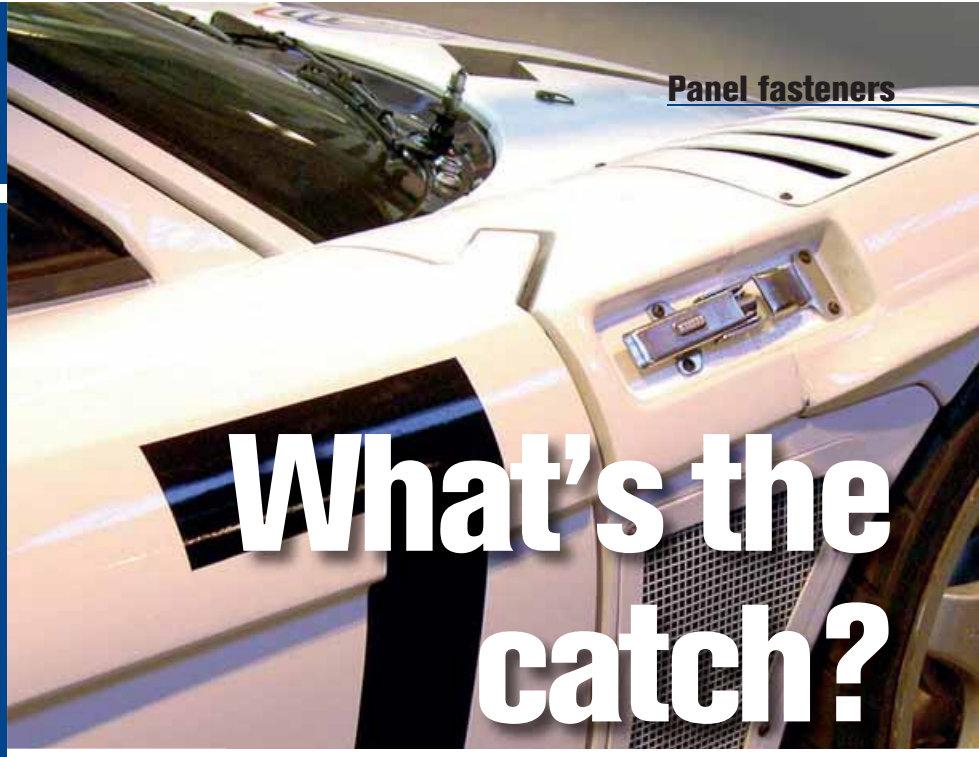


What's the catch?

There has been little progression in fastener technology in the last half century but recently some innovative designs have come to market

Words | Ian Wagstaff

UK-based Protex offers a large range of over-centre catches, as seen above

Quite recently a motorsport magazine carried a photo of an Australian V8 Holden at Bathurst, its bonnet adrift because it had not been fastened securely. This is not such an uncommon occurrence. Earlier this year a Belcar contender's bonnet flew off at the first corner at Zolder because a member of the pit crew had put the panel fastener pins in his pocket.

Perhaps it is not surprising that such incidents occur given the fact that, as Racecar observed last year, the science of panel fastening has not moved much over the past four decades. The traditional product has been the quarter-turn fastener. The two 'names' associated with this are Camloc and Dzus, although others have also been responsible for similar items. Dzus is said to have produced the original quarter-turn fastener in the early 1930s, initially for aerospace use. The Dzus fastener familiar today is virtually the same as that which would have been found on fighter 'planes in the Second World War.

"FASTENERS FOR MOTORSPORT APPLICATIONS SHOULD BE AIRCRAFT CERTIFIED"

The idea was to provide a vibration resistant, quick-action fastener with a pre-determined clamp setting – something that would be either done or undone. The cam design retains the fastener in place. Motorsport demands aerospace standards and Dzus has not really developed a new product for this sector for around 25 years.

As Specialty Fasteners and Components' (SFC) Graham Leo points out, the panel fastener is not something people give consideration to 'until the time comes to hold A to B.' About 12 months ago SFC stated that it was about to bring the business of securing bodywork into the 21st century. Since then, the company has been able to report that it has achieved what it describes as 'the biggest success so far' for its innovative, over-centre AeroCatch in that it was used on the bonnet and boot of Matt Neal's British Touring Car Championship-winning Honda Integra-R.

The drivers in this series have been known for the occasional →

Quarter-turn fasteners, such as those by Dzus and Camloc are still the industry standard

outbreak of panel bashing and so it was an ideal one for the AeroCatch to prove its worth. It has also found its way this year onto WTCC cars, endurance racers, and is now being used extensively at club level, particularly on rally cars where retro fitting onto existing studs – removing the old latch and replacing it with an AeroCatch – has been employed.

To remind you, the AeroCatch was launched towards the start of 2005, following an 18-month R&D programme carried out at XAT – the University of Exeter's commercial engineering department. SFC wanted a replacement for the standard bonnet pin that was flush mounted and had a double locking function. Importantly, to avoid incidents such as that which happened to the Belcar team, it should be obvious for driver and pit crew to see whether it was locked or not. The result is manufactured from high strength, glass-reinforced thermoplastic. Pressure releases a panel that then draws a sliding pin out of a hole in the end of a standard bonnet pin. The double locking function is achieved first by closing the panel and then by pressing on a protruding lever. Two versions, the 120 Flush and 125 Plus Flush series, are available – one a genuine flush mounting, the other with a mounting flange. Being flush fitted and easy to paint, they should not interfere with any livery. An optional sight window allows checking to see whether the AeroCatch has engaged the strike stud.

> **"THE 24-HOURS DEMAND THAT ALL EXTERNAL LATCHES MUST BE OPERABLE BY HAND"**

By its very nature, the AeroCatch is unsuitable for single seaters. However, it is not the only product available from SFC. The Devon-based company both manufactures and supplies fasteners for a wide range of industries, including the more traditional quick-release items also used in motorsport. Products offered include Camloc quarter-turn fasteners and toggle latches, Livelock, SFC's own Push-Turn Fasteners, captive screws and quick-release pins. AeroCatch is available throughout the world through a network of distributors such as the US-based Coast Fabrication.

Coast Fabrication points out that fasteners for motorsport applications should be aircraft certified (AN.MS.NAS) for strength and quality. In addition to AeroCatch, it distributes Alcoa fastening systems and MRC fasteners, both from major industrial concerns acknowledged within the aircraft industry. Alcoa, which this July sponsored the winning vehicle in the North American Solar Challenge, is currently responsible for the

SFC's innovative AeroCatch is a flush, double locking bonnet pin replacement

Camloc name when it comes to fasteners [ArvinMeritor still retains the right to use it for other products, namely in the shock absorber field]. It is also responsible for Livelock fasteners, which were first developed by Tridair for aerospace applications. These are suitable where juddering is a problem for standard fasteners. They feature a four start lead thread that prevents them from working up and down under vibration. Livelock fasteners are expensive though and are aimed at the top end of the market. An example of recent use is on the Aston Martin DBR9 GT1 cars.

A major UK distributor of fasteners used by the motorsport fraternity is Clarendon Engineering, now part of the IS-Group. Like Coast, it is also an official distributor for Alcoa. It holds a large inventory of aerospace-quality lines, including product from Southco, the US company that about a year ago became responsible for the familiar Dzus quarter-turn fasteners. In the USA Dzus had perhaps been more aggressive in its pursuit of motorsport business than in Europe, supplying actively to the drag and NASCAR fraternity. Under Southco there has been less interest in this sector as the group concentrates on larger and presumably more productive markets. The name Dzus is often used in a generic fashion to describe quarter-turn fasteners, but in fact the majority of these products found in motor racing tend to be Camlocs. However, Dzus probably has a greater penetration of the motorcycle sport market where its product is used extensively on fairings.

Dzus does not deal with the end user in motorsport but will sell through such distributors as Clarendon and Race Parts in the UK. Prior to the Southco takeover, the company did become involved, as a sponsor, of the Team Taurus Le Mans diesel project, supplying fast lead thread fasteners – not quarter turns as such – for the engine covers. Whilst a visible position for publicity, the Lola-Caterpillar was seen more as a hospitality vehicle to entertain OEMs, rather than for promotion to the motorsport world. →

Aston Martin DBR9 GT car uses Livelock fasteners, also available from SFC

Dzus fasteners (now owned by Southco) in use on the Taurus diesel project

Left and right: more over-centre catches from Protex. Its fasteners are available in different strengths depending on application

Redditch-based Protex Fasteners claims to manufacture the world's largest stock range of over-centre fasteners. Those typically employed on racecar bodywork include the type 50-1535 over-centre latch, as specified by Radical for securing a car's nose, centre section and rear bodywork. It is a shortened version of Protex's type 50-535 standard range adjustable catch, which is available in either stainless steel or mild steel with a passivated zinc plate finish. A simple locking action is featured that does not require the use of any tool.

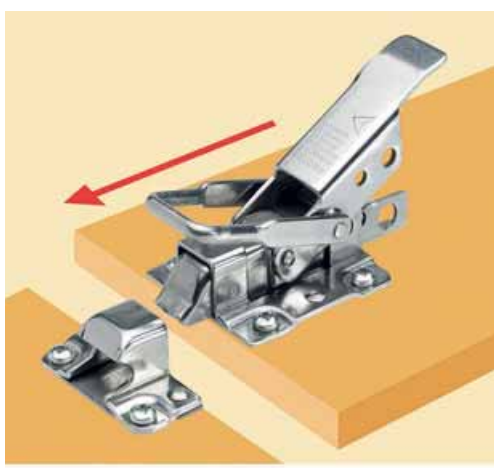
Heavier duty Protex products include the company's 60 and 70 series units, along with their corresponding type 61 and 71 fasteners, which feature a vibration-resistant integral safety catch. These have an ultimate strength of 454kgf, as opposed to the 350kgf of the 50-1535. In addition, Protex supplies a range of flush panel latches, quick-action fastener variants with screw adjustment, spring-claw fastening and a variety of safety locking devices.

It says, though, that the most demanding panel retention applications

> "JUDDERING IS A PROBLEM FOR STANDARD FASTENERS"

can be met by its patented CatchBolt design. This has been used by both Audi and Bentley to secure the composite nose, tail and centre bodywork sections on their R8 and Speed 8 Le Mans winners. Regulations for the 24-hours demand that all external latches and fastenings controlling access to the cars must be operable by hand, without the need for implements such as screwdrivers or coins.

The CatchBolt, which is mounted into moulded recesses, meets this requirement. Its initial closing action draws a mating keeper towards the main body of the fastener. Continued operation of the lever pushes a square section, spring-loaded bolt under the keeper. This acts on the bolt's tapered profile to ensure positive retention in all three axes. In stainless steel form, the CatchBolt has an ultimate strength of 600kgf in the longitudinal and lateral axes and 900kgf in the vertical plane. It is also available in plated mild steel. RE

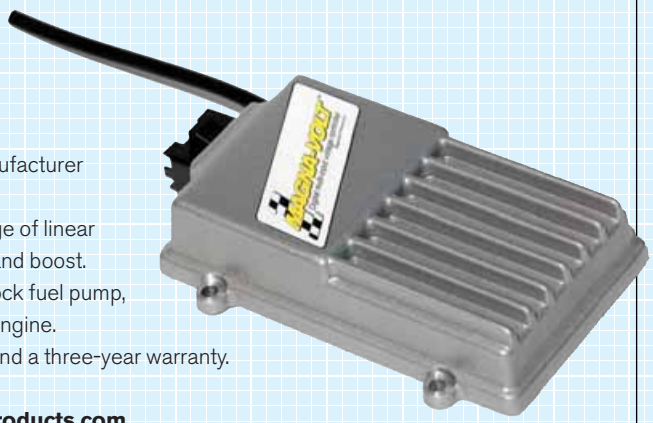


Protex's patented CatchBolt design is said to be the ultimate in heavy duty, hand operable panel retainer, as used on Audi R8s

RACEGEAR

New products and services for racecar engineers

Digital fuel control



A new digital voltage controller is now available from US-based supercharger manufacturer Magnuson Products.

The Magna-Volt multi-input digital voltage controller is said to have the advantage of linear power flow and reliability, allowing high-performance fuel delivery based on RPM and boost. When either of these reaches a pre-determined level it increases voltage to the stock fuel pump, maximising fuel efficiency and allowing for high performance modifications to an engine.

The plug-and-play unit comes pre-set and ready to install, with full instructions and a three-year warranty.

● **For more information call +1 (805) 289 0044 or visit www.magnusonproducts.com**

Evolution conversion

Australian-based engine management expert, MoTeC, has devised a powerful new engine management system for the Mitsubishi EVO IX.

The new plug-and-play ECU is based on the successful MoTeC M800 model and is available for road, race or rally.

Designed to achieve the best engine performance possible, the replacement board is completely programmable with an OEM connector and slots directly into the ECU case to avoid the need for additional sensors, hardware or wires.

The system offers users a variety of racebred selections, alongside a comprehensive package to optimise tuning flexibility and gain control of factory-managed functions.

Advanced functions include an overrun boost enhancement and upgrades such as Pro Analysis. Single or dual wideband Lambda can also be initiated using a password structure.

● **For more information call +61 3 9761 5050 or visit www.motec.com.au**

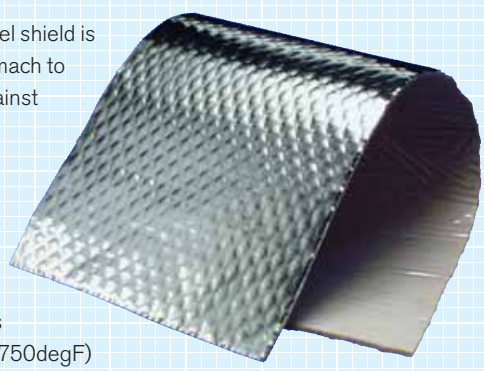
Cool race shirts

UK-based race and rally parts distributor, Demon Tweeks, is now supplying the new Cool Shirt driver cooling systems.

Designed to tackle the loss of performance that can be caused from heat fatigue, each shirt – either cotton or Nomex – has been designed with over 15m (50ft) of medical grade capillary tubing stitched into it. This is then attached to an internal pump and cooler, facilitating the flow of chilled water around the shirt during a race. Circulating cool water close to the skin is proven to gradually cool the body, preventing performance levels from dropping in high heat conditions.

● **For more information call +44 (0) 1978 664466 or visit www.demon-tweeks.co.uk**

Insulation shield



A new floor and tunnel shield is available from Agriemach to insulate racecars against heat and sound. Constructed from bonded aluminium and glass fibre, the custom fit shield is said to be able to endure temperatures of up to 955degC (1750degF) and is backed with an aggressive adhesive that assists fitting and can resist temperatures past 230degC (450degF).

The shield is 4mm thick and comes in various size sheets so can easily be trimmed and shaped to protect under bonnet areas, firewalls and exterior under-vehicle areas.

● **For more information call +44 (0) 1342 713743 or visit www.agriemach.com**

RACEGEAR

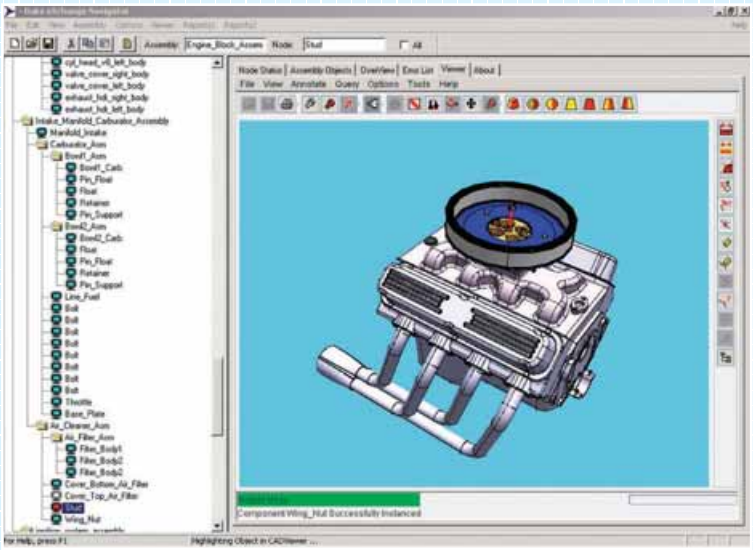
New products and services for racecar engineers

CAD file exchanger

New from product data exchange experts, Theorem Solutions, is the Data eXchange Navigator (DXN), a product aimed at speeding up the process of translating data from large assembly files. The company claims large component and sub-assembly data files can be targeted and translated faster and easier than before using its new system. The DXN tackles the problem of having to translate the whole assembly file when several users are working with various software programs.

It has been designed to read assembly information from all leading CAD systems, and to distinguish the orientation and offset of each component before translating it to the preferred CAD format and saving the original master assembly if necessary.

● For more information call +44 (0) 1543 444455 or visit www.theoremsolutions.com



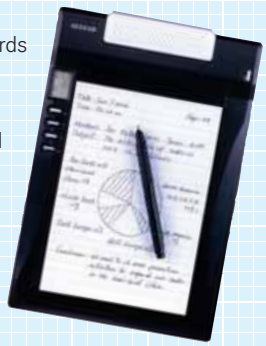
RACEGEAR

New products and services for racecar engineers

Digital notepad

UK-based Unimatic Engineers has created an electronic clipboard that allows manual notes and hand drawn diagrams to be digitally transferred onto a PC or laptop.

The DigiMemo A501 transfers any handwritten notes from an A5 notepad into an electronic file. It can then be viewed, edited and emailed, or used in union with My Scripts Notes. Files are transferred via a USB port to the DigiMemo where they can then be saved as an e-file and 8MB allows 1000 pages of notes to be saved. Additional Compact Flash memory cards can increase the storage space further.



The portable clipboard has the advantage that it can be used simultaneously be several users, with amendments being added as it is passed between consumers.

● For more information call +44 (0) 208 9221000 or visit www.unimatic.com

New Instron catalogue

Instron has announced the release of the second edition of its catalogue of accessories to improve material testing systems.

The 480-page catalogue features products designed to test the mechanical properties of materials and machinery. Some of the products featured include load cells, extensometers, grips and environmental chambers. Most products can also be tailored to adapt to equipment from other manufacturers.

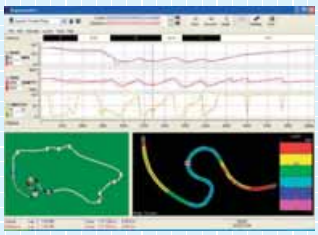
The catalogue includes a colour guide designed to inform readers which products achieve optimal results with various testing equipment and applications. The catalogue is free and can be ordered from the company's website.

● For more information call +44 (0) 1494 456815 or visit www.instron.com

RACEGEAR

New products and services for racecar engineers

Acquired knowledge



Stack has launched a new version of its popular DataPro data acquisition and analysis software.

The new DataPro 4 features the same successful characteristics from previous versions, alongside a host of new and improved features. Amongst these the 'advanced channel calculator' is the most noteworthy and provides users with a means of obtaining new analysis data from various recorded channels. So-called 'rainbow maps' are another significant advancement, designed to enable users to zoom into any section of the map whilst having the option of working in discreet or non-discreet modes.

Data from a 1Hz or 5Hz GPS unit can also be transferred from existing vehicle data channels thanks to the inclusion of a new GPS interface, too.

● **For more information call +44 (0) 1869 240404 or visit www.stackltd.com**

Cheating

An inside look at the bad things good NASCAR Nextel cup racers do in pursuit of speed

By Tom Jensen

It would be hard to turn out a bad book on this subject, given the wealth of amusing and technically interesting stories that have come out of NASCAR. There are tales of maximising the rules, bending the rules and totally disregarding them. Everything is mentioned and explained in detail – how they work and why crews tried them, from oversized engines to undersized cars.

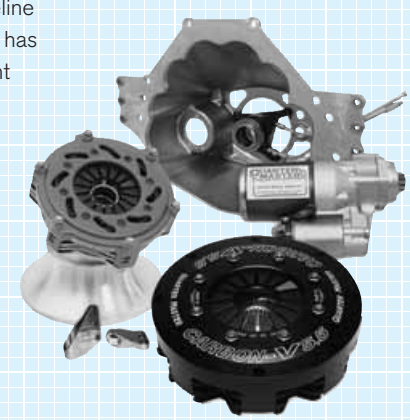
This book is inspirational, and reading it you will find yourself thinking up ways of circumventing rules yourself. It also details how the cheats were caught out (useful information in itself…). Sometimes through a lack of attention to detail and sometimes through sheer stupidity, but there were times when the teams got one over on everyone, Smokey Yunick being one of the leading exponents of this.

Jensen has been given good access to NASCAR's confiscated parts room and, whilst clearly getting along with the organisation, he is not afraid to rock the boat, going on to explore in some detail the controversy surrounding the confiscation of Tony Stewart's Joe Gibbs Chevrolet a couple of years ago. All in all, a must read.

● **Published by David Bull Publishing (www.bullpublishing.com), softbound, 312 pages, $17.95**

No quarter clutch

US racing clutch and driveline specialist, Quarter Master, has released a new, lightweight clutch package with rear mount starter.



