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Racecar engineering™

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20 YEARS OF INSIGHT

FORMULA 1 TECH UPDATE
Latest developments as the new season gets underway

ACCELERATING RACECARS
Bringing traditional analysis to bear on anti-effects

SUCCESS STORY
We reveal the greatest designer, car and innovation of the last two decades

INDYCAR 2012
WHICH RADICAL CONCEPT WILL GET THE GREEN FLAG?

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Damper ratios and how to use them

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This is it then – the 20th anniversary issue of *Racecar Engineering*. In absolute terms, it is a very short length of time but, such is the pace of life in motorsport, it seems like a lifetime. While preparing this month's edition, we had occasion to look at back issues of the magazine and, predictably enough, it brought home just how much things have moved on in the sport over the last two decades. At the same time, it was pleasing to see a number of familiar company names and individuals that were present in those early issues are still around now.

There is another common thread that runs through virtually the entire history of *Racecar Engineering*, and that is Tony Tobias. Variously known as the 'human dynamo', '10,000-volt man' or simply 'TT', the irrepressible Mr Tobias has been selling advertising on the magazine, promoting it at trade shows, exhibitions and motorsport events, and competing (with distinction) on behalf of the title in his beloved karting events virtually since he joined forces with another significant figure in the publication's history, Quentin Spurring. It therefore seemed entirely appropriate that, in marking this milestone, we ask Tony, Quentin and my predecessor in the editor's chair, Charles Armstrong-Wilson, to contribute some reminiscences concerning their time with the magazine. We also requested they cast their votes for what they consider to have been the most significant designer / engineer, car and technical innovation of the past 20 years. We'd be interested to your thoughts on their choices.

It only remains to say that we sincerely hope you enjoy celebrating 20 years of *Racecar Engineering* with us.

EDITOR
Graham Jones

For more technical news and content go to www.racecar-engineering.com/news

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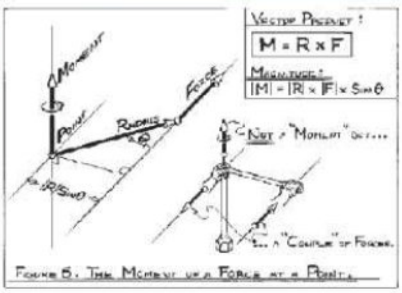

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INDUSTRY UPDATE

FORMULA 1

Hispania Racing Team rolls out new F1 Dallara

Last minute debut for former Campos outfit

THE LAST OF this year's F1 entries to be unveiled made a dramatic start into Formula 1 with its first laps of any circuit taking place in Practice 1 at the recent Bahrain Grand Prix.

HRT, which was previously named Campos Meta 1, is owned by Spanish businessman Jose Ramon Carabante, who bought out former owner Adrian Campos. Running the Valencia-based operation is one-time Force India team principal, Colin Kolles: 'While we are a new team in the paddock, we will be very proud to stand alongside such legendary names as Ferrari, McLaren, Williams and Lotus, as we hope to build our own reputation in the coming years.'

The team's first car, the HRT-Cosworth F110, looks an extremely neat and tidy design, as you would expect from Dallara. It has a lower nose than most, not dissimilar to that of fellow new entry Virgin's car. The join between the nose and chassis, however, owes more to Red Bull, with raised lumps on the outer corners, while the forward leg of the lower wishbone is mounted on the v section under the chassis. The HRT's front wing is three-piece, with a dramatically lowered main plane.

LAT

The HRT Dallara F110 made it's track debut at Sakhir

Sidepods are beautifully sculptured, with undercut leading edges, while the air intake on the engine cover, which slopes back rather than leading into a now fashionable shark fin, is nicely done, allowing for a clean air flow to the rear wing. Interestingly, the engine cover approach is similar to the other new teams' cars and that of the Williams – all of the teams using Cosworth engines, that is.

> **RACECAR SAYS...**
>
> **IN A YEAR WHEN being kind to your rubber is going to be crucial, it will be interesting to see if Dallara's GP2 experience with Bridgestone will benefit it in F1.**

While the car is far from adventurous in its design, Dallara will hope to benefit from its experience with Bridgestone rubber with its GP2-spec cars over the past five seasons, so HRT may prove to be a team to watch as the season develops.

Meanwhile, even though the team is brand new – and it's making use of two drivers who are novices at an F1 level – there is plenty of pedigree on the pit wall, including technical director Geoff Willis (who has wide F1 experience with Red Bull, Honda, Leyton House and Williams), Jacky Eeckelaert (formerly of Prost, Sauber and Honda) and Ben Agathangelou (formerly an aero' man at Tyrell, Benetton and Red Bull). Toni Cuquerella, a race engineer for Robert Kubica at BMW Sauber, is also on the squad.

How the new teams performed

JUST THREE OF the four new teams that were meant to be on the grid for the Bahrain Grand Prix made it to the Formula 1 World Championship opener. Here's how they got on...

LOTUS

This was the best of the new teams in terms of reliability and, while it was just a little down on the pace of the Virgin in qualifying, towards the end of the race Heikki Kovalainen was lapping within two seconds of Nico Rosberg in the fifth place Mercedes – his was the only new team-entered car to finish the race, although the other Lotus was classified in the final standings after retiring late in the race with hydraulic issues.