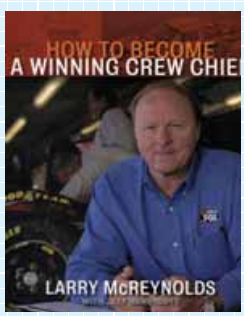
The 5.5 Optimum kit includes the company's lightest and stiffest ever magnesium bellhousing with integral engine mounts and a lightweight, billet, one-piece ring gear. Using the latest design software in its development has enabled the company to reduce the 5.5 clutch's moment of inertia and, at the same time, extend its durability.

It even claims the 5.5s moment of inertia is within 20 per cent of a carbon/carbon application.

● **For more information visit www.racingclutches.com**

How to be a winning crew chief

By Larry McReynolds, with Jeff Huneycutt



This practical guide to running a stock car covers everything from setting up your workshop to setting up your car. Aimed squarely at amateurs, the book gives the benefit of McReynolds' vast experience. British NHRPA teams could learn a lot, as could a lot of US amateur oval racers.

Plenty of good practical hints and tips are featured, but 'the stock car source book' might perhaps have been a better title. Whilst nowhere as detailed as Allan Staniforth's essential *Race and Rally Car Source Book*, it is far more targeted. If you run or plan to run stock cars of any type then this would be worth reading.

● **Published by David Bull Publishing (www.bullpublishing.com), softbound, 176 pages, $24.95**

Database

Section 1 lists manufacturers of Brand-Name Racecars.

Sections 2-3 list component manufacturers. Section 2 is dedicated to Chassis Components, Section 3 to Engine and Transmission Components

Sections 4-5-6 list equipment manufacturers Section 4 is dedicated to Factory Equipment Section 5 to Circuit Equipment Sections 6 to Driver Equipment

Sections 7-8-9-10 list companies that supply services. Section 7 is devoted to Chassis Engineering Services, Section 8 to Engine / Transmission / Suspension Services Section 9 to Testing Services Section 10 to Non-Engineering Services

To get your company listed in the racecar database please contact Andy King - 0208 726 8329 andy_kings@ipcmedia.com

Costs listed below:
Name and number £50 - 12 issues
Name and number bold
£70 - 12 issues
Logo and full company details
£420 - 12 issues including web, address, email etc etc
£210 - 6 issues

www.racecarengineering.com

Andy King on Tel: +44 (0)20 8726 8329

andy_king@ipcmedia.com

Database 1

RACECAR MANUFACTURERS

1.1 Racecar Manufacturers

A-MAC USA (1) 408 727 9288
Fax (1) 408 988 8998
A-Mac Fabrication, 1745 Grant Street, Suite 2, Santa Clara, CA 95050, USA

ASCARI Tel 01295 254800
Fax 01295 255944
Overthorpe Road, Banbury, Oxfordshire OX16 4PN England

APOLLO RACING DESIGN LTD Tel 01280 813580
Fax 01280 823015
Email info@apolloracingdesign.com
Website www.apolloracingdesign.com
Millgate Barn, Radclive, Bucks MK18 4AB, England

BARRELLI Italy (39) 02 782427
Flli Barrelli, Via La Spezia 5, 20156 Milan, Italy

BRD Race Cars Inc. Tel (1) 716 637 9467
16 Hollybrook Road, Brockport, NY 14420, USA

BODOLA Tel Sweden 46 171 27690
Fax Sweden 46 171 27690
Bodin ChassiTeknik, Skalbygatan 8, 745 37 Enkoping, Sweden

BREDA Italy (39) 049 9001895
Fax (390) 49 900 2821
Breda Racing s.r.l, via Buonarotti 10a, 35035 Mestrino,PD, Italy

BRYTEC Tel 01772 786500
Fax 01772 786500
Lower College, Hothersall Lane, Longridge, Preston, Lancashire PR3 2XB

CARBIR USA (1) 262 377 2850
Fax (1) 262 375 1602
Carbir Race Cars Inc, 1220 Falls Road, Grafton, WI 53024, USA

CHEEK Norway (47) 90 78 70 32
Fax (47) 69 19 02 55
Cheek Racing Cars, Flatebyvn 3, 1792 Tistedal, Norway

CHEETAH USA (1) 408 492 1331
Fax USA (1) 408 492 1333
Omni Fab, 380 Martin Avenue, Santa Clara, CA 95050

CHEVRON Tel 01300 348499
The Chevron Centre, Piddle Trenthide, Nr Dorchester, Dorset DT2 7RF, England

US Importer Continental Crosslé Tel (1) 513 777 4545
9000 Debbie Drive, West Chester, OH 45069, USA

DALLARA Italy (390) 525 550711
Fax (390) 525 53478
Dallara Automobili, Via Provinciale 33, 43040 Varano Melegari, Parma, Italy

DEBORA France (33) 381 52 02 10
36
Fax (33) 381 51 18 51
bis Rue du Docteur Moras, 25000 Besancon, France

DAN GURNEY'S ALL AMERICAN RACERS,INC
Tel USA 714 540 1771
Fax USA 714 540 3749
2334 South Broadway PO BOX 2186, Santa Ana, CA 92707, USA

DJ RACECARS Tel 01663 734518
Fax 01663 732 130
Email del@djracecars.fsnet.co.uk
Unit 10, Britannia Rd Est, Buxworth, Nr Whaley Bridge, High Peak, SK23 7NF

DOME CO. LTD 198-1 Hanajiricho, Yase, Sakyoku, Kyoto, Japan
Tel 81 (0)75744-3131
Fax 81 (0)75744-3035

DOME CARS. LTD Roebuck House, Cox Lane, Chessington, Surrey KT9 1DG England
Tel 0208 397 9999
Fax 0208 397 6830

DOWNS ENGINEERING Tel USA 707 938 1001
Fax USA 707 935 0481
19564 8th St. East, Sonoma, CA 95476 USA

DRAGON USA (1) 413 267 0904
Small Fortune Racing, 77 Stafford Hollow Road, Monson, MA 01057, USA

ELISE France (33) 1 47 49 15 66
1 Rue Pierre Cassin, 92500 Rueil Malmaison, Paris, France

EUROCAR Tel 01353 861168
Fax 01353 861877
SHP Motorsport, Unit 7 Farraday Business Park, Littleport, Ely, Cambridgeshire CB6 1SE, England

EXTREME CARS Australia (61) 396 822225
(61) 396 821119
(61) 396 900809
Email mrpro07@tpg.com.au
King Way House, 188-190 Kings Way, South Melbourne, Victoria 3205 Aus.

FABCAR USA (1) 317 872 3664
Fax (1) 317 872 3835
4148 West 99 Street Carmel Indiana

FORCE RACING CARS Tel/Fax 01823 698117
Clyse Farm, Stathe, Nr Bridgwater TA7 0JN England

GRAN TOURING CLASSICS 001 562 596 9242

GOULD Tel 01635 44466
Fax 01635 30056
Gould Engineering Services, Unit 7, Arnhem Road, Newbury, Berks, RG14 5RU

ICP/CITATION USA (1) 317 273 0089
Indianapolis Competition Products, 1717 Expo Lane, Indianapolis, IN 46214, USA

JADE Tel 01883 744 443
Fax 01883 744 443
Address Jade Motorsport Engineering, Unit 2 Pendell Farm, Pendell Road Bletchingley Surrey RH1 4QH

JEDI Tel 01933 440774
John Corbyn Motors, 36A Stanley Road, Wellingborough, Northamptonshire NN8 1DY, England

KBS USA (1) 909 355 4800
Fax (1) 909 355 5933
KBS Engineering, 8296 Fremontia, Suite B, Fontana, CA 91404, USA

KUDZU USA (1) 404 457 6300
Fax (1) 404 458 6118
5096 Peachtree Road, Atlanta, GA 30341, USA

LAZER USA (1) 906 863 5003
Campbell Motorsport, W7719 Fernwood Drive, Menominee, MI 49858, USA

LOLA Tel 01480 451301
Fax 01480 456722
Lola Cars International, Glebe Road, St Peters Hill, Huntingdon, Cambridgeshire PE18 7DS, England

US Importer
Tel (1) 317 244 2277 Fax (1) 317 390 2121
Lola Cars Inc, Suite B, 2801 Fortune Circle East, Indianapolis, IN 46241, USA

LUCCHINI Italy (39) 0376 391271
Fax (39) 0376 391200
Lucchini Engineering, via Valeggio 2, 45100 Mantova, Italy

LYNCAR ENGINEERING Tel 01635 860066
Fax 01635 860066
Email: lyncar001@btopenworld.com
Briff Lane, Bucklebury, Reading, Berkshire RG7 6SN

MAGNUM Tel 01933 442861
Fax 01933 22552
141 Laurence Leyland Industrial Estate, Wellingborough, Northamptonshire NN8 1RA, England

MALLOCK Tel 01604 863504
Fax 01604 863807
Mallock Racing, Rowley Wood Lane, Hartwell, Northamptonshire NN7 2QT, England

MARK BAILEY RACING Tel 01380 850130
Fax 01380 850140
MBR Building, 8A Jockey Lane Bromham, Chippenham, Wiltshire, SN15 2EZ

MATT WATERMAN MOTORSPORT DESIGN Tel 0408 216357

MYGALE Tel France 33 3 8621 8621
Fax France 33 3 8621 8622
Technopole du Circuit, 58470 Magny-Cors, France

OSELLA S.R.L Tel 0972 715852
Fax 0972 715391
Z.I Valle di Vitalba, 85020 Atella, (PZ)

PANOZ Tel USA (1) 770 967 2310
Fax USA (1) 770 965 8762
5294 Winder Highway, Braselton, GA 30517, USA

PHOENIX USA USA (1) 813 655 1199
Phoenix Race Cars, 364 Hairpin Drive, Sebring, FL 33870, USA Fax (1) 813 665 1199

PICCHIO S.p.A Tel 0039 0861 816015/16
Fax 0039 0861 86246/805651
Email: picchio@picchio.com or picchiospa@email.it
Website: www.picchio.com
Zona Industriale Ancarano 64010 - Ancarano (Teramo) Italy

PILBEAM Tel 01778 424838
Fax 01778 393032
Pilbeam Racing Design, Graham Hill Way,Cherry Halt Road, Bourne, Lincolnshire, PE10 9PJ

PIPER USA (1) 708 365 5334
Piper Engineering, 5N461 Meadowview Lane, St Charles, IL 60175, USA

PREDATOR USA (1) 313 681 1377
Fax (1) 248 681 1377
Crossroads Fabrication, 265 Hillcliff, Waterford, MI 48328, USA

PROTECH COMPOSITES LTD
Tel: +44(0) 1420 471 400
Fax: +44 (0) 1420 487 047
www.protechcomposites.co.uk
Unit 62, Woolmer Trading Estate
Bordon, Hampshire, GU35 9QF, UK

PROTOFORM USA (1) 607 739 7345
Protoform Race Engineering, 51 Ponderosa Drive, Horseheads, NY 14845, USA

RACEFAB USA (1) 713 694 8335
Fax (1) 713 694 8335
8307 Beauman Road, Houston, TX 77022, USA

RALT 01865 883354
Fax 01865 883789
Ralt Engineering, Sutton Farm House, Sutton, Witney, Oxfordshire OX29 5RD, England

US Importer
Tel (1) 310 533 1144 Fax (1) 310 530 0139
Ralt American, 23110 Kashiwa Court, Torrance, CA 90505, USA

RAPTOR USA (1) 215 775 1938
Performance Engineering, RD5 Box 5435, Mohnton, PA 19540, USA

RAY Tel 0208 680 9418
Fax 0208 688 4026
15 Silverwing Industrial Park, Horatius Way, Croydon, Surrey CR0 4RU, England

RILEY & SCOTT USA (1) 317 248 9470
Fax (1) 317 248 0182
1200 Main Street, Speedway, Indianapolis IN 46224, USA

RML LTD Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Ind Est, Wellingborough, Northants NN8 6TY England

SABRE USA (1) 714 693 0296
USA Race Cars, 1535 Harmony Circle, Anaheim, CA 92807, USA Fax (1) 714 693 3164

SCCA USA (1) 303 693 2111
Fax (1) 303 680 5633
Spec Racer, 7476 South Eagle Street, Unit 5, Englewood, CO 80112, USA

SCARAB Tel 01636 822033R
RS Racing & Specialised Services, High House,Kirton Road, Egmanton, Newark, Nottinghamshire NG22 0HF, England

SEZIO FLORIDA RACING Tel: 001 776 878145

SHELBY USA (1) 310 538 2914
Fax (1) 310 538 0126
Shelby Can-Am, Shelby Technologies Inc, 19021 South Figueroa, Gardena, CA 90248, USA

SPECTRUM Australia (61) 3 95 80 52 36
Fax (61) 3 95 80 53 31
Spectrum Racing Cars, Borland Racing Developments, 39 Industrial Drive, Braeside, Victoria, Australia 3195

STRYX Tel 01789 750567
Fax 01789 292183
Minerva Developments, Grafton Lodge, Binton, Stratford-on-Avon, Warwickshire CV37 9TX, England

SPICE RACING CARS LTD Tel 01483 203956
Fax 01483 203956
Int House, 31 Church Road, Hendon, NW4 4EB, England

SWIFT US Importer International Racing Products
Tel (1) 800 793 0496
1034 Riva Ridge, Great Falls, VA 22066, USA

SYMBOL Italy (39) 0362 903967
Symbol Team srl, via Fiume 17, Carate Brianza, 20048 MI, Italy

TAMPOLLI Italy (39) 055 8873268
Fax (39) 055 8825777
Tampolli Engineering, via degli Artigiani 44-46, Calenzano, 50041 FI, Italy

TOM'S Japan (81) 3370 46801
Fax (81) 3370 46805
6-13-10 Todoroki Setagaya-ku, Tokyo, Japan 158

TPG 0039 682 32225

VAN DIEMEN Tel 01953 888195
Fax 01953 888178
Van Diemen International Racing Services, Chalk Road, Snetterton, Norfolk NR16 2JZ, England

US Importer Primus Racing
Tel (1) 813 522 7544 Fax (1) 813 522 7417
3608 Morris Street, St Petersburg, FL 33407, USA

Database 2
COMPETITION CAR CHASSIS COMPONENTS

2.1 Chassis/BodyWork Ancillaries

AEROFOILS

ACTIVE ENG USA (1) 714 637 1155

AERODINE COMPOSITES GROUP, LLC
Tel: 317 271 1207 Fax: 317 271 4455
www.aerodinecomposites.com
8201 Indy Lane, Indianapolis, Indiana 46214

ANDREAM LTD CUSTOMIZED COMPOSITE WINGS
Tel: 01953 885775 / Fax: 01953 884176
Email: dave.greenwood@eidisnet.co.uk
Unit 12 Norwich Road Industrial Estate, Watton, Norfolk IP25 6DR

CGB CONSULTANTS 01202 661707
DJ RACECARS LTD 01663 734518
JANUS TECHNOLOGY 01753 869996

PROTECH COMPOSITES LTD
Tel: +44(0) 1420 471 400 Fax: +44 (0) 1420 487 047
www.protechcomposites.co.uk
Unit 62, Woolmer Trading Estate
Bordon, Hampshire, GU35 9QF, UK

LOLA Tel 01480 451101 / Fax 01480 456722
Lola Cars International, Glebe Road, St Peters Hill, Huntingdon, Cambridgeshire PE18 7DS, England
US Importer
Tel (1) 317 244 2277 / Fax (1) 317 390 2121
Lola Cars Inc, Suite B, 2801 Fortune Circle East, Indianapolis, IN 46241, USA

ROAD & STAGE M/SPORT 01524 844066
SARDOU France (33) 1 60 01 03 67
THE WING SHOP Tel: 01258 860716
Fax: 01258 860716
E-mail: info@wingshop.co.uk
Web: www.wingshop.co.uk
SPA AEROFOILS LTD 01827 260026
UNI OF MARYLAND USA (1)301 405 6861
QINETIQ 02700 100942
ZEUS MOTORSPORT 01604 878101

FASTENERS

ABC AUTOSPORT BEARINGS - COMPONENTS
Tel : +44(0)1932 225777 Fax : +44(0)1932 222225
Unit 3 Shepperton Business Park
Shepperton, Middlesex TW17 8AA

ALL WAYS FORWARD 01242228111
ARP USA (1) 805 525 5152
ARROW SUPPLY 01234 840404
CLARENDON 01455 841200
COAST FABRICATION USA (1) 714 842 2603
DATUM ENGINEERING 02476 383032
DZUS FASTENERS EUROPE 01252 714422
FASTENER FACTORY 01327 311018
FLUID CONTROL PRODUCTS INC USA (1) 217 324 3737
Fax (1) 217 324 3717
PROTEX FASTENERS LTD 01527 63231
SPECIALITY FASTENERS 01803 866371
STAUBLI France (33) 4 50 65 60 60
TRIDENT RACING SUPPLIES TEL 01327 857812
FAX 01327 858096
Unit 31, Silverstone Circuit, Northants NN12 8TN

FIRE EXTINGUISHERS

LIFELINE 02476 712999
LINREAD NORTHBRIDGE MOTORSPORT 01162 572924
RALLY DESIGN 01795 531871
SAFETY DEVICES 01353 724202
SPA DESIGN 01827 288328
SPA TECHNIQUE USA (1) 317 271 7941
ATL USA (1) 201 825 1400 Fax (1) 201 825 1962
Aero Tec Laboratories Inc.
Spear Road Industrial Park, Ramsey, NJ 07446-1221, USA

FUEL CELLS

ATL UK 01908 351700 Fax 01908 351750
Aero Tec Laboratories Ltd (Europe).
1 Patriot Drive, Rooksley, Milton Keynes MK13 8PU
FUEL SAFE SYSTEMS USA (1) 714 842 2211
GOMM METAL DEVELOPMENTS 01483 764876
KS MOTORSPORT Germany (49) 2271 44905
PRONALS France (33) 320 99 75 10
TRANSAUTOSPORT 01772 454647
ACTIVE ENG USA 001 714 637 1155
GARTRAC 01428 682263
ROLLCENTRE 01480 464052
SAFETY DEVICES 01353 724202
SIGMA Switzerland (41) 61 9717600
CORBEAU 01424 854499
GRAND PRIX RACEWEAR 020 8987 5500
MOMO USA 001 714 637 1155
EARS MOTORSPORTS 01625 433773
KS MOTORSPORT Germany (49) 2271 44905
OMP USA (1) 973 361 0508
MOMO USA 001 714 637 1155
LUKE 01323 844791
Total Restraint Systems 01722 326080
TRW SABELT 020 7736 2881
WILLANS 01264 810712

RUBBER & ELASTOMERIC COMPONENTS

BUTSER RUBBER LTD Tel: 01730 894034

2.2 Electrical Systems

REDLINE MOTORSPORT Tel 01606 737500
Fax 01606 737683

ALTERNATORS

BOSCH 01895 834466
Germany (49) 711 8111 USA (1) 312 865 5200
BRISE AUTO ELECTRICS 01322 277622
MM COMPETITION 08707 444666
McCLAREN ELECTRONICS 01483 261400

CABLES

CENTURY CABLES Tel 01733 210600 / Fax 01733 210082
Email kwhincup@yahoo.com / web www.centurycables.com
IS MOTORSPORT USA (1) 317 244 6643
PERFORMANCE WIRING SOLUTIONS +44 (0)1954 253620
RINGSPANN 01234 342511
SPEEDY CABLES 020 7226 9228
SPOT ON CONTROL 0118 979 0682
TRIDENT RACING 01327 857822
CONTINENTAL USA (1) 513 459 8863

CONNECTORS

BERU F1 SYSTEMS 01374 646200
DEUTSCH 01424 852721
IS MOTORSPORT USA (1) 317 244 6643
MAGNETI MARELLI Italy (39) 02 972 27570
MM COMPETITION 08707 444666
PERFORMANCE WIRING SOLUTIONS +44 (0)1954 253620
SAKATA MOTORSPORT ELEC. INC. (714) 446 9473
SERVO & ELECTRONIC SALES LTD 01797 322500
SPECIALITY FASTENERS 01803 866677
RAYCHEM 01793 572217

DISTRIBUTORS

IS MOTORSPORT USA (1) 317 244 6643
MM COMPETITION 08707 444666
PALLAS CONNECTIONS 01869 277053
PAD RACING NZ (64) 3 3386 288

IGNITION SYSTEMS

BOSCH UK 01895 834466
Germany (49) 711 8111 USA (1) 312 865 5200
SBD MOTORSPORT 0208 391 0121
EFI TECH USA (1) 310 793 2505
HELLA UK 01295 272233
LUMENITION 020 7403 4334
MAGNETI MARELLI Italy (39) 02 972 27570
MM COMPETITION 08707 444666
MOTEC Australia (61) 3 9761 5050
MOTEC (EUROPE) UK 08700 119100
MOTEC JAPAN Japan (81) 489 46 1734
MOTEC SYSTEMS USA USA (1) 714 897 6804
MSD IGNITION USA (1) 915 857 5200
PI RESEARCH 01954 253600
PIAA (UK) 01934 814812
STACK 01869 240404
McCLAREN ELECTRONICS 01483 261400
THE STRAIN GAUGING CO 01256 320666

LIGHTS

HELLA 01295 272233
PIAA 01934 818 430
PRODRIVE 01295 254400

LOAD CELLS

NOVATECH MEASUREMENTS 01424 852 744

SPARKPLUGS

BERU 01295 272233
BOSCH Germany (49) 711 8111
UK 01895 834466 USA (1) 312 865 5200
CHAMPION AUTO 0151 522 3000
KS MOTORSPORTS Germany (49) 2271 44905
MAGNETI MARELLI Italy (39) 02 972 27570
MM COMPETITION 08707 444666
NGK Japan (81) 52 872 5937 UK 0208 202 2151

SPARKPLUG LEADS

MAGNETI MARELLI Italy (39) 02 972 27570
MM COMPETITION UK 08707 444666

WIRING HARNESSES

A.N. MOTORSPORT DESIGN 01628 776320
COMPETITION DATA SYS USA (1) 716 631 2880
DC ELECTRONICS 01621 856451
SBD MOTORSPORT 0208 391 0121
EFI TECH USA (1) 310 793 2505
BERU F1 SYSTEMS 01374 646200
MAGNETI MARELLI Italy (39) 02 972 27570
MM COMPETITION 08707 444666
MOTEC Australia (61) 3 9761 5050
MOTEC (EUROPE) UK 08700 119100
MOTEC JAPAN Japan (81) 489 46 1734
MOTEC SYSTEMS USA USA (1) 714 897 6804
PALLAS CONNECTIONS 01869 277053
PERFORMANCE WIRING SOLUTIONS +44 (0)1954 253620
RAYCHEM 01793 572217

SAKATA MOTORSPORT ELEC. INC. Tel (714) 446 9473
Fax (714) 446 9247
Website www.sakatamotorsport.com
689 S. State College Blvd, Unit F Fullerton, CA 92831

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THE STRAIN GAUGING CO 01256 320666
TONY JAMES 01379 854485

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Email: sales@zica.uk.com Website: www.zica.uk.com
21 Anglevale, Top Angel, Buckingham, Buckinghamshire, MK18 1TH

2.3 Controls

GEARSHIFT SYSTEMS

CENTURY CABLES Tel 01733 210600 / Fax 01733 210082
Email kwhincup@yahoo.com / web www.centurycables.com
DAVID BROWN 01484 422180
SBD MOTORSPORT 0208 391 0121
HEWLAND ENG 01628 827600
JACK KNIGHT 01483 764326
PRODRIVE 01295 273355
QUAIFE ENGINEERING 01732 741144
RICARDO MIDLANDS TECHNICAL CENTRE 01926 319399
RINGSPANN (UK) 01234 342511
THE STRAIN GAUGING CO 01256 320666
STONE FOUNDRIES 020 8853 4648

HYDRAULIC VALVES

A.N. MOTORSPORT DESIGN 01628 776320
LEE PRODUCTS 01753 886664
MOOG CONTROLS 01684 296600

INSTRUMENTATION

ACTIVE SENSORS 01202 480620
CRANFIELD IMPACT CENTRE 01234 750944
LMI STACK USA 001 714 637 1155
LUMENITION 020 7403 4334
MAGNETI MARELLI Italy (39) 02 972 27570
MM COMPETITION 08707 444666
MOTEC Australia (61) 3 9761 5050
MOTEC (EUROPE) UK 08700 119100
MOTEC JAPAN Japan (81) 489 46 1734
MOTEC SYSTEMS USA USA (1) 714 897 6804
PENNY & GILES 01202 409409
PI RESEARCH 01954 253600
QINETIQ 08700 100942
SPA DESIGN 01827 288328
STACK 01869 240404
McCLAREN ELECTRONICS 01483 261400
THE STRAIN GAUGING CO 01256 320666
VARIOHM 01327 351004

MIRRORS

GRAND PRIX RACEWEAR 0208 987 5500
SPA DESIGN 01827 288328

PEDALS

AP RACING 02476 63595
CHEVRON RACING 01565 777395
LOLA Tel 01480 451101
Fax 01480 456722
TILTON USA (1) 805 688 2353
WILWOOD ENG USA (1) 805 388 1188

STEERING SYSTEMS

FLAMING RIVER USA (1) 440 826 4488
MOBILIS Canada (1) 450 647 1890
RALLY DESIGN 01795 531871
ZF Germany (49) 7541 772543
UK 0115 9869211

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FAX: USA (1) 307 235 1551
Website: www.woodwardsteering.com
PO Box 4479, 3592 Burd Road, Casper, WY82604, USA

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DEMON TWEEKS 01978 664466
MOUNTNEY 01525 383055

SWITCHES & KILL-SWITCHES

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MAGNETI MARELLI Italy (39) 02 972 27570
MM COMPETITION 08707 444666
SAKATA MOTORSPORT ELEC. INC. (714) 446 9473
TONY JAMES 01379 854485
TRIDENT RACING 01536 770777

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Email: kwhincup@yahoo.com
Web: www.centurycables.com
JLS MOTORSPORT 0121 525 7733
KINSLER USA (1) 810 362 1145
LUMENITION 020 8403 4334
RALLY DESIGN 01795 531871
SPOT-ON CONTROL 0118 9790682
RINGSPANN 01234 342511

2.4 Suspension Systems

DEREK BENNETT ENG 01565 777433
DON FOSTER RACING France
(33) 4 70 58 0308
DYNAMIC SUSPENSIONS 01842 755744
GROUND CONTROL USA (1) 916 638 7888
LOLA Tel 01480 451101
Fax 01480 456722
PROFLEX UK 01200 442345
RICARDO MIDLANDS TECHNICAL CENTRE 01926 477208
ROD MILLEN MOTORSPORT USA (1) 714 8472111

2.5 Suspension Components

ANTIROLL BARS

COIL SPRINGS 01142 758573
COMPTECH USA USA (1) 916 933 1080
DEREK BENNETT ENG 01565 777395
DON FOSTER RACING France (33) 4 70 58 0308
DTM CONSULTANTS UK 01865 407726
GROUND CONTROL USA (1) 916 638 7888
KIC INT MOTORSPORTS USA (1) 604 589 3354
HARROP Australia (61) 3 9499 7433
PRECISION USA (1) 708 766 4402

BEARINGS & BUSHES

ABC AUTOSPORT BEARINGS - COMPONENTS
Tel : +44(0)1932 225777
Fax : +44(0)1932 222225
Unit 3 Shepperton Business Park
Shepperton, Middlesex TW17 8AA

AURORA BEARING USA (1) 630 859 2030
FASTENER FACTORY 01327 311018
GETECNO Italy (39) 010 835 6016
QINETIQ 08700 100942

GOLDLINE BEARINGS Tel 01952 292401
Fax 01952 292403
Stafford Park 17, Telford, TF3 3DG

GROUND CONTROL USA (1) 916 638 7888
RESB 0121 520 8271
ROSE BEARINGS 01522 500933

COILSPRINGS

COIL SPRINGS 01142 758 573
COMPTECH USA USA (1) 916 933 1080
EIBACH 01455 285850
EIBACH Germany (49) 2721 511220
GROUND CONTROL USA (1) 916 638 7888
HYPERCOILS USA (1) 574 753 6622
HERBERT TERRY 01527 64261
PERFORMANCE SPRINGS 01253 716900
WOODHEAD 0113 2441202

DAMPERS

DTM CONSULTANTS UK 01865 407726
DYNAMIC SUSPENSIONS 01842 755744
PROFLEX UK 01200 442345
GROUND CONTROL USA (1) 916 638 7888
JRZ SUSPENSION -314 02619155
MONROE AUTO EQUIPMENT 01904 631441
MORRIS DAMPERS INC USA (1) 586 826 9141
MOTON Netherlands (31) 413 259838
OHLINS RACING UK 0208 974 1615
PENSKE RACING SHOCKS USA (1) 215 375 6180
UK 01827 288328
ROEHRIG USA (1) 336 431 1827

RODS & ROD-ENDS

AURORA BEARING CO USA (1) 630 859 2030

ABC AUTOSPORT BEARINGS - COMPONENTS
Tel : +44(0)1932 225777 Fax : +44(0)1932 222225
Unit 3 Shepperton Business Park
Shepperton, Middlesex TW17 8AA

FASTENER FACTORY 01327 311018
GOLDLINE BEARINGS 01952 292401
GROUND CONTROL USA (1) 916 638 7888
KINSLER USA (1) 810 362 1145
RESB INTERNATIONAL 0208 390 8076
ROSE BEARINGS 01522 500933
SPECIALITY FASTENERS 01803 866371

SEALS

SPECIALITY FASTENERS 01803 866371
WALTHER 01442 891929

STRUT BRACES

DEMON TWEEKS 01978 664466
EIBACH Germany (39) 2721 5110
UK 0455 282850
USA (1) 714 727 3700
FASTENER FACTORY 01327 311018
OHLINS RACING UK 0208 974 1665

2.6 Braking Systems

ALCON COMPONENTS 01827 312500
AP RACING 02476 639595
ATE 0208 654 8836
CARBONE INDUSTRIE France (33) 0472 355700

CIRCUIT SUPPLIES (U.K.) LTD
CIRCUIT SUPPLIES (UK) LTD Tel 01525 385888
Fax 01525 385898
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Web: www.circuitsupplies.com
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
DELPHI BRAKE SYSTEMS 01926 472472
EBC BRAKES 01604 583144
ENDLESS BRAKES Japan (81) 267 68 0071

brembo

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Tel: 01908 220777
Email: info@grandprixwear.com
Web: www.grandprixwear.com
Unit 3 Fitzhamon Court, Featherstone Road, Wolverton Mill, Milton Keynes MK12 6LB
GOODRIDGE UK 01392 369090
USA (1) 310 533 1924 USA (1) 317 244 1000 USA (1) 704 662 9095
MOSA FREIN Belgium (32) 81 73 32 71

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PERFORMANCE FRICTION (1) 800 521 8874
EUROPE +44 (0) 1280 843 390

Redline MOTORSPORT

REDLINE MOTORSPORT Tel 01606 737500
Fax 01606 737683
E-mail info@redlinemotorsport.co.uk
WILWOOD ENG USA (1) 805 388 1188

2.7 Brake Components

CALIPERS

ALCON COMPONENTS 01827 312500
AP RACING 02476 639595
BREMBO Italy (39) 035 605111
UK 02476 659168
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
GKN SQUEEZEFORM 01952 244321
PERFORMANCE FRICTION USA (1) 803 222 2141
01280 843390
EUROPE +44 (0) 1280 843 390
PROFESSIONAL M/SPORTS 01626 332289
QINETIQ 08700 100942
RACE BRAKES New Zealand (64) 9377 2000
TAR.OX Italy (39) 039 5787814
WILWOOD USA (1) 805 388 1188

DISCS

ALCON COMPS 01827 312500
AP RACING 02476 639595
ATE 020 8654 8836
BREMBO Italy (39) 2 240 9631
UK 01280 700664
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
CARBONE INDUSTRIE France (33) 0472 355700

HAWK PERFORMANCE

GRANDPRIX RACEWEAR
Tel: 01908 220777
Email: info@grandprixwear.com
Web: www.grandprixwear.com
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PERFORMANCE FRICTION USA (1) 803 222 2141
EUROPE +44 (0) 1280 843 390
MARDI GRAS M/SPORTS 01327 858 006
RAYBESTOS USA (1) 815 363 9000
TAR.OX Italy (39) 039 5787814
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

FLUIDS

ALCON COMS 01827 312500
AP RACING 02476 639595
BENDIX France (33) 14 972 2305
UK 01942 723828
CASTROL 01793 512712
CASTROL Malaysia (603) 245 2642
CASTROL USA (1) 305 270 9433
CASTROL USA (1) 973 305 3912
PERFORMANCE FRICTION USA (1) 803 222 2141
01280 843390
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

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ALCON COMPS 01827 312 500
AP RACING 02476 639595
BT BRAKE TECHNOLOGY Germany (49) 6003 829119
USA (1) 239 772 4261
CARBONE INDUSTRIE France (33) 14 972 2305

Carbon Metallic®
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EUROPE +44 (0) 1280 843 390
EBC BRAKES 01604 583344
ENDLESS BRAKES Japan (81) 267 68 0071
FERODO 01298 812520
FGR 01885 400639
MINTEX 01274 854000
PAGID MOTORSPORTS USA (1) 941 772 4261
PERFORMANCE FRICTION USA (1) 803 222 2141
01280 843390
RAYBESTOS USA (1) 815 363 9000
TAR.OX Italy (39) 039 5787814
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

VALVES

ALCON COMPS 01827 312 500
AP RACING 02476 639595
TILTON USA (1) 805 688 2353
WILWOOD USA (1) 805 388 1188

2.8 Wheels

DYMAG RACING UK 01249 655481
HILLGARD Sweden (46) 300 60590
KINESIS MOTORSPORT USA (1) 760 598 5300
MOMO Italy (39) 0276 111072
SPARCO Italy (39) 011 470 2343

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CO-ORD SPORT 01384 216102
DUNLOP 0121 306 6000
Australia (61) 330 50333
Ireland (353) 178 3599

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Fax Canada (1) 902 2282241
Email vintyre@aol.com
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GOODYEAR Germany (49) 2234 82031
USA (1) 216 796 2121
Canada (1) 416 684 7418
MICHELIN 01782 402384
France (33) 73 90 77 341
TOYO 01933 411144
YOKOHAMA 01582 633339
Japan (81) 33 432 7111

2.10 Fuels & Lubricants

AGIP Italy (39) 65 9981
BP 01442 232323
BURMAH 01793 511521
PETROCHEM CARLESS 01372 380532
CASTROL 01793 512712
CASTROL Malaysia (603) 245 2642
CASTROL USA (1) 305 270 9433
CASTROL USA (1) 973 305 3912
CENTURY 01782 202521
DUCKHAMS OILS 0208 290 0600
ELF France (33) 1 4744 4546
UK 0208 902 8820
ESSO UK 01372 222000
MILLERS OILS 01484 713201
QINETIQ 08700 100942
RED LINE OILS 01476 861195
REPSOL Spain (34) 91 456 53 00
UK 0207 581 1933
SLICK 50 UK 0116 2881522
USA (1) 713 932 9954
STP USA (1) 305 771 1010
UK 01488 682655
TECH-LINE USA (1) 919 480 0905
TEXACO UK 0207 719 3000
VALVOLINE USA (1) 606 264 7222

Database 3
ENGINE & TRANSMISSION COMPONENTS

3.1 Engine Components

BEARINGS

BRITISH TIMKEN 01604 730047
CONNAUGHT 01795 843802
FASTENER FACTORY 01327 311018
RESB 0121 520 8271
QINETIQ 08700 100942
QUAIFE ENGINEERING 01732 351747
VANDERVELL 01788 538500

BLOCKS

INTEGRAL POWERTRAIN 01908 278600
PERFORMANCE CONNAUGHT 01795 843802
MILLINGTON 01746 789268
STONE FOUNDRIES 020 8853 4648
TREMELLING PATTERN 01494 533897

CAMSHAFTS

AUTOSPRINT 01675 464857
CAT-CAMS Belgium (32) 3 320 2560
COMPETITION CAMS USA (1) 901 795 2400
CONNAUGHT 01795 843802
CROWER USA (1) 619 422 1191
DAVID NEWMAN 01689 857109
SBD MOTORSPORT 0208 391 0121
DUNNELL ENGINES 01449 677726
FGR 01885 400639
HARROP Australia (61) 3 9499 7433
KATECH USA (1) 313 791 4120
KENT CAMS Tel 01303 248666
KENT CAMS BY JT FRANCE (33) 3207 46480
LUNATI USA (1) 901 365 0950
PAD RACING New Zealand (64) 3 3386 288

PIPER CAMS

PIPER CAMS Tel 01233 500200
Fax 01233 500300
www.pipercams.co.uk
2 St. John's Court, Ashford Business Park, Ashford, Kent, TN24 0SJ
QUAIFE ENGINEERING 01732 351747
SWINDON RACING ENGINES 01793 531321
TWR ENGINES 01993 871000
ULTRADYNE USA (1) 601 349 4447

CAMSHAFT DRIVES

CONNAUGHT 01795 843802
DAVID BROWN 01484 422180
SBD MOTORSPORT 0208 391 0121
KENT CAMS 01303 248666
PIPER CAMS 01233 500200
QUAIFE ENGINEERING 01732 351747
SWINDON RACING ENGINES 01793 531321

CONRODS

ARIAS FORGED PISTONS USA (1) 310 532 9737
ARROW PRECISION 01455 234200
ATECH MOTORSPORTS USA (1) 330 630 0888
CLARENDON ENG 01455 841200

ARROW

ARROW PRECISION ENGINEERING LTD
Tel +44 (0) 1455 234200
Fax +44 (0) 1455 233545
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Email: enquiries@arrowprecision.co.uk
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CARILLO IND. USA (1) 949 498 1800
CONNAUGHT 01795 843802
CO-ORD SPORT 01384 216102
CROWER USA (1) 619 422 1191
SBD MOTORSPORT 0208 391 0121
ENGINES & DYNO SERVICES 01708 857108
FARNDON ENG 02476 366910
MANLEY PERFORMANCE USA (1) 732 905 3366
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PANKL Austria (43) 3862 512500

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Fax: +33(0)320746489
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Website: www.jacquemintuning.com
SAENZ USA (1) 305 717 3422
SCHRICK Germany (49) 21 91 9500
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Fax: (1) 805 650 0742
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Fax +44 (0) 1455 233545
Website www.arrowprecision.co.uk
Email: enquiries@arrowprecision.co.uk
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BLANC AERO France (33) 296 68 33 39
CARRILLO INDUSTRIES USA (1) 949 498 1800
COAST FABRICATION USA (1) 714 842 2603)
COSWORTH 01604 752444
USA (1) 310 534 1390
CROWER USA (1) 213 543 1390
SBD MOTORSPORT 0208 391 0121
LINREAD NORTHBRIDGE MOTORSPORT
Tel 01162 572924 Fax 01162 572901
Viking Road, Wigston, Leicester, LE18 2BL
PANKL Austria (43) 386 251 2500
ATECH MOTORSPORTS USA (1) 330 630 0888

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Fax: +44 (0)1384 216109
Email: sales@coordsport.com
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DKE 01455 273738
EAGLE USA (1) 901 345 5886
FARNDON ENG 02476 366910
GRAINGER & WORRALL 01902 324460
LAYSTALL ENGINEERING 01902 451789

NORTHBRIDGE MOTORSPORT

LINREAD NORTHBRIDGE MOTORSPORT Tel 01162 572924
Fax 01162 572901
Viking Road, Wigston, Leicester, LE18 2BL
MILLINGTON 01746 789268
SWINDON RACING ENGINES 01793 531321

CRANKSHAFTS

CUSTOM CRANK Tel: 01902 422144
Fax: 01902 422133
Web: www.customcrank.co.uk
Email: markhenry.rigg@btinternet.com
THE CRANKSHAFT PEOPLE

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VIBRATECH USA (1) 716 895 8000

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ARROW PRECISION ENGINEERING LTD
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Fax +44 (0) 01455 233545
COMPTECH USA USA 001 916 933 1080
FARNDON ENG 02476 366910
HARROP Australia (61) 39 499 7431
KAITEN PRODUCTS USA (1) 714 220 2227
QUARTERMASTER USA (1) 847 540 8999
SWINDON RACING ENGINES 01793 531321

GASKETS

COMETIC BY JT FRANCE (33) 03207 46480
GOETZE Germany (49) 221 21 74690
GORE-TEX USA (1) 410 392 3200

HEADS

INTEGRAL POWERTRAIN 01908 278600
DUNNELL ENGINES 01449 677726
KENT AEROSPACE 01795 415000

INJECTORS

ASNU 0208 420 4494
HOLLEY PERFORMANCE USA (1) 502 781 9741
KINSLER USA (1) 810 362 1145
KS MOTORSPORT Germany (49) 2271 44905
MARREN USA (1) 203 732 4565

INTAKE MANIFOLDS

SBD MOTORSPORT 0208 391 0121
DUNNELL ENGINES 01449 677726
EDELBROCK USA (1) 310 781 2222
GRAINGER & WORRALL 01902 324460

JENVEY DYNAMICS 01746 768810
KINSLER USA (1) 810 362 1145
LINGENFELTER USA (1) 219 724 2552
SCHRICK Germany (49) 21 91 9500
SWINDON RACING ENGINES 01793 531321

LINERS

AE PISTONS 01274 729595
APPERLEY HONING 01242 525868
CROMARD 01902 451789
DATRON SLEEVES USA (1) 760 603 9895
GOETZE Germany (49) 217 4690
GKN SQUEEZEFORM 01952 244321
LAYSTALL ENG 01902 451789
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PISTONS

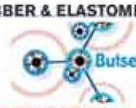
ACCRALITE PISTONS Tel 0121 525 6450
Fax 0121 553 5951
Accralite Piston Division, Spon Lane South, Smethwick, West Midlands B66 1QJ
AE PISTON PRODUCTS 01274 729595
ARIAS 01401 784022
ARIAS FORGED PISTONS USA (1) 310 532 9737
BATTEN PERFORMANCE USA (1) 313 946 9850
CONNAUGHT 01795 843180
COSWORTH 01604 752444
USA (1) 310 534 1390
HEPWORTH & GRANDAGE 01274 729595
JE PISTONS USA (1) 714 898 9763
MALVERN RACING USA (1) 804 971 9668
MANLEY PERFORMANCE USA (1) 732 905 3366
OMEGA PISTONS 0121 559 6778
PAD RACING New Zealand (64) 3 3386 288
ROSS USA (1) 310 644 9779

ROSS PISTON STOCKISTS
Tel 01384 216102 Fax 01384 216109
Website: www.coordsport.com
Email: sales@coordsport.com
Kings Street, Dudley West Midlands DY2 8PX
SWINDON RACING ENGINES 01793 531321
TOTAL SEAL USA (1) 602 678 4977
WISECO PISTON USA (1) 216 951 6600
Canada 800 265 1029

PISTON RINGS

AE PISTON PRODUCTS 01274 729595
ARIAS FORGED PISTONS USA (1) 310 532 9737/1900
CORDS PISTON RING 0208 998 9923
FORD AUTO ENG USA (1) 805 2983785
GOETZE Germany (49) 221 217 4690
HI-TECH USA (1) 801 972 8766
TOTAL SEAL USA (1) 602 678 4977
TWR ENGINES 01993 871000

RUBBER & ELASTOMERIC COMPONENTS



BUTSER RUBBER LTD Tel: 01730 894034 / Fax: 01730 894344
Website: www.butserrubber.com
Email: butserrubber@btinternet.com
Mint Road, Liss, Hampshire GU33 7BQ

VALVES

DEL WEST ENG USA Tel: (1) 661 295 5700
Fax: (1) 661 295 8300
28128 West Livingston, Valencia CA 91355, USA
FERREA USA (1) 954 733 2505
GGS VALVES LTD 01483 415444
QINETIQ 08700 100942
MANLEY PERFORMANCE USA (1) 732 905 3366
RACING ENGINE VALVES USA (1) 954 772 6060
SCHRICK Germany (49) 21 91 9500
SUPERTECH PERFORMANCE USA (1) 408 448 2001
SWINDON RACING ENGINES 01793 531321
VALVE TECHNICS 01604 706541
XCELDYNE TECHNOLOGIES USA (1) 336 472 8281

VALVE SEATS

ARROW PRECISION ENGINEERING LTD
Tel +44 (0) 1455 234200
Fax +44 (0) 1455 233545
CHE PRECISION INC Tel (1) 805 499 8885
Fax (1) 805 499 7810
2640 Lavery CT,Unit C, Newbury Park, CA91320, USA
SERDI 01895 232215
SWINDON RACING ENGINES 01793 531321

VALVESPRINGS

CONNAUGHT 01795 843802
DIAMOND USA (1) 313 792 6620
EDELBROCK USA (1) 213 781 2222
HERBERT TERRY & SONS 01527 64261
KENT CAMS 01303 248666
KURT KAUFFMANN Germany (49) 711 518300
MANLEY PERFORMANCE USA (1) 732 905 3366
PERFORMANCE SPRINGS 01253 716900
SCHMITTHELM Germany (49) 62 217660

VALVE SPRING RETAINERS

GGS VALVES LTD 01483 415444

VALVE GUIDES

ARROW PRECISION ENGINEERING LTD
Tel +44 (0) 01455 234200
Fax +44 (0) 01455 233545
KAITEN PRODUCTS USA (1) 714 220 2227
SERDI 01895 232215

3.2 Engine Ancillaries

AIR FILTERS

INDUCTION TECH GROUP Tel 02476 305386
Fax 02476 307999
Unit B, Quinn Close, Seven Stars Industrial Estate, Whitley, Coventry CV3 4LH
K&N ENGINEERING USA 800 858 3333
K&N FILTERS (EUROPE) UK 01925 636950
KINSLER USA (1) 248 362 1145
PIPERCROSS 01604 671100

CARBURETTORS

BG FUEL SYSTEMS USA (1) 706 864 8544
CARBURETOR SHOP USA (1) 909 481 5816
SOLEX France (33) 14 729 7171
WEBER Italy (39) 51 417995
WEBCON 01932 787100

EXHAUST SYSTEMS

ACTIVE ENGINEERING USA (1) 714 637 1155
BURNS STAINLESS USA (1) 949 631 5120

GDS EXHAUSTS Tel: 01280 702510 / Fax: 01280 705225
Email: sales@gds-exhausts.co.uk
Website: www.gds-exhausts.co.uk
Unit 8C Boundary Road, Brackley NN13 7ES

GOOD FABRICATIONS LTD
Tel: +44 (0)1844 202850 / Fax:(0)1844 202833
Email: info@goodfabs.com www.goodfabs.com
Unit 3a, Drakes Farm, Drakes Drive, Long Crendon, Aylesbury, Bucks HP18 9BA England
FLOWMASTER USA (1) 616 463 4113
JETEX EXHAUSTS 01789 298989
MARK ORTIZ USA (1) 715 835 3291
PIPER CAMS 01233 500200
SPECIALISED EXHAUST 0208 648 4786

FUEL FILTERS

AN MOTORSPORT DESIGN 01628 776320
CONNAUGHT 01795 843802
EARL'S PERFORMANCE UK 01327 858221
Fax 01327 858473
Unit 17 Silverstone Circuit, Towcester, Northamptonshire NN12 8TL, England
ED PINK RACING ENGINES USA 818 785 6740
EXACT ENGINEERING 01803 866464
FHS MOTOR RACING 01753 513080
FLUID CONTROL PRODUCTS INC USA (1) 217 324 3737
FRAM EUROPE 01443 223000
KINSLER USA (1) 248 362 1145
LEE PRODUCTS 01753 886664
SPV RACING Australia (61) 2 791 9899
THINK AUTOMOTIVE 0208 568 1172
TJ FILTERS 01752 667675
WEBCON 01932 787100

FUEL INJECTION

AC ROCHESTER USA (1) 716 359 6361
ASNU Tel 0208 420 4494
BGC MOTORSPORT 0208 880 4205
BOSCH 01895 834466
Germany (49) 711 811
USA (1) 312 865 5200
CONNAUGHT 01795 843802
SBD MOTORSPORT 0208 391 0121
FLUID CONTROL PRODUCTS Tel (1) 314 291 7223
GENESIS ELECTRONIC SYSTEMS 01635 582255
INDUCTION TECHNOLOGY 02476 305386
JENVEY DYNAMICS 01746 768810
JOHN WILCOX COMPETITION 01455 230576

KINSLER FUEL INJECTION Tel: USA (1) 248 362 1145
Fax: USA (1) 248 362 1032
Email: kinsler@kinsler.com Website: www.kinsler.com
LINGENFELTER USA (1) 219 724 2552
MAGNETI MARELLI Italy (39) 2 648 351
MM COMPETITION SYSTEMS 08707 444666
MARREN USA (1) 203 732 4565
MILLINGTON 01746 789268
MOTEC Australia (61) 3 9761 5050
MOTEC (EUROPE) UK 08700 119100
MOTEC JAPAN Japan (81) 489 46 1734
MOTEC SYSTEMS USA USA (1) 714 897 6804
NIPPON DENSO Japan (81) 56 625 5511
UK 0208 591 7700
PECTEL CONTROL SYSTEMS +44 (0)1954 253810
SAKATA MOTORSPORT ELEC. INC. (714) 446 9473
TWM INDUCTION USA (1) 805 967 9478

FUEL LINES

AEROQUIP USA (1) 419 238 1190
AN MOTORSPORT DESIGN 01628 776320

ATL USA (1) 201 825 1400
Fax (1) 201 825 1962
Aero Tec Laboratories Inc, Spear Road Industrial Park, Ramsey, NJ 07446-1221, USA
ATL UK 01908 351700 / Fax 01908 351750
Aero Tec Laboratories Ltd (Europe), 1 Patriot Drive, Rooksley, Milton Keynes, MK13 8PU
BROWN AND MILLER UK 01753 553610
USA 704 793 4319
CONNAUGHT 01795 843180
EXACT ENGINEERING 01803 866464
FAE MACHINE USA 317 243 3092
FLEXOLITE 01684 891898
FUEL SAFE UK 01799 541955
USA (1) 714 842 2211
GOODRIDGE CA USA (1) 310 533 1924
GOODRIDGE INDY USA (1) 317 244 1000
GOODRIDGE EAST USA (1) 704 662 9095

GOODRIDGE UK Tel 01392 369090 / Fax 01392 441780
Exeter Airport Business Park, Exeter, EX5 2UP
HENRY'S ENG USA (1) 410 535 3142
JLS MOTORSPORT Tel 0121 525 7733

KRONTEC MASCHINENBAU Gmbh
Fitting & Hose Systems
Pommernstraße 33 93073 Neutraubling
Tel: 09401 5253-0
Fax: 09401 5253-10
KS MOTORSPORTS Germany (49) 2271 44905
PRONAL'S France (33) 320 99 75 10
SPECIALTY FASTENERS 01803 866371
SPV RACING Australia (61) 2 791 9899
THINK AUTOMOTIVE 0208 568 1172
FLEXOLITE 01684 891898
GOODRIDGE 01392 369090
PRONALS France 33 3 20997510
RACETECH 01327 359912
WELDON RACING PUMPS USA (1) 216 232 2282

XRP INC Tel USA (1) 562 861 4765
FAX USA (1) 562 861 5503
5630 Imperial Highway, South Gate, CA 90280, USA

FUEL VALVES

AN MOTORSPORT DESIGN 01628 776320
ATL USA (1) 201 825 1400
UK 01908 351700
EXACT ENG 01803 866464
KINSLER USA (1) 248 362 1145
PRONALS France 33 3 20 997510
SPECIALTY FASTNERS 01803 866371

HOSES & HOSE-ENDS

AEROQUIP USA (1) 419 238 1190
AN MOTORSPORT DESIGN 01628 776320

BROWN AND MILLER UK Tel: 01753 553610
Fax: 01753 577477
Unit 7-7A, Langley House, Middle Green Trading Estate, Langley, SL3 6DF USA Tel: 704 793 4319
Fax: 704 793 4321
4005 Dearborn Place NW, Concord, NC 28027
DELPHI BRAKES SYSTEMS 01926 472472
EARL'S USA (1) 310 609 1602
EXACT ENG 01803 866464
FASTENER FACTORY 01327 311018
FHS MOTOR RACING 01753 570863
FLUID CONTROL PRODUCTS INC USA (1) 217 324 3737
Fax (1) 217 324 3717
GOODRIDGE UK 01392 369090
GOODRIDGE CA USA (1) 310 533 1924
GOODRIDGE INDY USA (1) 317 244 1000
GOODRIDGE EAST USA (1) 704 662 9095
HCL FASTENERS 01282 411992
HENRY'S ENG USA (1) 410 435 3142
JLS MOTORSPORT 0121 525 7733
KINSLER USA (1) 248 362 1145
SAMCO SPORT 01443 238464

SFS PERFORMANCE Tel: 01582 488040
Fax: 01582 412277
Website: www.sfsperformance.co.uk
Unit E Kingsway Industrial Estate, Kingsway Luton LU1 1LP
SPECIALTY FASTNERS 01803 866371
SPEED FLOW 0208 530 6664
THINK AUTOMOTIVE 0208 568 1172
UNICLIP AUTOMOTIVE 01932 355277
XRP INC USA (1) 562 861 4765

INTERCOOLERS

AH FABRICATIONS 01432 354704
FLUID CONTROL PRODUCTS INC USA (1) 217 324 3737
Fax (1) 217 324 3717
PACE PRODUCTS 01440 760960
SERCK MARSTON 0208 965 2151
SFS PERFORMANCE 01582 412 697

OIL COOLERS

AEROQUIP USA (1) 419 238 1190
CV PRODUCTS USA (1) 910 883 4096
DOCKING & CO 01372 857164
EARL'S USA (1) 310 609 1602
EXACT ENGINEERING 01803 866464
FAE MACHINE USA 317 243 3092
FLUID CONTROL PRODUCTS INC USA (1) 217 324 3737
Fax (1) 217 324 3717
GOODRIDGE UK 01392 369090
GOODRIDGE CA USA (1) 310 533 1924
GOODRIDGE INDY USA (1) 317 244 1000
GOODRIDGE EAST USA (1) 704 662 9095
LAMINOVA Sweden (46) 85 907 4045
PROCOMP 0121 350 3258
SECAN France (33) 14 790 6512
SERCK MARSTON 020 8965 2151
SETRAB Sweden (46) 40 158060
SPECIALTY FASTNERS 01803 866371
SPV RACING Australia (61) 2 791 98899
THINK AUTOMOTIVE 020 8568 1172
TREVOR MORRIS ENG 01547 530289

OIL FILTERS

AN MOTORSPORT DESIGN 01628 776320
COSWORTH 01604 752444
USA (1) 310 534 1390
EARL'S USA (1) 310 609 1602
ED PINK ENGINES USA 818 785 6740
EXACT ENGINEERING 01803 866464
FLEXIBLE HOSE 01753 570863
FRAM FILTERS 01443 223000
KINSLER USA (1) 248 362 1145

OIL PUMPS

ED PINK RACING ENGINES USA 818 785 6740
KENT CAMS 01303 248666
PACE PRODUCTS 01440 760960
PACET 01628 526754
SPV RACING Australia (61) 2 791 9899
SWINDON RACING ENGINES 01793 531321
TITAN MOTORSPORT 01480 474402

OIL SEALS

RACE-TEC NAK 02380 246986
PIONEER WESTON (WYKO) 0161 703 2011

OIL SUMPS

AH FABRICATIONS 01432 354704

A.R.E DRY SUMP SYSTEMS
USA: (1) 916 987 7629
www.drysump.com
CONNAUGHT 01795 843802
JENVEY DYNAMICS 01746 768810
MILODON USA (1) 818 407 1211
PACE PRODUCTS 01440 760960
STONE FOUNDRIES 0208 853 4648
SWINDON RACING ENGINES 01793 531321
TITAN MOTORSPORT 01480 474402
TREVOR MORRIS ENG 01547 530289

OIL TANKS

BS ENGINEERING 01908 618080
GARTRAC 01428 682263
GOMM METAL DEVELOPMENTS 01483 764876
KS MOTORSPORT Germany (49) 2271 44905
MIDAS METALCRAFT 01933 355512
PACE PRODUCTS 01440 760960
THINK AUTOMOTIVE 020 8568 1172

RUBBER & ELASTOMERIC COMPONENTS

BUTSER RUBBER LTD Tel: 01730 894034

STARTER MOTORS

ARK RACING 01785 715234
EARL'S USA (1) 310 609 1602
RTRAC Germany (49) 9725 5075
STARTLINE UK LTD 01933 665752

THROTTLE BODIES

JENVEY DYNAMICS 01746 768810
KINSLER USA (1) 248 362 1145
LINGENFELTER USA (1) 219 724 2552
LUMENITION 0207 493 4334
SWINDON RACING ENGINES 01793 531321
TWM INDUCTION USA (1) 805 967 9478

THROTTLE VALVES

JENVEY DYNAMICS 01746 768810
KINSLER USA (1) 248 362 1145
LUMENITION 0207 493 4334
TREVOR MORRIS ENG 01547 530289
TWM INDUCTION USA (1) 805 967 9478

TURBOCHARGERS

GARRETT AUTOMOTIVE 01695 22391
HOLSET ENG 01484 422244
INTERPRO ENGINEERING 01454 412777
QINETIQ 08700 100942
TURBO TECHNICS 01604 764005

WATER COOLERS

AH FABRICATIONS 01432 354704
DOCKING & CO 01327 857164
DENSO MARSTON 01274 582266
NIPPON DENSO Japan (81) 56 625 5511
UK 0208 591 7700
PACE PRODUCTS 01440 760960
SERCK MARSTON 0208 965 2151

WATER INJECTION

ERL 01273 581007

WATER PUMPS

DAVIES, CRAIG Australia (61) 39 499 7433
ED PINK RACING ENGINES USA 818 785 6740
EDELBROCK USA (1) 213 781 2222
TREVOR MORRIS ENG 01547 530289

3.3 Engine Electronics

COMPUTER SUPPLIERS

ACES	01206 395324
ADVANCED AUTOMOTIVE	01753 642019
COMPETITION DATA	USA (1) 716 631 2880
FUELTRONICS	Australia (61) 88363 2199
PAD RACING	New Zealand (64) 3 3386 288
PERFORMANCE TRENDS	USA (1) 248 473 9230
RACELOGIC	01280 823803

DATA-ACQUISITION

ACTIVE SENSORS	Tel 01202 480620 Fax 0120 24806641
ADVANCED AUTOMOTIVE	01753 642019
BGG RACING	USA (1) 602 274 2537
BOSCH	01895 834466 Germany (49) 711 8111 USA (1) 312 865 5200
COMPETITION DATA SYS	USA (1) 716 631 2880
COMPUTECH SYSTEMS	USA 800 870 8383
COMPUTERACE TIMING	01905 796090
CORSA INSTRUMENTS	USA (1) 313 761 1545
2D DEBUS	Germany (49) 721 944850
DATASPARES ACQUISITION	0208 463 9222
DATRON TECHNOLOGY	01908 261655
DIGICON ENGINEERING	Canada (1) 604 984 9437
FOREFRONT	USA (1) 404 448 9550

Intercomp

INTERCOMP	**USA Tel (1) 763 476 2531 Fax (1) 763 476 2613 14465 23rd Avenue N, Minneapolis, MN 55447, USA**
ISAAC INSTRUMENTS INC.	**Tel: (450) 658 7520 Fax: (450) 658 3322 Email: isaac@isaac.ca Website www.isaac.ca 25 Robert, Chamby, Quebec, Canada J3L 1S2**
LONGACRE	USA (1) 425 485 0620
McCLAREN ELECTRONICS	01483 261400
MM COMPETITION SYSTEMS	08707 444666
MOTEC	Australia (61) 3 9761 5050
MOTEC (EUROPE)	UK 08700 119100
MOTEC JAPAN	Japan (81) 489 46 1734
MOTEC SYSTEMS USA	USA (1) 714 897 6804
MOTECH	USA (1) 804 973 1399
MOTOR SPORT ELEC	Australia (61) 7 3290 1399
MOTORSPORTS INTERFACE	01327 311011
MTS Powertrain Tech	**Tel 01932 351516 Fax 01932 351517 7 Glen Court,Canada Road, Byfleet, Surrey KT14 7JL**
NIPPON DENSO	Japan (81) 56 625 6051
PECTEL CONTROL SYSTEMS	+44 (0)1954 253610
PENNY & GILES	01202 409409
PERFORMANCE TRENDS	USA (1) 248 473 9230
PI RESEARCH	**01954 253600**
POLY LOGIC	01462 620166
QINETIQ	08700 100942
QUANTUM SUSPENSION	01243 865058
RACE DATA ENGINEERING	USA (1) 714 449 1445
SAKATA MOTORSPORT ELEC. INC.	(714) 446 9473
STACK	**Tel 01869 240404 Fax 01869 245500 email: sales@stackltd.com Wedgewood Road, Bicester Oxfordshire, OX26 4UL**
STEVE BUNKHALL	01223 303025
VARIOHM	01327 351004

ENGINE MANAGEMENT SYSTEMS

ADVANCED AUTOMOTIVE	01753 642019
ASNU	0208 420 4494
BOSCH	01895 834466 Germany (49) 711 8111 USA (1) 312 865 5200
CONNAUGHT	01795 843802
DATASPARES	0208 463 9229
SBD MOTORSPORT	0208 391 0121
McCLAREN ELECTRONICS	01483 261400
MM COMPETITION	08707 444666

MoTeC

MOTEC PTY LTD	**Aus Tel: 613 9761 5050 Aus Fax: 613 9761 5053 Japan +81 489 461 734 121 Merringdale Drive Croydon South Victoria Australia UK: +44 8700 119100 USA +1 714 895 7001**
PECTEL CONTROL SYSTEMS	+44 (0)1954 253610
PRECISION RACE SERVICES	USA (1) 248 844 1060
SAKATA MOTORSPORT ELEC. INC.	(714) 446 9473
STACK	**01869 240404**
SUPERCHIPS	01280 816781
TERRY SHEPHERD TUNING	01695 574454
WALBRO ENGINE MANAGEMENT	**USA (1)989 872 7091**
ZYTEK SYSTEMS	0121 323 2323

ENGINE SENSORS

ACTIVE SENSORS	Tel 01202 480620 Fax 01202 480664 Unit 12, Wilverley Rd, Christchurch, Dorset, BH23 3RU England
AVL DEUTSCHLAND Gmbh Germany	(49) 6134 7179-0
DATASPARES	0208 463 9229
ENTRAN	01923 893 999
KISTLER INSTRUMENTS	01420 544477

kulite

KULITE SENSORS	**Tel 01256 460646 Kulite House, Stroudley Road, Basingstoke, RG24 8UG, England**
MAGCANICA INC	USA 858 454 8950
McCLAREN ELECTRONICS	01483 261400
THE STRAIN GAUGING CO	**01256 320666**
VARIOHM	01327 351004

REV-LIMITERS

LUCAS ELECTRICAL	0121 536 5050
LUMENITION	020 7403 4344
MM COMPETITION	08707 444666

3.4 Transmission Components

CLUTCHES

alcon

ALCON	**Tel +44 (0) 1827 723700 Fax +44 (0) 1827 723701 Email info@alcon.co.uk www.alcon.co.uk Apollo, Tamworth, Staffordshire B79 7TN**

AP RACING

AP RACING	**(0)24 7663 9595 Fax (0) 24 7663 9559 Wheler Road, Coventry, CV3 4LB**
FICHTEL & SACHS	0208 654 8835
GOODRIDGE	01392 369090
LOLA	Tel 01480 451301 Fax 01480 456722
QUARTER MASTER	USA (1) 847 540 8999 Fax (1) 847 540 0526 510 Telser Road, Lake Zurich, IL 60047, USA
SUPER CLUTCH	UK 01926 812136
RTRAC	Germany (49) 9725 5075

SACHS RACE ENGINEERING

SACHS RACE ENGINEERING GmbH	**Tel +49 9721-984300 Fax +49 9721-984299 Email service.sre@sachs.de Website www.sachs-race-engineering.de Ernst-Sachs-Strasse 62, 97424 Schweinfurt, Germany**
SACHS BOGE	UK 01788 822353
TILTON ENGINEERING	USA (1) 805 688 2353 Fax (1) 805 688 2745 25 Easy Street, Buellton, CA 93427 USA
WILWOOD ENGINEERING	Fax (1) 805 388 4938 USA (1) 805 388 1188 436 Calle San Pablo, Camarillo, CA 93012, USA

COMPLETE TRANSMISSIONS

RICARDO

RICARDO MIDLANDS TECHNICAL CENTRE	**Tel: 01926 319399 Fax: 01926 319352 Email: rastimmonds@mtc.ricardo.com Website: www.ricardo.com Southam Road, Radford Semele, Leamington Spa CV31 1FQ**

CWP'S

DAVID BROWN	01484 422180
DTS	USA (1) 313 778 0540
JCM TRANSAXLES	USA (1) 303 695 6093
MARK BAILEY RACING	01380 850130
XTRAC LTD	**01635 293800**

DIFFERENTIALS

AJEC INDUSTRIES	01242 222739
GEARACE LIMITED	01869 277563
GKN AXLES	0207 930 2424
HEWLAND ENG	01628 827600
JCM TRANSAXLES	USA (1) 303 695 6093
MARK BAILEY RACING	01380 850130
QUAIFE ENGINEERING	01732 741144
RICARDO	01273 455611
RICARDO MIDLANDS TECHNICAL CENTRE	01926 319399
TOM'S DIFFERENTIALS	USA (1) 310 634 8431
TRAN-X GEARS LTD	02476 659061
XTRAC LTD	**01635 293800**
ZEXEL-GLEASON	USA (1) 716 464 5000

DRIVESHAFTS

TORQline CTG Composite Driveline Products

CTG	**Tel: +44 (0)1295 220130 Fax: +44 (0)1295 220138 Email: motorsport@ctgltd.co.uk www.ctgltd.co.uk Thorpe Park, Thorpe Way, Banbury, Oxfordshire OX16 4SU United Kingdom**

GKN Motorsport

GKN MOTOR SPORT	**Tel 0121 313 1661 Fax 0121 313 2074 Unit 5, Kingsbury Business Park, Kingsbury Road, Minworth, Sutton Coldfield, Birmingham B76 9DL, England**
METALORE	USA (1) 310 643 0360
PANKL	0043 3862 33999
TEX RACING	USA (1) 910 428 9522
TRAN-X GEARS LTD	02476 659061

GEARS

B&M

BGM	**001 818 882 6422 www.bmracing.com Chatsworth CA 91311 USA**
COLLEDGE & MORLEY	02476 462328
COMPTECH USA	USA (1) 916 933 1080
DAVID BROWN	01484 422180
GEARACE LIMITED	01869 277563
HEWLAND ENG	01628 827600
JCM TRANSAXLES	**USA (1) 303 695 6093**
KERSCHBAUMER	**Ger (49) 6074 47 663**
MARK BAILEY RACING	01380 850130
PANKL	0043 3862 33999
TEX RACING	USA (1) 910 428 9522
RICARDO MIDLANDS TECHNICAL CENTRE	01926 319399
TRAN-X GEARS LTD	02476 659061
XTRAC LTD	01635 293800

UNIVERSAL JOINTS

FLAMING RIVER	USA (1) 440 826 4488
GEARACE LIMITED	01869 277563

4.1 Factory Hardware

AIR LINES & FITTINGS

A.N. MOTORSPORT DESIGN	01628 776320
EARL'S	**UK 01327 858221**
EXACT ENGINEERING	**01803 866464**
Fhs Motor Racing Ltd	**01753 513080**
GOODRIDGE UK	**01392 369090**
GOODRIDGE CA	USA (1) 310 533 1924
GOODRIDGE INDY	USA (1) 317 244 1000
GOODRIDGE EAST	USA(1) 704 662 9095
INGERSOLL RAND	01204 690690
JLS MOTORSPORT	**0121 525 7733**
KRONTEC	**Germany (49) 9401 703062**
REGENT	01908 612602
ROTOTEST	Sweden 46 8512 55890
THINK AUTOMOTIVE	0208 568 1172

AIR TOOLS

DESOUTTER AUTOMOTIVE	0208 205 4884

paoli AVVITATORI

DINO PAOLI S.R.L.	**Tel: +390 522 300828 Fax: +390 522 304864 email: info@dinopaoli.com Website: www.dinopaoli.com Via Guido Dorso, 542100, Reggio Emilia, Italy**
FACOM	01932 566099
INGERSOLL RAND	01204 690690
JLS MOTORSPORT	0121 525 7733

CNC MACHINING CENTRES

ABSOLUTE MACHINE TOOL	USA (1) 440 324 5333
BOSTON DIGITAL	USA (1) 508 473 4561
BRIDGEPORT MACHINE	USA (1) 248 299 1750
DEREK ROBINSON	0116 266 2222
DEWCO	USA (1) 765 962 7201
MACHINERY SALES	USA (1) 510 490 4000
MAKINO	USA (1) 800 552 3288
MEDDINGS MACHINES	01752 893277
MILLS ENGINEERING	01603 745531
MILLSITE ENGINEERING	USA (1) 304 273 5353
RGS PERFORMANCE	USA (1) 716 434 2509
RMT MECHATRONICS	01565 650411
SERDI	**01895 232215**
SOUTHWESTERN IND	USA (1) 310 608 4422
SPA AEROFOILS LTD	01827 260026
TGS	USA (1) 940 668 1002
TOYODA EUROPE	02476 547200

CRACK DETECTION

ABS PRODUCTS	USA (1) 714 671 0728
DCM TECH	USA (1) 800 533 5339
KRAUTKRAMER BRANSON	USA (1) 717 242 0327

CRYOGENIC TEMPERING

FROZEN SOLID	01449 674914

DUST EXTRACTION EQUIP

DENCER	01789 470198

DYNAMOMETERS: CHASSIS

FROUDE CONSINE	01905 856800 **International Dynamometers LTD/Dynapack USA 001 559 292 3800 New Zealand 64 4587 0484**
LAND & SEA	USA (1) 603 329 5645
KISTLER Instruments Ltd	01420 544477
ROTOTEST	Sweden (46) 8 532 55890
SUPERFLOW	USA (1) 800 471 7701 Belgium 3215 216300
UNICO (UK) LTD	01908 260000

DYNAMOMETERS: DAMPER

BEHRENTS SPEED CENTER	USA (1) 914 651 7389
CZECH MATE	USA (1) 800 819 7223
DYNAMIC SUSPENSIONS	**Can (1) 905 470 8778 UK 01842 755744**
ND TECH SHOCK DYNOS	USA (1) 520 624 3907
SCHMITT EUROPE	UK 02476 697192
SPA DESIGN	**01827 260026**
SPA TECHNIQUE	**USA (1) 317 271 7941**
TAT	Germany (49) 7252 84258

DYNAMOMETERS: ENGINE

AVL	Germany (49) 61 34 71 790
DSP TECHNOLOGY	01932 351516
DYNAMIC TEST SYSTEMS	01842 755744
ENGINE & DYNAMOMETER	**01708 857108**
FROUDE CONSINE	01905 856800
JKM AUTOMOTIVE	USA (1) 508 966 2531
LAND & SEA	USA (1) 603 329 5645
LOTUS ENGINEERING	01953 608000
MOTORSPORTS INTERFACE	01788 890412
TAT	**Germany (49) 7252 84258**

DYNAMOMETER INSTRUMENTATION

AQUIRED DATA SYSTEMS	USA (1) 810 566 0131
DEPAC DYNO SYSTEMS	USA (1) 315 339 1265
DYNOLAB	USA (1) 206 243 8877
FROUDE CONSINE	01905 856800
LAND & SEA	USA (1) 603 329 5645
KISTLER Instruments Ltd	01420 544477
PERFORMANCE TRENDS	**USA (1) 248 473 9230**
QUADRANT SCIENTIFIC	**USA (1) 303 666 8414**
ROEHRIG ENGINEERING	**USA (1) 336 431 1827**
SUPERFLOW	USA (1) 800 471 7701 Belgium 3215 216300
TAT	Germany (49) 7252 84258

ENGINE BALANCING EQUIP

ABS PRODUCTS	USA (1) 714 671 0728
BC GEROLAMY	USA (1) 916 638 9008
POWERHOUSE PRODUCTS	USA 800 872 7223
SCHMITT EUROPE	02476 697192
SUNNEN PRODUCTS	USA (1) 800 772 2878
WINONA VAN	Canada (1) 800 833 4870

ENGINE HOISTS

MR GASKET PERFORMANCE	USA (1) 216 398 8300
SILVER SEAL	USA (1) 800 521 2936

ENGINE STANDS

ABS PRODUCTS	USA (1) 714 671 0728
BLUEBIRD	USA (1) 800 808 2473
C-LINE	USA (1) 800 645 7267
DYNAMIC TEST SYSTEMS	USA (1) 800 243 3966
GOODSON	**USA (1) 507 452 1830**
JEGS	USA (1) 614 294 5451
MOROSO PERFORMANCE	USA (1) 203 453 6571
MR GASKET PERFORMANCE	USA (1) 216 398 8300
RACER COMPONENTS	USA (1) 903 581 5976
SCRIBNER	USA (1) 916 638 1525

FLOW BENCHES

ASNU	0208 420 4494
AUDIE TECHNOLOGY	USA (1) 610 630 5895
CV PRODUCTS	USA (1) 800 448 1223
CLO-FLOW	South Africa (27) 11 9631128
DEPAC DYNO SYSTEMS	USA (1) 315 339 1265
FLOWDATA	USA (1) 714 632 7828
HODGE MFG	USA (1) 800 262 4634
PERFORMANCE TRENDS	USA (1) 248 473 9230
ROEHRIG ENGINEERING	USA (1) 336 431 1827
SUPERFLOW	USA (1) 800 471 7701 Belgium 3215 216300
TAT	Germany (49) 7252 84258

GENERATORS: PORTABLE

HANCO GENERATING	USA (1) 800 413 6688
LINCOLN ELECTRIC	USA (1) 216 481 8100

HORIZONTAL/VERTICAL MACHINING CENTRES

MAKINO	USA (1) 800 552 3288
MILLS	01603 745531
MITSUBISHI-YAMAZEN	0208 549 9161
RGS PERFORMANCE	USA (1) 716 434 2509
TOYODA	02476 547200

LATHES

RMT MECHATRONICS	01565 650411
LOCK-N-STITCH	USA (1) 800 736 8261
MAGNAFLUX	USA (1) 847 657 5300
THE STRAIN GAUGING CO	**01256 320666**

RAPID PROTOTYPING

CRP TECHNOLOGY	Italy (39) 059 821135
3D SYSTEMS	UK 01442 282600

TOOL CABINETS

DURA	01295 712800

GWS SYSTEMS

GWS Systems Oy **Tel: 01403 276445**
Fax: 01403 276434
Email: sales@gwssystems.co.uk
Website: gwssystems.co.uk
Units 10-12 Horsham Court, City Business Centre, 6 Brighton Road, Horsham, West Sussex RH13 5BA

LISTA	01908 222333
MAC TOOLS	USA (1) 614 755 7000

WELDING EQUIPMENT

AMILLER ELECTRIC MFG	USA (1) 800 426 4553

4.2 Factory Software

CAD & CAM SOFTWARE

BRIDGEPORT MACHINE	USA (1) 248 299 1750
DASSAULT SYSTEMES	USA (1) 818 673 2134
DELCAM	0121 766 5544
EXA	USA (1) 781 676 8551
MITUTOYO UK	01264 353123
PARAMETRIC TECHNOLOGY	01252 817000
QinetiQ	08700 100942

PARTS USE LIFING

ADVANCED RACING SYSTEMS	USA (1) 513 893 2773
LIFECHECK	01285 720665
KINETIC RACING TECHNOLOGIES	USA (1) 248 245 2130
NOSKECOMP	Australia 07 32 88 3895

PERF. SIMULATION

D.A.T.A.S	01603 506526
PI RESEARCH	01954 253600
PERFORMANCE TRENDS	USA (1) 248 473 9230
RICARDO	USA (1) 734 397 6666
SERVOTEST	0208 707 1400
VEHICLE DYNAMICS PERFORMANCE	USA (1) 512 450 1035

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CIRCUIT EQUIPMENT

5.1 Pits Equipment

AIR COMPRESSORS

COMPAIR UK	01494 465000
COMPAIR UK	01473 602222
ROTOTEST	**Sweden 46 8532 55 890**

AIR LINES & FITTINGS

EXACT ENGINEERING	**01803 866464**
FASTENER FACTORY	**01327 311018**
FHS Motor Racing Ltd	01753 513080
GOODRIDGE	**UK 01392 369090**
GOODRIDGE CA	**USA (1) 310 533 1924**
GOODRIDGE INDY	**USA (1) 317 244 1000**
GOODRIDGE EAST	**USA (1) 704 662 9095**
JLS MOTORSPORT	**0121 525 7733**
KRONTEC	Germany (49) 9401 703062
	Fax (49) 9401 70 24 76
	Berliner Straße 31, 93073 Neutraubling, Germany
MOTORSPORTS NZ	NZ 0064 2596 5599
THINK AUTOMOTIVE	0208 568 1172

BATTERY CHARGERS

POWER TRANS SOLUTIONS	**-Tel 01722 332126**
	Fax 01722 333 522
	www.wynall.com
	Stephens Road, Church Fields
	Salisbury, Wiltshire, FP2 7NX
TRIDENT	01327 857822

CAMBER GAUGES

DEMON TWEEKS	**01978 664466**
75 Ash Road South, Wrexham Industrial Estate, Wrexham, Clwyd LL13 9UG, Wales	
HARRISON AUTO	USA (1) 602 254 0024
LONGACRE RACING	USA (1) 425 885 3823
OMS RACING	**0113 2575956**
PACE PRODUCTS	01284 850960

Redline Motorsport

REDLINE MOTORSPORT **Tel 01606 737500**
Fax 01606 737683
E-mail info@redlinemotorsport.co.uk
TRIDENT **01327 857822**

CHASSIS STANDS

DEMON TWEEKS	**01978 664466**
SMR COMPONENTS	USA (1) 708 949 9100

COMPUTER HARDWARE

ADVANCED AUTOMOTIVE	01753 642019
CALEX INSTRUMENTATION	01525 373128
CRANFIELD	**01234 751361**
DYNOLAB	USA (1) 206 243 8877
FASTER SYSTEMS	USA (1) 415 332 6064
FUELTRONICS	Australia (61) 0883632199
FUJITSU	0208 573 4444
GENESIS	**01635 582255**
KISTLER	Switzerland (41) 52 224 111
NOVA	USA (1) 615 832 6355
OLIVETTI	0208 785 6666
PERFORMANCE TRENDS	USA (1) 248 473 9230
RACING CAR COMPUTERS	01279 812496
STACK	01869 240404

CORNER SCALES

A.R.T.	**USA (1) 914 889 4499**
DEMON TWEEKS	**01978 664466**
LONGACRE RACING	**USA (1) 206 885 3823**
NOVATECH	01424 852744
REDLINE MOTORSPORT	**Tel 01606 737500**
ROLLCENTRE	01480 464052

DAMPER DYNAMOMETERS (PORTABLE)

DYNAMIC SUSPENSIONS	01842 755744
ROEHRIG ENGINEERING	USA (1) 313 344 8120
SERVOTEST LTD	**020 8707 1400**
SPA DESIGN	01827 288328
SPA TECHNIQUE	USA (1) 317 271 7941

EAR DEFENDERS

DEMON TWEEKS	**01978 664466**
FASTENER FACTORY	01327 311018
RACING RADIOS	USA (1) 404 366 3796
REDLINE MOTORSPORT	**Tel 01606 737500**

ELECTRIC STARTERS

POWER TRANS SOLUTIONS	**01722 332126**

ENGINE HOISTS

DUNLOP AUTOMOTIVE	0121 384 4444
FACOM	UK 01932 566099

ENGINE STANDS

GUYON RACING	Canada (1) 403 277 6020
TITAN MOTORSPORT	01480 474402

FIRE EXTINGUISHERS

CHUBB	01932 785588

FEV

FEV **Tel 01243 555566 Fax 01234 555660**
Email sales@f-e-v.co.uk
www.f-e-v.co.uk
Unit 10 Ford Lane Business Park, Ford, West Sussex BN18 0UZ

FIREMASTER	0208 852 8585
LIFELINE FIRE SYSTEMS	**02476 712999**
Mardi Gras Motorsports	01327 858 006
OMP	0208 696 7031
	Italy (39) 10 680 851
QINETIQ	08700 100942
SILVERSTONE RACE SERVICES	01327 858441
SPA DESIGN	**01827 288328**
SPA TECHNIQUE	**USA (1)317 271 7941**
TRIDENT	**01327 857822**

FLOOR CRANES

ANRICK TRADING	NZ (04) 5899371
FASTNER FACTORY	01327 311018
SLINGSBY	01274 721591

FUME EXTRACTORS

DENCER	01789 470198
INGERSOLL RAND	01204 690690

HAND PUMPS

EXACT ENGINEERING	01803 866464
FACOM	01932 566099
SILVERSTONE RACE SERVICES	01327 858441
SNAP-ON	USA (1) 414 656 5372
	0161 969 0126
WURTH UK	0208 310 6666

HAND TRUCKS

OMS RACING	01132 575956
SILVERSTONE RACE SERVICES	01327 858441

HEAD TORCHES

ESSEX RACING	USA (1) 404 889 4096
HELLA	01295 272233

JACKS

ARGO MANUFACTURING	USA (1) 630 377 1750
DEMON TWEEKS	01978 664466
DUNLOP AUTOMOTIVE	02476 667738
FACOM	UK 01932 566099
FASTENER FACTORY	01327 311018
JLS MOTORSPORT	0121 525 7733
KS MOTORSPORT	Germany (49) 2271 44905
PADDY.HOPKIRK LTD	01525 850800
PERFORMANCE MACHINE	USA (1) 303 828 4546
REDLINE MOTORSPORT	**Tel 01606 737500**
SLINGSBY	01274 721591
DEMON TWEEKS	01978 664466
KS MOTORSPORT	Germany (49) 2271 44905
MARDI GRAS MOTORSPORTS	01327 858 006
MECHANIX WEAR	USA (1) 661 257 0474
RALLY DESIGN	01795 531871
SILVERSTONE RACE SERVICES	01327 858441

NOISE METERS

CIRRUS RESEARCH	01723 891655

PIT BARRIERS

KAISER & KRAFT	01923 233312
SLINGSBY	01274 721591

PIT BOARDS

ACTIVE ENGINEERING	USA 001 714 637 1155
DEMON TWEEKS	01978 664466
GRAND PRIX RACEWEAR	0208 987 5500
KS MOTORSPORT	Germany (49) 2271 44905
REDLINE MOTORSPORT	**Tel 01606 737500**
TRIDENT	01327 857822

PIT CANOPIES

PIT BITS	01727 858297

PIT LANE MARKERS

KAISER & KRAFT	01923 233312
SLINGSBY	01274 721591

PIT TROLLEYS

CHAMPION	01953 888664
DEMON TWEEKS	**01978 664466**
GTC COMPETITION	01483 272151
LISTA	01908 222333
REDLINE MOTORSPORT	**Tel 01606 737500**
OMS RACING	0113 2575956

PYROMETERS

AP RACING

AP RACING Tel 02476 639595
Fax 02476 639559
Wheler Road, Coventry, CV3 4LB

RADIO SCANNERS

QINETIQ	08700 100942
RACING RADIOS	USA (1) 404 366 3796

RADIO SYSTEMS/INTERCOMS

AUTOCOM	01926 431249
AUTOTEL RACE RADIO	01508 528837
MRTC	0150 981 2610
QINETIQ	08700 100942
STRODE SOUND	01761 419248

RAIN SUITS

DEMON TWEEKS	**01978 664466**
GRAND PRIX PROMOTIONS	01474 879524
JAYBRAND	01733 68247
REDLINE MOTORSPORT	**Tel 01606 737500**

REFUELLING LINES & VALVES

DUNLOP	01235 863863
EXACT ENGINEERING	**01803 866464**
GTC COMPETITION	**01483 272151**
KRONTEC	Germany (49) 9401 703062
PREMIER FUEL SYSTEMS	01332 850515
THE STRAIN GAUGING CO	**01256 320666**

REFUELLING RIGS

DEMON TWEEKS	**01978 664466**
GTC COMPETITION	01483 272 151
PREMIER FUEL SYSTEMS	01332 850515
REDLINE MOTORSPORT	**Tel 01606 737500**
SPA DESIGN	**01827 288328**
THE STRAIN GAUGING CO	01256 320666

SCISSOR PLATFORMS

SLINGSBY	01274 721591

SETUP FLOORS

ACTIVE ENGINEERING	**USA 001 714 637 1155**
4-PATCH	01376 348246
KS MOTORSPORT	Germany (49) 2271 44905
ME MOTORSPORT	01884 253070
RML	01933 402440
THE STRAIN GAUGING CO	**01256 320666**
SPA AEROFOILS LTD	01827 260026
UNIVERSITY OF HERTFORDSHIRE	01707 284270

SETUP GAUGES

A.R.T.	**USA (1) 914 889 4499**
CYBER DYNAMICS	**01869 347812**
DEMON TWEEKS	**01978 664466**
ILONGACRE RACING	**USA (1) 206 885 3823**
ME MOTORSPORT	01884 253070
REDLINE MOTORSPORT	**Tel 01606 737500**
THE STRAIN GAUGING CO	**01256 320666**

SPACE HEATERS

FASTENER FACTORY	01327 311018

STOPWATCHES

CASIO	0208 450 9131
DEMON TWEEKS	**01978 664466**
GRAND PRIX RACEWEAR	**020 8987 5500**
KS MOTORSPORT	Germany (49) 2271 44905
RACING RADIOS	USA (1) 404 366 3796
REDLINE MOTORSPORT	**Tel 01606 737500**
TRIDENT	**01327 857822**

STORAGE SYSTEMS

KAISER & KRAFT	01923 233312
LISTA (UK) LTD	01908 222333
POLSTORE STORAGE	01403 750000
PRONALS	France (33) 3201 997510

TAPE

DEMON TWEEKS	**01978 664466**
CLARENDON	**01455 841200**
DRC RACE CAR	USA (1) 609 397 4455
FASTENER FACTORY	01327 311018
KS MOTORSPORT	Germany (49) 2271 44905
RALLY DESIGN	01795 531871
REDLINE MOTORSPORT	**Tel 01606 737500**
TRIDENT	01327 857822

TIMING SYSTEMS

CASIO	0208 450 9131
CONTINENTAL SPORT	USA (1) 513 459 8888
ME MOTORSPORT	01884 253070
MOTEC	Australia (61) 3 9761 5050
MOTEC (EUROPE)	UK 08700 119100
MOTEC JAPAN	Japan (81) 489 46 1734
MOTEC SYSTEMS USA	USA (1) 714 897 6804
MST SPORTS TIMING	01684 573479
Pi RESEARCH	**01954 253600**
PIT BITS	01727 858297
STACK	01869 240404
UNISYS	0208 453 5562
VULCAN ENTERPRISES	USA (1) 602 759 7926

TOOL CABINETS

FACOM	UK 01932 566099
KAISER & KRAFT	01923 233312
POLSTORE STORAGE	01403 750000
SLINGSBY	01274 721591

TORQUE WRENCHES

FACOM UK	01932 566099
NORBAR TORQUE TOOLS	01295 270333
RALLY DESIGN	01795 531871

TRACKING GAUGES

A.R.T.	**USA (1) 914 889 4499**
DEMON TWEEKS	**01978 664466**
GMD COMPUTRACK	**Austra (61) 2 9644 1946**
REDLINE MOTORSPORT	**Tel 01606 737500**
THE STRAIN GAUGING CO	**01256 320666**

TYRE PRESSURE GAUGES

BERU F1 SYSTEMS	01374 646200
GRAND PRIX RACEWEAR	0208 987 5500
THE STRAIN GAUGING CO	**01256 320666**
TRIDENT	**01327 857822**

TYRE TEMPERATURE GAUGES

THE STRAIN GAUGING CO	**01256 320666**
TRIDENT	01327 857822

TYRE TROLLEYS

OMS RACING	**01132 575956**

TYRE WARMERS

BANDIT	**Australia (61) 3 9318 0644**
DEMON TWEEKS	**01978 664466**
GRAND PRIX RACEWEAR	**020 8987 5500**
JAYBRAND	01733 68247
REDLINE MOTORSPORT	**Tel 01606 737500**
SEEKERS	0151 524 0919

5.2 Paddock Equipment

AWNINGS

ALFRED BULL	01483 575492
ALRESFORD TECTONICS	01962 736316
AWNING COMPANY	01204 363463
BARKERS	**020 8653 1988**
DEANS AWNINGS	01942 241399
MAYFLOWER	01494 712131
PIT BITS	01727 858297
TOP MARQUEES	01623 749777

MOTORHOME HIRE

ATLANTIC COAST	01297 552222
DAVID WILSON'S TRAILERS	01825 740696
DUDLEYS	01993 703774
MIDLAND INTERNATIONAL	02476 336411
SPIRES OF OXFORD	01865 875539
WESTCROFT AMERICAN	01902 731324

Database 6
COMPETITION CAR CHASSIS COMPONENTS

6.1 Driver's Equipment

ANTI MIST FLUIDS

DEMON TWEEKS Tel 01978 664466 / Fax 01978 664467
Hugmore Lane, Llan-y-Pwll, Wrexham, Clwyd LL13 9YE, Wales
GRAND PRIX RACEWEAR Tel 0208 987 5500
Fax 0208 742 8999
Power Road, Chiswick, London, W4 5PY, England

REDLINE MOTORSPORT Tel 01606 737500
Fax 01606 737683
E-mail info@redlinemotorsport.co.uk

BOOTS & GLOVES

DEMON TWEEKS	01978 664466
GRAND PRIX RACEWEAR	0208 987 5500
MECHANIXWEAR	USA (1) 805 257 0474
REDLINE MOTORSPORT	**Tel 01606 737500**

COOL CAPS & SUITS

DEMON TWEEKS	01978 664466
GRAND PRIX RACEWEAR	020 8987 5500
REDLINE MOTORSPORT	**Tel 01606 737500**

DRIVING SUITS & ACCESSORIES

DEMON TWEEKS	01978 664466
GRAND PRIX RACEWEAR	020 8987 5500
REDLINE MOTORSPORT	**Tel 01606 737500**

HELMETS & ACCESSORIES

QINETIQ Tel 44 (0) 8700 100942
www.QinetiQ.com
Cody Technology Park,
Ively Road , Farnborough, Hampshire, GU14 0LX

Database 7
CHASSIS ENGINEERING SERVICES

7.1 Chassis Services

BODYWORK SPECIALISTS

ABBEY PANELS	02476 644999
ADVANCED COMPOSITES	01773 763441
ANDY ROUSE ENGINEERING	02476 635182
AERO APPLICATIONS	USA (1) 562 597 0001
AERODINE COMPOSITES	USA (1) 317 271 1207
AERODYNAMIC CONSULTANTS	**(666) 729 5628**
APPLIED FIBREGLASS	01842 765339
ASQUITH BROTHERS	01924 402001
CGB Consultants Aerodynamics	01202 617 1707
CML GROUP	0151 647 5531
COMPOSITE DESIGN	USA (1) 727 539 0605
CRANFIELD UNIVERSITY	01234 754152
CROPREDY BRIDGE GARAGE	01295 758444
DEREK PALMER ENGINEERING	01555 893315
DON FOSTER	**France (33) 470 580308**
EARS MOTORSPORT	01625 433773
FIBRESPORTS	01268 527331
GRAHAM HATHAWAY RACING	01621 856956
GTC COMPETITION	01483 272151
GTI ENGINEERING	01280 700800
HAMLYN MOTOR SERVICES	01582 841284
HEDDINGTON COACHWORKS	01380 850198
INTAPORSCH	01273 834241
LOTUS ENGINEERING	01953 608000
LYNX MOTORS	01424 851277
MERLIN BODYCRAFT	01280 705156
MITCHELL	NZ (64) 78236188
PODIUM DESIGN	07000 763486
SPA COMPOSITES	01543 432904

COMPOSITES SPECIALISTS

Active engineering	USA 001 714 637 1155
ACTIVA TECHNOLOGY	**020 8974 1615**
ÆOLUS TECHNOLOGY	**USA (1) 970 472 1288**
AERODINE COMPOSITES	USA (1) 317 271 1207
APPLIED FIBREGLASS	01842 765339
ASTEC	01332 875451
BGK RESINS	0208 464 7734
CGB CONSULTANT AERODYNAMICS	01202 660707
CARBON FIBRE TECHNOLOGY	01508 488257
CARBONE INDUSTRIE	France (33) 14 972 2305
COMPOSITE AUTOMOTIVE TECH	01249 443418
COMPOSITE DESIGN	**USA (1) 727 539 0605**
COMPOSITE WINGS	**01953 885478**

Cranfield UNIVERSITY

CRANFIELD UNIVERSITY Tel 01234 754902
Fax 01234 751671
Cranfield, Bedfordshire, MK43 0AL
www.motorsport.cranfield.ac.uk
motorsport@cranfield.ac.uk

CROSBY GRP	01327 857042
CTG	+44 (0)1295 220130
CTS	**01480 459378**
DELTA COMPOSITES	01280 824498
DEREK BENNETT	**01565 777395**
ELAN COMPOSITES	USA (1) 706 658 2853
DU PONT	UK 01438 734000
	Switzerland (41) 22 717 5111
	USA (1) 302 774 1000
FIBREGLASS FABRICATIONS	0208 568 0293
G FORCE COMPOSITES	01243 544192
HEYES ENGINEERING	01453 750491
HITCO	USA (1) 213 516 5707
JANUS TECHNOLOGY	01753 869996

KOMPREX Tel 0191 416 8200 Fax 0191 415 5962
Website www.komprex.com
Email sales@komprex.com
58-59 Hutton Close, Crowther Ind Est,
Tyne & Wear NE38 0AH

LOTUS ENGINEERING	01953 608000
MICRO CRAFT	**USA (1) 909 947 1843**
MIRA	**0247 6355 000**
NERO	01254 202085
PANKL	Austria (43) 3862 512500
PODIUM DESIGN	07000 763486
PRONAL'S	France (33) 320 99 75 10
QINETIQ	08700 100942
RICHARD HINTON RACING	01279 771667
RMCS (CRANFIELD)	01793 785359
SAMCO sport	**01443 238 464**
SECART	USA (1) 203 798 6698
SCOTT BADER	01933 663100
SPA COMPOSITES	01543 432904
SQUARE ONE MOTORSPORT	01825 723425
STRAND GLASSFIBRE	0208 568 7191
TAG EQUIPMENT	01787 477790
TECHFLEX	USA (1) 201 729 6253
TECHNICAL RESIN BONDERS	01480 52381
TONY THOMPSON RACING	01664 812454
TURBO HEAT	**01535 664903**
UNIVERSITY OF HERTFORDSHIRE	01707 284270
VIN MALKIE RACING	01565 777395
ZEUS M/SPORT ENG LTD	01604 878101

DESIGN AND ANALYSIS

ENABLING TECHNOLOGIES CONSULTING ENGINEERS LTD
Tel +44 (0)1983 550480 Fax +44 (0)1983 550489
Email office@enablingtechnologies.co.uk
Web enablingtechnologies.co.uk
Innovation Centre, St Cross Business Park,
Monks Brook, New Port, Isle of Wight PO30 5WB, England

LOLA Tel 01480 451301
Fax 01480 456722

RICARDO MIDLANDS TECHNICAL CENTRE
Tel 01926 477208 Fax 01926 477222
Email: pmarkwick@mtc.ricardo.com
Website: www.ricardo.com
Southam Rd, Radford Semele, Leamington Spa CV31 1FQ

FABRICATION

ABBEY PANELS	02476 644999
A-MAC FABRICATION	USA (1) 408 727 9288
ANDY ROUSE ENGINEERING	02476 635182
ANEX SYSTEMS	01869 345038

AUTOMOTIVE FABRICATION Tel/Fax 001 214 745 1148
Email weld666@airmail.net
1027 Levee Street Dallas, Texas 75207

ASTEC	01332 875451
AZTEK	01509 261299
BBW	**01483 722 713**
BOB SPARSHOTT ENGINEERING	01908 618080
BRADY FABRICATIONS	01869 252750
BRISE ALLOY FABRICATIONS	01322 222343
BSS PARTS	01772 601602
CHEVRON RACING	01565 777395
CHIP GANASSI RACING	01243 544192
CML GROUP	0151 647 5531
COLMET PRECISION	01296 681658
COMPOSITE DESIGN	USA (1) 727 539 0605
COMPETITION FABRICATIONS	01953 454573
CRANFIELD UNIVERSITY	01234 754152
CTG RACING	01202 871102
DEREK BENNETT	**01565 777395**
DJ RACECARS	01663 734518
DOCKING ENGINEERING	01327 857164
EUROTECH MOTORSPORT	0121 3314944
FOXCRAFT ENGINEERING	01264 810110
B Y G FORCE PRECISION ENG	01243 544192
GOMM METAL DEVELOPMENTS	01483 764876
GRAHAM HATHAWAY RACING	01621 856956
GTC COMPETITION	01483 272151
HAMLYN MOTOR SERVICES	01582 600745
HAUS OF PERFORMANCE	USA (1) 714 545 2755
JAGO DEVELOPMENTS	01243 789366
KRONTEC MASCHINENBAU	(49) 9401 700352
LOTUS ENGINEERING	01953 608000
LYNX MOTORS	01424 851277
MACDONALD RACE ENG	**0208 889 1633**
MATRIX ENGINEERING	USA (1) 888 249 0013
MASON ENGINEERING	USA (1) 805 527 6624
MICRO CRAFT	**USA (1) 909 947 1843**
MIKE TAYLOR DEVELOPMENTS	01609 780123
MIRKO RACING	USA (1) 408 776 0073
POLSON	01446 820371
PREMIER AEROSPACE	01332 850515
QinetiQ	08700 100942
RACEPREP 3001	01903 734499
RBS	01788 543094
RETRO TRACK & AIR UK	01453 545160
RICARDO MIDLANDS TECHNICAL CENTRE	
	Tel: 01926 477152
	Fax: 01926 319352
	Email: iain.wight@ricardo.com
RILEY & SCOTT	USA (1) 317 248 9470
Ray Mallock LTD (RML)	**Tel 01933 402440**
	Fax 01933 676519
	www.rmlmallock.co.uk
	6-10 Whittle Close, Park Farm Industrial Estate,
	Wellingborough, Northants NN8 6TY England
SNAPDRAGON MOTORSPORTS	USA (1) 413 2560861
SPA AEROFOILS LTD	01827 260026
SOUTH CERNEY ENGINEERING	01285 860295
UNICLIP AUTOMOTIVE	01932 355277
VAN DYNE ENGINEERING	USA (1) 714 847 4417
VIN MALKIE RACING	01565 777395

MOULDING

ADVANCED COMPOSITES	01773 763441
AERODINE COMPOSITES	USA (1) 317 271 1207
ASTEC	01332 875451
BENTLEY CHEMICAL TRADING	01562 515121
BUTSER RUBBER	01730 894034
CML GROUP	0151 647 5531
COMPOSITE DESIGN	USA (1) 727 539 0605
COMPOSITE WINGS	01953 885478
CROSBY GRP	01327 857042
CROMPTON TECH GROUP	01295 220130
CTG	+44 (0)1295 220130
G FORCE COMPOSITES	01243 544192
GRIFFITHS ENGINEERING	01582 600629
JANUS TECHNOLOGY	01753 869996
MICRO CRAFT	**USA (1) 909 947 1843**
PROTECH COMPOSITES LTD	**Tel: +44(0) 1420 471 400**
	Fax: +44 (0) 1420 487 047
	www.protechcomposites.co.uk
	Unit 62, Woolmer Trading Estate
	Bordon, Hampshire, GU35 9QF, UK
ROSS COURTNEY	01384 291919
STARTLINE UK LTD	01933 665752
SECART ENGINEERING	001 203 798 6698

SPACEFRAME DESIGN

ÆOLUS TECHNOLOGY	**USA (1) 970 472 1288**
ENABLING TECHNOLOGIES LTD	01983 550483
COSINE TECHNOLOGY	01706 378851
CRANFIELD UNIVERSITY	01234 754152
DAVID POTTER CONSULTING	0033(0) 494 339090
DEREK BENNETT ENGINEERING	**01565 777395**
MAGNUM CARS	01933 442861
Ray Mallock LTD (RML)	**Tel 01933 402440**
	Fax 01933 676519
	www.rmlmallock.co.uk
	6-10 Whittle Close, Park Farm Industrial Estate,
	Wellingborough, Northants NN8 6TY England
STARTLINE UK LTD	01933 665752

Database 8
DRIVETRAIN & SUSPENSION ENGINEERING SERVICES

8.1 Engine Services

RACE PREPARATION

ALDON	01384 572553
ANDY ROUSE ENGINEERING	02476 635182
AUTOKRAFT	0121 777 2083
AZTEK	01509 261299
BJ MOTOR ENGINEERS	0161 748 8663
BR MOTORSPORT	01926 451545
DAVE CROSS MOTOR SERVICES	01246 477566
SBD MOTORSPORT	0208 391 0121
CLEM COMPETITION	USA (1) 214 503 8044
CONCEPT MOTORSPORT	0208 568 0293
CONTINENTAL M/SPORT	USA (1) 513 459 8888
DBR MotorSport	**Tel 0161 627 4189 Fax 0161 627 4189**
	Unit 4 Forge Ind Estate, Green Acres Road,
	Oldham Lancashire, OL4 7LE
DJ RACECARS	01663 734518
DTM POWER	01865 407726
DUNNELL ENGINES	01449 677726
EARS MOTORSPORT	01625 433773
EDS	01508 857108
ELABORAZIONE COLASUNO	0207 738 8331
ENGINE DATA ANALYSIS	01977 516622
ENGINE SHOP	01280 812199
FISCHER ENGINEERING	USA (1) 818 767 8840
FORWARD ENGINEERING	01676 523526
GEMINI ENGINEERING	01474 534779
GEOFF RICHARDSON ENGINEERING	01480 861599
GF BECK MOTORSPORT PREPARATION	01646 621184
GOLDFLOW	01491 875554
GOODMAN RACING ENGINES	01327 300422
GRAHAM HATHAWAY RACING	01621 856956
GRIFFIN MOTORSPORT	01793 771802
HARPERS PERFORMANCE	01642 818188
HARTWELL	01202 556566
HAUS OF PERFORMANCE	USA (1) 714 545 2755
HT RACING	01474 872888
IRMSCHER	01543 414466
IVAN DUTTON	01923 816277
JANSPEED MOTORSPORT	01722 321833
J MATTIS ENGINETECH	Greece 003 019 512 761
JOHN WILCOX COMPETITION ENG	01455 230576
JONDEL	01933 411993
KENT AUTO DEVELOPMENTS	01303 874082
KREMER RACING	Germany (49) 221 170125
LE SPORT	France (33) 14 582 4400
LIGHTNING PERFORMANCE	USA (1) 904 439 5283
LINGENFELTER	**USA (1) 219 724 2552**
MARDI GRAS MOTORSPORTS	01327 858 006
MATHWALL ENGINEERING	01252 703191
MATRIX ENGINEERING	USA (1) 888 249 0013
MAXSYM ENGINE TECH	**01608 685155**
MERLIN DEVELOPMENTS	01283 511184
MILLINGTON	01746 789468
MINERVA MOTORSPORT	01509 233970
MINISTER RACING ENGINES	01634 682577
MIRKO RACING	USA (1) 408 776 0073
MIS M/SPORTTECHNIK GERMANY	(49)2638680394
MOUNTUNE RACE ENGINES	01621 854029
NEIL BROWN ENGINEERING	01775 723052
PHIL JONES ENGINE DEV	01454 310936
PHIL MARKS ENGINE DEV	01564 824869
PRICE MOTORSPORT	USA (1) 812 546 4220
PRIMA RACING	0115 9491903
PRODRIVE	01295 273355
QUICKSILVER RACE	USA (1) 3016988 9009
QUORN ENGINE DEVELOPMENTS	01509 412317
RACE ENGINE DEVELOPMENT	USA (1) 760 630 0450
RACESPEC	01925 636959
RACE TECHNIQUES	01242 245640
RACING BENT	USA (1) 714 779 8677
RANDLINGER	Germany (49) 761 16373
ROAD & STAGE MOTORSPORT	01524 844066
ROADSPEED PERFORMANCE	01453 750864
RPM FRANCE	(33) 3 86 66 00 08
SCARBOROUGH	Canada (1) 416 759 9309
SEARLE	0208 305 2250
STEVE CARBONE RACING	USA (1) 918 835 6596
SWAYMAR	01932 868377
SWINDON RACING ENGINES	01793 531321
TECNO	01268 764047
TERRY SHEPHERD TUNING	01695 574454
THINK AUTOMOTIVE	**Tel 0208 568 1172**
	Fax 0208 847 5338
	Email matt@thinkauto.co.uk
	292 Worton Road, Isleworth, Middlesex, TW7 6EJ
THUNDERBIRD RACING INT LTD	01623 622848
VAN DYNE ENGINEERING	USA (1) 714 847 4417
WARRIOR	01825 764833
ZYTEK ENGINEERING	01332 48974
ZEUS MOTORSPORT ENGINEERING LIMITED	
	Tel 01604 878111 Fax 01604 878111
	The Racing Stables, Blisworth Hill Farm,
	Stoke Road, Blisworth, Northants NN7 3DB

8.2 Engine Services

REBUILDS

ANDREASON RACING	01300 348499
ANEX SYSTEMS	01869 345038
BTR PREPARATIONS	01977 522348
EARS MOTORSPORT	01625 433773
GTC COMPETITION	01483 272151
HAUS OF PERFORMANCE	USA (1) 714 545 2755

HEWLAND ENGINEERING Tel 01628 827600
Fax 01628 829706
Waltham Road, Maidenhead, Berks, SL6 3LR

JACK KNIGHT	01483 764326
JP RACE CENTRE	01327 858151
KREMSPEED EQUIPMENT INC. USA	(1)814 724 4086
MARK BAILEY RACING	01380 850130
MATRIX ENGINEERING	USA (1) 888 249 0013
ME MOTORSPORTS	01884 253070
QUAIFE ENGINEERING	**Tel 01732 741144**
	Fax 01732 741555
	Email info@quaife.co.uk
	www.quaife.co.uk
	Vestry Road, Sevenoaks, Kent, TN14 5EL
ROADSPEED PERFORMANCE	01453 750864
TONY THOMPSON RACING	01664 812454
ZF	Germany (49) 7541 77 2543
	UK 0115 9869211

8.3 Suspension Services

SETUP SPECIALISTS

ACTIVE ENGINEERING USA (i) 714 637 1155
ANDREASON RACING 01300 348499
ATHON MOTORSPORT 0114 2490 272
AZTEK 01509 261299
BEAUFORT RESTORATION 01795 870288
DAVID POTTER CONSULTING 00353(0)1494 339090
BRADY FABRICATIONS 01869 252750
CRANFIELD UNIVERSITY 01234 754152
DON FOSTER France (33) 470 580308
EARS MOTORSPORT 01625 433773
GEOSCAN (G.I.L. Design) 01225 790568
LOLA Tel 01480 451301
Fax 01480 456722
HAUS OF PERFORMANCE USA (i) 714 545 2755
INTERPRO ENGINEERING 01454 412777
LOTUS ENGINEERING 01953 608000
MARDI GRAS MOTORSPORT 01327 858006
MARK ORTIZ USA (i) 704 933 8876
PILBEAM RACING DESIGNS 01778 424838
PODIUM DESIGNS 07000 763 486
Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
FSUSPENSION TECHNOLOGY 01327 858558

SHOCKBOX DAMPER SERVICES Tel: 07919 340550
Website: www.shockbox.co.uk
Email: ghbj@compuserve.com
67 Blackthorn Road, Attleborough, Norfolk, NR17 1YJ UK
THE STRAIN GAUGING CO 01256 320666
UNIVERSITY OF HERTFORDSHIRE 01707 284270

ENGINEERING SERVICES

RACING INDUSTRY TECHNICAL SERVICES
USA (i) 248 645 1724

8.4 Metal Services

BEAD & SAND BLASTING

BLAST-IT-ALL USA (i) 800 353 2612
CAMCOAT PERFORMANCE COATINGS 01925 445003
COMPAIR AUTOPOWER 01494 465000
HANKOE MOTORSPORT 01753 527779
MACDONALD RACE ENG 0208 889 1633
SWAYMAR CASTING 01932 868377
AEROMET 01795 415000
GM DESIGN 0117 985 9964
GRIFFITHS ENGINEERING 01582 600629
HILLGARD Sweden (46) 300 60590
JENVEY DYNAMICS 01746 768810
KENT AEROSPACE CASTINGS 01795 476333
PANKL Austria (43) 3862 512500
QUAIFE ENGINEERING 01732 741144
QDF COMPONENTS 01332 760260
QUARTERMASTER USA (i) 847 540 8999
QINETIQ Tel 08700 100942
www.QinetiQ.com
Cody Technology Park, Ively Road, Farnborough, Hampshire, GU14 0LX
ZEUS ALUMINIUM 01384 482222

COATINGS

BALZERS LTD Tel 01908 377277 Fax 01908 361362
www.balzers.co.uk
Bradbourne Drive, Tilbrook, Milton Keynes, MK7 8AT, UK
CAMCOAT PERFORMANCE COATINGS 01925 445003

CTG Tel: +44 (0)1295 220130 Fax: +44 (0)1295 220138
E-mail: motorsport@ctgltd.co.uk
www.ctgltd.co.uk
Thorpe Park, Thorpe Way, Banbury, Oxfordshire OX16 4SU United Kingdom
LURO COTE USA (i) 909 885 3223
KENT MOTORSPORT CASTINGS 01795 662288
POETON 01452 300500
POLYMER DYNAMICS USA (i) 713 694 3296
QINETIQ 0 8700 100942
SWAIN TECH USA (i) 716 889 2586
WALLWARK HEAT TREATMENT 0161 7979111

ZIRCOTEC PERFORMANCE COATINGS
Tel: 0870 190 8480 Fax: 0870 190 8488
E-mail: enquiries@zircotek.co.uk
www. zircotek.com
528.10 Unit 2 Harwell business Centre, Didcot, Oxfordshire OX11 0QJ United Kingdom

FINISHING

ALUMINIUM SPECIAL 01384 291900
APPERLEY HONING 01242 525868
ARMORALL PRODUCTS 01799 513130
CML GROUP 0151 647 5531
GRIFFITHS ENGINEERING 01582 600629
HEPWORTH INTERNATIONAL 01484 711720
JENVEY DYNAMICS 01746 768810
KENT AEROSPACE CASTINGS 01795 476333
QUAIFE ENGINEERING 01732 741144
QINETIQ 0 8700 100942
RICHARD BARRETT MOULDS USA 353 282 9842
ZEUS ALUMINIUM PRODUCTS 01384 482222

FOUNDRIES

AEROMET 01795 415000
BA HARRISON 0116 2769351
GM DESIGN 0117 985 9964

FINECAST 01903 765821
H GRIFFITHS ENGINEERING 01582 600629
JENVEY DYNAMICS 01746 768810
KENT AEROSPACE CASTINGS 01795 476333
KENT MOTORSPORT CASTINGS 01795 662288
QUALCAST 01332 760260
UK RACING CASTINGS 01227 750877

HEAT TREATMENT

AR CORNELL 01245 268098
AUTOSPRINT 01675 464857
AVONBAR 01932 840058
BEAUFORT RESTORATION 01795 830288
JENVEY DYNAMICS 01746 768810
PANKL Austria (43) 3862 512500
QUANTUM HEAT TREATMENT 01908 642242
TECVAC 01954 233700
ZEUS MOTORSPORT 01604 878101

MACHINING

ABBEY PANELS 02476 644999
ACTIVE ENGINEERING USA (i) 714 637 1155
APPERLEY HONING 01242 525868
ATHENA MANUFACTURING LP USA (i)512 928 2693
AVONBAR 01932 840058
AZTEK 01509 261299
BEAUFORT RESTORATION 01795 830288
CML GROUP 0151 647 5531
COLEMAN MACHINE USA (i) 906 863 8945
DATUM ENGINEERING 02476 383032
FORMULA FABRICATIONS 01953 605490
DONCASTERS LTD 01332 864900
JENVEY DYNAMICS 01746 768810

KRONTEC GMBH Tel Germany (49) 9401 5253-0
Fax Germany (49) 9401 5253-10
Pommernstrabe 33, 93073 Neutraubling, Germany
LANGSTONE ENGINEERING LTD 02392 452430
LINGENFELTER USA (i) 219 724 2552
LOTUS ENGINEERING 01953 608000
MACDONALD RACE ENG 0208 889 1633
MASON ENGINEERING USA (i) 805 527 6624
METAL SPINNERS 0191 267 1011
MILSPEC PRODUCTS USA (i) 407 814 8997
QINETIQ 0 8700 100942
PANKL AUSTRIA (43) 3862512500
PERFORMANCE MACHINE USA (i) 303 828 4546
PREMIER AEROSPACE 01332 850515
PREMIER FUEL SYSTEMS 01332 850515
QUAIFE ENGINEERING 01732 741144
RICARDO INC USA (i) 734 397 6666
RICHARD BARRETT MOULDS USA 353 282 9842
TITAN MOTORSPORTS 01480 474402
TREVOR MORRIS ENGINES 015474 289
TRICK MACHINING 01493 751666
VIN MALKIE 01565 777395

METAL MATRIX COMPOSITES

BP METAL COMPOSITES 01252 37

CRANFIELD UNIVERSITY Tel 01234 754902
Fax 01234 751671
Email motorsport@cranfield.ac.uk
www.motorsport.cranfield.ac.uk
Motorsport Group, Cranfield University, Cranfield, Bedfordshire, MK43 0AL
GM DESIGN 0117 985 9964
MMCC USA (i) 617 893 4449
PANKL Austria (43) 3 8625 12500

METAL SUPPLIERS

ADVANCED METALS INTERNAT 01923 210250
AIRCO METALS LTD 0118 973 0509
ALUMINIUM SPECIAL 01384 291900
APPERLEY HONING 01242 525868
BRADY FABRICATIONS 01869 252750
BRITISH ALCAN ALUMINIUM 01753 887373
AVESTOPOLART LTD 0114 2443311
BYWORTH MATERIAL SERVICES 01453 821609
COLUMBIA METALS 01604 810191
CROMPTON TECH GROUP 01295 220130
MASON ENG USA (i) 805 527 6624
RICHARD BARRETT MOULDS USA 353 282 9842
RGB STAINLESS 0121 558 3111
SMITHS HIGH PERFORMANCE 01767 604708
SPA AEROFOILS LTD 01827 260026

Tel: +44 (0) 1908 260707 Fax: +44 (0) 1908 260404
Email: sales@superalloys.co.uk
Number 1 Garamonde Drive, Wymbush Milton Keynes MK8 9DF UK.

TITANIUM SPECIALISTS

AIRCO METALS LTD 0118 973 0509
A.N. MOTORSPORT DESIGN 01628 776320
APPERLEY HONING 01242 525868
ATHENA MANUFACTURING LP USA (i)512 928 2693
CML GROUP 0151 647 5531
COAST FABRICATION USA (i) 714 842 2603
DATUM ENGINEERING 02476 383032
DONCASTERS LTD 01332 864900
PANKL Austria (43) 3 8625 12500
QINETIQ 0 8700 100942
SPA AEROFOILS LTD 01827 260026

TITANIUM INTERNATIONAL Tel: 0121 789 5764
Fax: 0121 784 8054
Email: nhoskison@tiltd.co.uk
Keys House, Granby Avenue, Garretts Green, Birmingham B33 0SP

TUBE FORMING

CONTRACT MFG & ASM USA (i) 920 720 4225
MALVERN AIRCRAFT 01684 892600
SPA AEROFOILS LTD 01827 260026

8.5 Race Preparation

CHASSIS

ACTIVE ENGINEERING USA (i) 714 637 1155
AMS 01831 500363
AMT MOTORSPORT 01444 483477
ANEX SYSTEMS 01869 345038
AUTOMECH 0161 775 1851
AVONBAR 01932 840058
BARWELL MOTORSPORT 0208 397 4411
BR MOTORSPORT 01926 451545
BRR MOTORSPORT 01327 858055
CHRIS LEWIS MOTORSPORT 01677 422623
DEREK BENNET ENG 01565 777395
PRO MOTORSPORT 01555 893315
DOME CARS LTD Japan (81) 75 744 3131
DON FOSTER France (33) 470 580308
FOXCRAFT ENGINEERING 01264 810110
FRP RACING 01494 771609
GRAHAM WISEMAN 01278 685349
HAUS OF PERFORMANCE USA (i) 714 545 2755
HAWKINS RACING 0208 579 1438
INTERPRO ENGINEERING 01454 412777IVAN
JACK CRONE RACING USA (i) 909 371 6090
JOHN VILLAGE AUTOMOTIVE 01246 450580
K2 RACE ENGINEERING 01825 766728
MACDONALD RACE ENG 020 8889 1633
MARDI GRAS MOTORSPORT 01327 857246
MARK BAILEY RACING 01380 850130
MARK DUNHAM RACE ENG 01353 648922
MATRIX ENGINEERING USA (i) 888 249 0013
MELTUNE PX MOTORSPORT 01923 242536
MIRKO RACING Tel USA (i) 408 776 0073
Fax USA(i) 408 779 9319
16890 Church Street, Building no.14, Morgan Hill, CA 95037, USA
PLANET MOTORSPORT 01403 891553
PODIUM DESIGNS 07000 763486
QINETIQ 0 8700 100942
RACECRAFT INTERNATIONAL 01789 297000
RACE TEC DESIGN & ENGINEERING 01386 871292
RILEY & SCOTT USA (i) 317 248 9470
Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
ROY KENNEDY RACING 01327 858055
SCHNITZER Germany (49) 8654 2034
SHENPAR PRODUCTS 01332 862901
STARTLINE UK LTD 01933 665752
STORM MOTORSPORT 01474 85 4367
TECH-CRAFT MOTORSPORT 01926 496075
TOLLBAR RACING 01433 631698
TT AUTOMOTIVE RACING 0147 485 3456
VIN MALKIE 01565 777395
ZAKSPEED Germany (49) 2636 87923

9.1 Chassis Testing

CALIBRATION SERVICES

RICARDO INC USA 001 734 397 6666
THE STRAIN GAUGING CO 01256 320666
TORQUE FAST CALIBRATION 01782 744212
UNIVERSITY OF HERTFORDSHIRE 01707 284270

CRASH TESTING

CRANFIELD UNIVERSITY 01234 754152
CRANFIELD IMPACT CENTRE 01234 751361
KISTLER INSTRUMENTS LTD 01420 544477
MIRA LTD 0247 635 5000
QINETIQ 0 8700 100942
Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
www.rmlmallock.co.uk
6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northants NN8 6TY England
THE STRAIN GAUGING CO 01256 320666

MEASUREMENT EQUIPMENT

AUTOSPRINT 01675 464857
BEAUFORT RESTORATION 01795 83288
BERU F1 SYSTEMS 01374 646200
CCA DATA SYSTEMS 01525 378938
CRANFIELD INSTITUTE 01908 694134
GENESIS ELECTRONIC SYSTEMS 01923 893 999
INSTRON SCHENK 01494 456789
INTERCOMP USA +763 476 2531
KISTLER INSTRUMENTS LTD 01420 544477
LONGACRE USA (i) 425 485 0620
LOTUS ENGINEERING 01953 608000
MICROLEASE 0208 427 8822
MIRA LTD 0247 635 5000
MOTORSPORTS INTERFACE 01788 890412
QINETIQ 0 8700 100942
ROEHRIG ENGINEERING Tel USA (i) 336 431 1827
ROTO TEST AB Sweden (46) 85 325 5890
THE STRAIN GAUGING CO 01256 320666

ROLLING ROADS

ALDON AUTOMOTIVE 01384 78508
AUTOMECH 0161 775 1851
AUTOPOINT 01842 766226
AUTOSPRINT 01675 464857
BD ENGINEERING 01795 843980
PIT STOP 01993 850654
BSJ MOTOR ENGINEERS 0161 748 8663
BOSCH 01895 834466
BBR GTI LTD 01280 702389
BRUNO HANSON Denmark (45) 65 99 1616
CARBURETTOR CENTRE 0208 340 5057
CHAMPION MOTORS 01621 857444
CRANFIELD INSTITUTE 01908 694134
DERBY AUTO ACCESSORIES 01332 671493
DTM CONSULTANTS (UK) 01865 407726
ELABORAZIONE COLASUNO 0207 738 8131
FGR 01885 400639
FROUDE CONSINE 01905 856800
INTERPRO ENGINEERING 01454 412777
JANSPEED MOTORSPORT 01722 321833
MACHTECH 01923 269788
MATRIX ENGINEERING USA (i) 888 249 0013
MIRA LTD 0247 635 5000
MOTORSCOPE 01609 780155
OHIO STATE UNIVERSITY USA (i) 614 292 5491
OSELLI ENGINEERING 01865 248100
RE PERFORMANCE CENTRE 0161 761 1177
RICHARD LONGMAN RACING 01202 486589
ROADSPEED PERFORMANCE 01453 750864
SARDOU France (33) 16 00 10 367
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SOUTHAMPTON UNIVERSITY 01703 585044
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TIPTON GARAGE 01404 812090

STRESS ANALYSIS

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LOLA Tel 01480 451301
Fax 01480 456722

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email candbaero_indy@email.msn.com
6210 La Pas Trail, Indianapolis, IN 46268, USA
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CAPITAL PATTERNS 0208 777 9276
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MICRO CRAFT USA (i) 909 947 1843
MIRA 0247 635 5000
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THE STRAIN GAUGING CO 01256 320666

9.2 Engine Testing

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AUTOSPRINT 0121 236 5133

AVL DEUTSCHLAND Gmbh GERMANY (49) 6134 7179-0
CRANFIELD INSTITUTE 01908 694134
CRANFIELD UNIVERSITY 01234 754152
INTEGRAL POWERTRAIN 01908 278600
KISTLER Instruments Ltd 01420 544477
LOTUS ENGINEERING 01953 608000
MACHTECH 01923 269788

MIRA LTD 0247 635 5000
MOTORSPORTS INTERFACE 01788 890412
MTS Powertrain Tech Tel 01932 351516
PETROCHEM CARLESS LTD 01372 360000
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QINETIQ 0 8700 100942
RICARDO 01273 45561
TREVOR MORRIS ENGINES 0154 74289

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DYNAMIC TEST USA (1) 800 243 3966
DYNOMITE USA (1) 603 329 5645
ENGINE & DYNAMOMETER 01708 857108
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LOTUS ENGINEERING 01953 608000
MACHTECH 01923 269788
MIS M/SPORTTECHNIK Germany (49)2683680394
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Ricardo Inc USA (1) 734 397 6666
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ARIAS 01403 784022
ATKINSONS MOTORSPORT 01539 732500
AUTOKRAFT 0121 777 2083
AUTOMECH 0161 7751851
AUTO SPECIALISTS USA (1) 704 786 0187
AVONBAR 01932 840058
EVOLUTION ENGINEERING 0207 703 2225
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BJ MOTOR ENGINEERS 0161 748 8663
BOB WIRTH RACING USA (1) 510 487 3279
BRAYTON ENGINEERING USA (1) 517 279 8458
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BRODIE BRITTAIN (BBR) 01280 702389
CAMBRIDGESHIRE SPORTS 01954 210248
CARBONE RACING USA (1) 918 835 6596
CENTRAL AUTO TECH 0121 4558392
COMPETITION ENGINE 01296 435389
CONCEPT MOTORSPORT 0208 568 0293
CONNAUGHT 01795 843802
DAVE CROFTS 01246 477666
DAWSON AUTO DEVELOPMENT 01327 857729
DESIGN & DEVELOPMENT 01695 574454
DRAGON PROJECT RACING TEL 0118 974 4175
DUNNELL ENGINES 01449 677726
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HARPERS PERFORMANCE 01642 818188
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HODSON ENGINEERINBG 01732 463658
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INTEGRAL POWERTRAIN 01908 278600
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IVAN DUTTON 01923 816277
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JENNETTS ENGINES 01993 891776
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KREMER RACING Germany (49) 221 17 1025
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01564 824869
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RICARDO 01273 794144
ROAD & STAGE MOTORSPORT 01524 844066
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SEARLE 0208 305 2250
SCHENCK PEGASUS USA (1) 248 689 9000
SOUTH CERNEY ENGINEERING 01285 860295
SPECIALISED ENGINES 01375 378606
STERLING ENGINES USA (1)209 267 5081
SWIFT MOTORSPORT 0191 5867311
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TREVOR MORRIS ENGINES 0154 74289
VAN DYNE ENGINEERING USA (1) 714 847 4417
WARRIOR 01825 764831
WESLAKE DEVELOPMENTS 01797 224000

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AM TEST SYSTEMS 01253 780780
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CRANFIELD UNIVERSITY 01234 754152
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LINGENFELTER USA (1) 219 724 2552
LOTUS ENG 01953 608000
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NEIL BOLD ENGINEERING 01204 71636
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RICARDO 01273 794144
TREVOR MORRIS ENGINES 0154 74289
U.M.P.S 01784 439771

FUEL ANALYSIS

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CRANFIELD INSTITUTE 01908 694134
LOTUS ENGINEERING 01953 608000
QINETIQ 0 8700 100942

INJECTION ANALYSIS

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CRANFIELD INSTITUTE 01908 694134
LOTUS ENGINEERING 01953 608000
QINETIQ 0 8700 100942
RICARDO 01273 794144

RACE ENGINE DESIGN

RICARDO CONSULTING ENGINEERS
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Email: dmorrison@ricardo.com
Website: www.ricardo.com
Shoreham by Sea, West Sussex. BN43 5FG

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CCA DATASYSTEMS 01525 378938
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MACHTECH 01923 269788
MIRA LTD 0247 635 5000
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MOTORSPORTS INTERFACE 01788 890412
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TREVOR MORRIS ENGINES 0154 74289

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TEST CELL DESIGN

MARTYR TEST TECHNOLOGY 01386 792125

9.3 Transmission Testing

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ANTHONY BEST DYNAMICS 01225 867575

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HEWLAND ENGINEERING 01628 827600
LOTUS ENGINEERING 01953 608000
MACHTECH 01923 269788
MARK BAILEY RACING 01264 860114
MIRA LTD 0247 635 5000
PDS RACING 01977 601928

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Fax 01732 741555
Email info@quaife.co.uk www.quaife.co.uk
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RICARDO 01926 319399
ROADSPEED PERFORMANCE 01453 750864
SCHENCK PEGASUS CORP (1) 248 689 9000
SERVOTEST LTD 020 8707 1400
SIEMENS AG Germany (49) 941 790 5313
THE STRAIN GAUGING CO 01256 320666
ZF Germany (49) 7541 77 2543
UK 0115 9869211

9.4 Suspension Testing

TESTING SERVICES

ANDY ROUSE ENGINEERING 02476 635182
CRANFIELD INSTITUTE 01908 694134
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HAUS OF PERFORMANCE USA (1) 714 545 2755
INSTRON SCHENK 01494 456789
JENVEY DYNAMICS 01746 768810
LOLA Tel 01480 451301
Fax 01480 456722
MARDI GRAS MOTORSPORT 01327 858006
MIRA LTD 0247 635 5000
PILBEAM RACING DESIGNS 01778 424838
RACE TEC DESIGN & ENG 01386 871292
RACRAFT MOTORSPORT 01707 45946
RATRACE MOTORSPORT 0208 203 8700
RICARDO 01273 794144
RICHARD HINTON RACING 01279 771667
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Ray Mallock LTD (RML) Tel 01933 402440
Fax 01933 676519
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SERVOTEST LTD 020 8707 1400
SCHENCK PEGASUS USA (1) 248 689 9000
SPA DESIGN LTD 01827 288328
STARTLINE UK LTD 01933 665752

9.5 Brake Testing

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MTS POWERTRAIN TECHNOLOGY 01932 351516
DYNOMITE USA (1) 603 329 5645
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PO Box, CH-8408 Winterhur, Switzerland
MIRA LTD 0247 635 5000
WILWOOD ENG USA USA (1) 805 388188
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TESTING SERVICES

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EUROPEAN FRICTION 017 9714837
MIRA LTD 0247 635 5000
RICARDO 01273 45561
SIEMENS AG Germany (49) 941 790 5313
THE STRAIN GAUGING CO 01256 320666

9.6 Metal Testing

CRACK TESTING

BEAUFORT RESTORATION 01795 81288
CML GROUP 0151 647 5531
CRANFIELD UNIVERSITY 01234 754152
GM DESIGN 017 985 9964
MIRA LTD 0247 635 5000
ORANGE COUNTY USA (1) 800 359 8378
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RMCS (CRANFIELD) 01793 785359
SCHENCK PEGASUS USA (1) 248 689 9000
SPA AEROFOILS LTD 01827 2600226
STRAIN GAUGING CO 01256 320666
SWINDON RACING ENGINES 01793 531321
UNIVERSITY OF HERTFORDSHIRE 01707 284270
VIN MALKIE RACING 01565 777395
WESTLAND HELICOPTERS 01935 702190

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AR CORNELL 01245 268098
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BA HARRISON 0116 2769351
CML GROUP 0151 647 5531
CRANFIELD UNIVERSITY 01234 754152
GRIFFITHS ENGINEERING 01582 600629
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DONCASTERS 01332 864900
MRE 0208 889 1633
MIRA LTD 0247 635 5000
NITRIDING SERVICES 01952 677372
ORANGE COUNTY USA (1) 800 359 8378
RICARDO 01273 45561
QINETIQ 0 8700 100942
RMCS (CRANFIELD) 01793 785359
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SCHENCK PEGASUS USA (1) 248 689 9000
THE STRAIN GAUGING CO 01256 320666
UNIVERSITY OF HERTFORDSHIRE 01707 284270
ZEUS MOTORSPORT 01604 878101

Database 10

SERVICES - GENERAL

10.2 Paddock Services

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UNION AIR TRANSPORT 0161 436 7074
WINWEST Australia (61) 2 522 4618

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ATLANTIC COAST 01297 552222

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ULTRA INTERNATIONAL 01766 770011
WESTCROFT AMERICAN 01902 731324
11/56 MOTORSPORT 01543 480309
BRIAN JAMES TRAILERS 01327 260733
DAVID WILSON'S TRAILERS 01825 740696
DC TRAILERS 01406 380224
ELLIS ENGINEERING 01277 631274
HOPKINS MOTORSPORT 0117 9509294
MOBILE PROMOTIONS 01832 733460
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Don't forget the tyres

A recurring theme in Aerobytes is the surprisingly large-scale influence of small changes to components. This month it's rear tyres

Tyre shape can change, even in one model from one manufacturer. This can have surprising effects on drag and airflow characteristics around a racecar

LAT

Tyres are a major source of aerodynamic drag, especially on single seaters, and frequently also generate lift that counteracts some of the body and wing-generated downforce. So changes to tyre size, via width or diameter, will cause potentially significant changes to aerodynamic forces. But what about changes to tyre *shape*? They may all start out round, but in cross section tyres can vary in shape between brands, and possibly between 'models' or types within a given brand. Is this something to be concerned about, aerodynamically speaking? Going by the results of this particular study by Advantage CFD on a Reynard 2KI ChampCar, the answer to that question is a definite 'yes'.

The aim of the study was to better simulate actual tyre geometry by investigating the influence of sidewall shape. The comparison here was between the shapes of a model tyre used on the 40 per cent scale wind tunnel car and that of a bulging sidewall variation more closely resembling the real tyre current at the time. Width and rolling radius remained unchanged. Both were modelled in CAD (see figure 1) and evaluated using CFD on the virtual car model in 'road course' configuration. Total downforce was up by 6.18 per cent yet total drag only increased by 0.28 per cent. Flows around and, especially, in the wake of wheels are difficult to predict using steady-state CFD because of the unsteady nature of wheel wakes. And dynamic changes to tyre shape (through weight transfer and aero load) were not modelled here either. But this 'snapshot' showed force changes that were pretty significant.

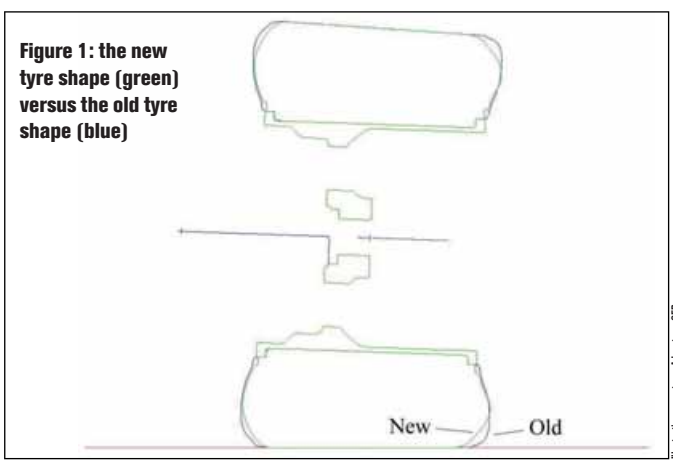


Figure 1: the new tyre shape (green) versus the old tyre shape (blue)

Illustrations courtesy, Advantage CFD

The biggest contributor to the change in downforce was the underfloor, which provided approximately three quarters of the increase. There was also a marked decrease in rear wheel lift, which also contributed to the overall downforce increase. Other significant increases in downforce came from the rear wing and the so-called 'flugelhorns' (the radiator exit ducts and flip ups ahead of the rear wheels). And principally because all the gains in downforce were felt at the rear there was a marked shift in aerodynamic balance in that direction.

As usual, the delta Cp plots illustrate where changes in surface pressures occurred as a result of the change to the geometry, and hint at possible mechanisms. Figures 2 and 3 show that the upper surface pressures were only slightly affected by the change in tyre shape, with small areas of decreases (negative, green colour) and increases (positive, yellow and red). In passing, notice that the front wing flaps were slightly affected by the change of rear tyre shape...

Figures 4 and 5 demonstrate vividly where the bulk of the downforce →

Figure 2: static pressures change little on the upper surfaces

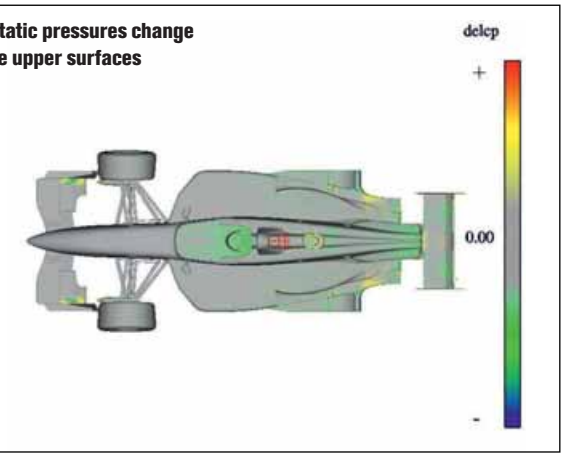


Figure 3: static pressures change little on the upper surfaces

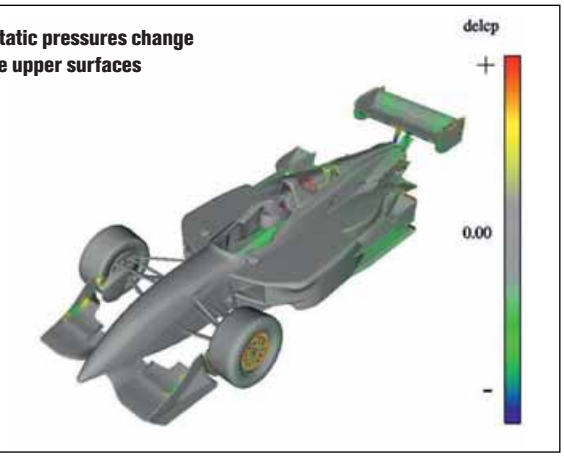


Figure 4: widespread change to the static pressures under the car

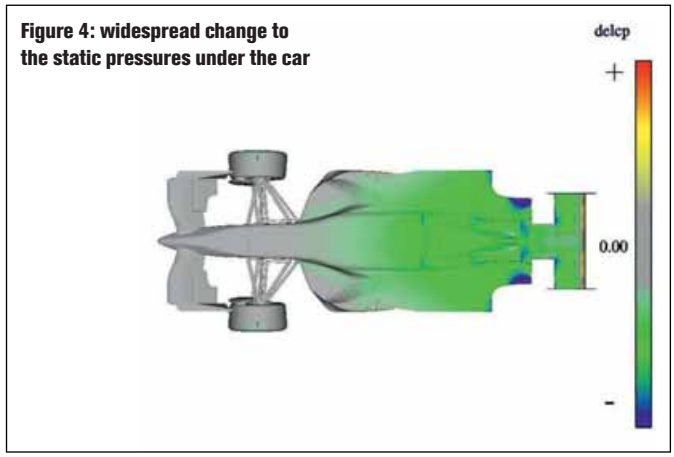
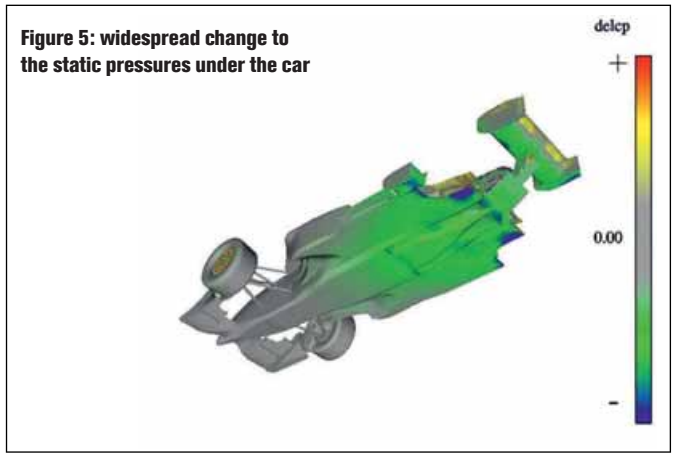


Figure 5: widespread change to the static pressures under the car

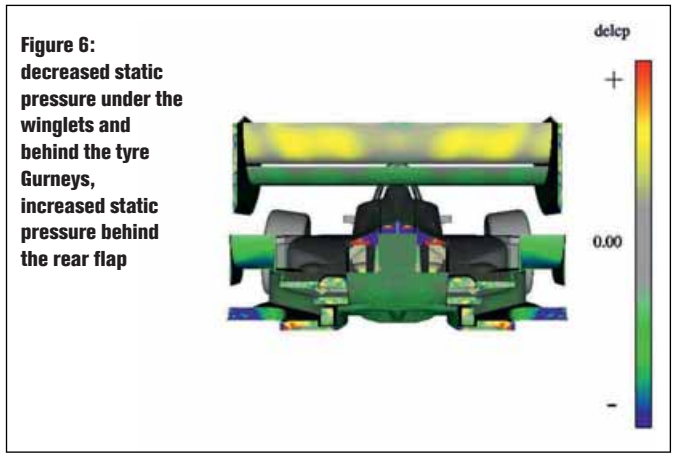


increase from the new tyre shape arose, with a widespread decrease in static pressure in the rear two thirds of the underfloor. The underside of the rear wing mainplane also benefited from increased suction. Notice how the most marked decreases in static pressure (blue areas) occurred just inboard of the rear tyres (not shown for clarity). Figure 6 shows marked decreases in static pressure on the back of the rear 'tyre Gurneys' (bottom, left and right), which were associated with the above mentioned blue areas on the underfloor adjacent to the rear tyres. And there was also a marked decrease in static pressure on the underside of the sidepod winglets. There was also an *increase* in static pressure evident on the back of the rear wing flap, and we'll come back to that shortly.

So what mechanisms were at work? The evidence from the delta Cp plots points to the cause of these changes in surface pressures being located, unsurprisingly, adjacent to the rear tyres, but low down. There were no significant changes occurring to upper surface pressures of the racecar body - for example, the sidepod winglets saw a decrease in pressure on their undersides but not on their top surfaces. Furthermore, the most intense pressure changes were quite localised, adjacent to the lower side of the rear tyres. And yet the widespread pressure change across so much of the underfloor points to a more global effect that acted like a skirt, better sealing the underfloor area from detrimental lateral flow from outboard. The conclusion is that the change to the tyre shape modified the flow structure around the lower sidewall, in this instance with highly beneficial effect. The increased suction on the rear wing mainplane and the winglet undersides probably stemmed from mutually beneficial interaction with the underbody. Not shown in these plots, but referred to earlier, is that rear wheel lift markedly reduced with the new tyre shape, and this may have been due to changes on the lower or upper half of the rear tyres.

The changes to drag as the result of altering tyre shape were small, but important because of that. There was a small increase in drag from the underfloor but this was offset by a reduction in drag from the rear wing,

Figure 6: decreased static pressure under the winglets and behind the tyre Gurneys, increased static pressure behind the rear flap



which can be explained by the increases in static pressure on the rear of the flap mentioned earlier. The increases on the rear flap are located behind the areas of most marked static pressure decrease (blue) on the leading edge of the mainplane, and the consequent steeper chord-wise pressure gradients may have lead to earlier flow separation. There was also a small decrease in drag from the rear wheels, which may just have been due to the slightly smaller frontal area of the tyres and their more rounded shape.

If the aim of this study was to demonstrate that small details matter when it comes to simulating reality with CFD (or indeed wind tunnel) models then the results here are clear. But a further inescapable thought is that if there are potential gains as significant as this to be had, in categories where tyre choice is free, it could be worthwhile evaluating different brands in this way. Perhaps the major players could persuade their suppliers to develop more aerodynamic tyres? Indeed, one wonders if any of the big teams have already followed this route. Speculative (or informed) responses to racecar@ipcmedia.com please...

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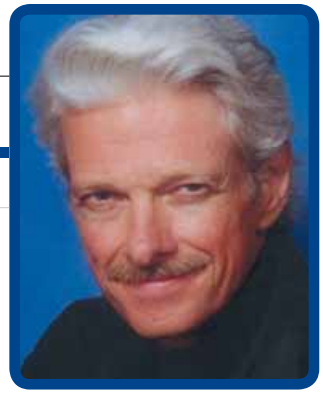

Load transfer in cornering

LAT

Forward acceleration will always compress the rear suspension in a front-wheel drive car but even in steady-state cornering there will be a longitudinal effect due to attitude or drift angle

Q **If a car starts to corner and 400lb of load is transferred from the inside rear tyre to the outside rear tyre, this leaves zero load on the inside rear tyre. But the car continues to speed up in the turn, reaching the limit of adhesion, and now there is 600lb of load on the outside rear tyre. Where does this additional 200lb of load come from? Does it all come off the inside front tyre? If you have a rear anti-roll bar, it can actually push the inside tyre up into the tyre well so I guess this would be a negative load on the inside rear tyre?**

For the sake of argument, let's assume the following conditions apply: 1) total rear roll resistance is 600lb/inch of rear suspension travel; 2) the static weight on each rear tyre is 400lb; 3) the car's rear suspension compresses one inch when cornering at the limit, therefore there is 600lb of load transfer onto the outside rear tyre.

A If I understand the question correctly, you are supposing that the outside rear suspension compresses one inch from static, implying that the tyre gains 600lb of transferred load, which would make its load 1000lb. If we are assuming that the car is in steady-state cornering on a flat, smooth, un-banked turn, with no geometric anti-roll or pro-roll, and no aerodynamic downforce, you are describing an impossible case scenario. Unless something adds load to the rear wheel pair beyond the static value, the outside wheel cannot have more load than the total for the wheel pair.

> **"THERE CAN BE NO SUCH THING AS A NEGATIVE TYRE LOAD"**

There can be no such thing as a negative tyre load, unless the tyre can somehow pull upward on the road surface. Short of creating a tread →

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. In these pages Mark answers your queries on chassis set-up and handling. If you have a question to put to him, email to **markortiz@vnet.net**, call **704-933-8876** or write to **Mark Ortiz, 155 Wankel Dr., Kannapolis, NC 28083-8200 USA**

LAT

If the rear suspension reaches 100 per cent load transfer and further lateral acceleration is applied, the inside rear wheel will start to lift off the ground. In this situation, an anti-roll bar will merely prevent the inside suspension from reaching full droop. The result is an average displacement from static of zero

compound that is sticky beyond our usual conception, or nailing the tyre to the road (either of which would make it very difficult for the car to attain enough speed to corner hard), that just can't happen. It is also impossible for load to transfer from the front wheels to the rear wheels when the car is only accelerating laterally.

What will happen if the rear suspension reaches 100 per cent load transfer, and then further lateral acceleration is applied to the car, is that the inside rear wheel will lift off the ground. The car will continue to roll, but without any further motion of the rear suspension. That implies that the rear ride height, measured from middle of the frame to ground, will increase as the wheel lifts off the road.

The anti-roll bar will push the inside tyre up into the wheel well, only in the sense that it may prevent the inside suspension from reaching full droop – not in the sense of compressing the inside suspension beyond static position. The suspension's ride displacement from static will be zero. Its roll displacement will be two thirds of an inch per wheel. The inside wheel will be off the ground, yet the suspension will be extended only two thirds of an inch beyond static. The outside wheel will be compressed two thirds of an inch from static. The average displacement of the two wheels, from static, will be zero.

> **"ROLL DISPLACEMENT WILL BE TWO THIRDS OF AN INCH PER WHEEL"**

We may say that in this situation the rear suspension is *saturated* in terms of load transfer; it has absorbed all the load transfer that it can. Any further load transfer must be absorbed by the front suspension alone. This implies that the inside front wheel will lose load, but that load will not go to the outside rear; it will go to the outside front. The total load on the front wheels and the total load on the rear wheels cannot change.

Remember, though, that we made a number of simplifying assumptions here: purely lateral acceleration; no bumps; no banking; no geometric anti-roll or pro-roll; no aerodynamic downforce. In the real world, any combination of these might be present, meaning that we could very well have data acquisition traces showing an inch of compression from static on the outside rear.

To know how much added load we would need to get that added one third of an inch of ride compression, we would need to know the rear suspension's wheel rate in ride as well as in roll. The required extra load wouldn't necessarily be 200lbs. If the wheel rate in ride were 300lb/in, we'd have that condition (100lb/wheel divided by 300lb/in = one third of an inch/wheel).

If the only factor compressing the rear suspension is banking of the turn, and if the tyres are racing slicks with a coefficient of friction around 1.30, we'd need about a 25-degree banking to generate 200lb of extra load. A banking around 35 degrees would do this without the tyres generating any cornering force.

If the turn is flat, and the only factor compressing the rear suspension is aerodynamic downforce, we'd need 200lb of that at the rear axle if the wheel rate in ride is 300lb/in. If the wheel rate in ride is less, these values decrease. If the wheel rate in ride is greater, the values increase.

The suspension geometry can generate a downward jacking force. This would be most likely in a lowered strut-style suspension, when most or all of the load is on the outside tyre. In most cases, this will not be enough to compress the suspension a third of an inch unless the ride rate is very soft, but the effect could add to others to produce that much compression.

Forward acceleration will usually compress the rear suspension. In a front-wheel-drive car, it always will. We think of steady-state cornering as purely lateral acceleration, but actually there will be a car-longitudinal (x-axis) component, even at constant speed, because of the car's attitude angle or drift angle.

Since any or all of these effects can be present, it is entirely possible for the rear suspension to be compressed more than we would calculate for pure cornering on a flat surface. But something has to add ride compression for the condition described here to occur. RE

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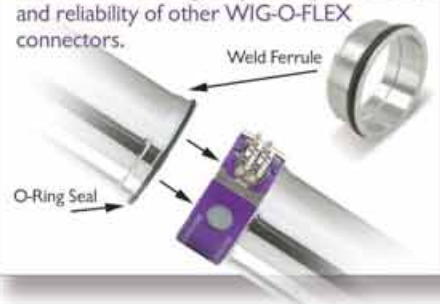

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