***RE* opinion: 9/10 – strong debut**

VIRGIN

The famously CFD-only Virgin certainly looks neat and was quick too, one of them lining up as the fastest of the new cars. However, the reliability issues that have dogged the team throughout winter testing returned – hydraulic problems seeing to one car (a recurring theme) on lap three, while the other went out with a gearbox glitch.

***RE* opinion: 5/10 – must sort out reliability**

HRT

A brave effort for the re-named Spanish squad and its new Dallara (see lead story above) and, while it was outside the 107 per cent of the quickest car's time once used as a qualifying requirement, it was still a remarkable effort, given that the car had not turned a wheel until Friday practice. Neither car finished, but the Bruno Senna car did last longer than the Virgins, before succumbing to a broken radiator. The other car was crashed earlier in the race.

***RE* opinion: 7/10 – did well in the circumstances**

The fourth team, US F1, has now failed in its bid to race in F1 in 2010.

SPORTSCARS

Audi's nose job

AUDI HAS UNVEILED a dramatic new split nose version of its R15 turbo-diesel LMP1 car, with which it hopes to win back the Le Mans 24 Hours crown from Peugeot this year.

The nose job, which is reminiscent of the approach taken by Red Bull in Formula 1, is part of what looks like a low-drag set up for Audi, although some of the modifications to the car are a result of regulation changes and also of a protest from Peugeot regarding the aerodynamic package on last year's R15.

Audi Sport head of technology, Martin Mühlmeier, said of the recent modifications: 'Due to the reduction of engine power as a result of the regulations, we have tried to make the car's aerodynamics even more efficient than before, and to improve the Cd value and downforce parameters.'

Mühlmeier added: 'After Le Mans 2009, our specifications for the R15 plus listed about 20 key items. Efficiency and reliability were at the top of the list, but we also looked at details like improved night time lighting of the track. We were able to meet this wish of the drivers with a new headlight concept.'

The 'R15 plus', as Audi calls it, also has a modified fuel tank and cooling system, while the 5.5-litre V10 TDI engine has been tweaked to meet with the smaller air restrictors and reduced supercharging pressure required by the new regulations. 'Our objective was to keep power loss to a minimum, despite the limitations imposed by the regulations,' said Ulrich Baretzky, head of engine technology at Audi Sport. 'We managed to do that through a lot of detailed work.'

The new R15 plus is a study in detail design to keep the car ahead of the regulations

BRIEFLY...BRIEFLY...BR

ATLANTIC CANNED FOR 2010

One of the USA's best known single-seater categories, Formula Atlantic, has been scratched for this year, the organisers citing a lack of entries as the reason. Formula Atlantic suffered from thin grids in 2009, with fields of just 10 cars taking part in the final races of the season, and the outlook for this year looked little better. However, the organisers insist that the series is merely 'on hiatus' until the economy improves and that Formula Atlantic, which has been a part of the US race scene since 1976, will return to US tracks in the future.

SOME-FIN FISHY

LMP1 and LMP2 prototypes are to sprout long engine cover 'shark fins', as modelled by many of the current generation of Formula 1 cars, for next season. The exact dimensions of the fin have yet to be revealed, but it is believed they will be at least as high as the top of the rear wing. The wing is to aid stability and to help stop LMP cars taking flight after they have gone into a spin.

GT2 POSTPONED

The FIA GT2 European Championship has been called off for 2010 due to a lack of entries, although it is hoped that it will run in 2011. GT2 previously ran as a class within the FIA GT Championship alongside GT1 but, with the formation of the new GT1 World Championship this year, GT prime mover Stephane Ratel had planned that GT2 was to become a stand alone series. However, that plan has come to nothing and for this year a one-off GT2 European Cup is set to be run within the Spa 24 Hours instead.

SEEN TRUCKING FUELS

Some of the NASCAR Truck Series teams are now using a new dry break fuel filler system, which will become mandatory in the Truck Series this year and, if successful, will also be used in Sprint Cup and the Nationwide Series. Although more expensive than the current system, it means a 'catch-can man' is not needed to catch excess fuel spilled from the overflow vent hose as the new system is self-venting. However, the device is slower to fill than the old dump-can version so most teams have only used it at the larger tracks this year and it's seen as a disadvantage at the short tracks. Safety and eventual cost savings are cited as reasons for the system being introduced.

WATCH THIS

To celebrate Cosworth's return to F1 this year, here are a couple of films to show you how the company went racing some 30 years ago...

Go to: **http://www.racecar-engineering.com/vids**

• MORE NEWS ONLINE AT WWW. RACECAR-ENGINEERING.COM

NASCAR

Sprint Cup spoilers ready for action

LAT

The contentious rear spoilers have been pronounced ready for a roll out at Martinsville

NASCAR SPRINT CUP teams recently tested the series' new spoiler at the Talladega Superspeedway.

The spoiler, which replaces the rear wing on the Car of Tomorrow, was tested by 24 cars at Talladega – the first time it had been run at a restrictor plate track – and in several different set ups as teams tried to find the perfect balance for drafting and drag levels. The cars started with a 4.5in tall, u-shaped rear spoiler that included two 12in extension flaps on either end. By the time the test ended the flaps had been removed and the spoiler narrowed two inches from its original 64.5in profile.

NASCAR pronounced itself happy with the spoiler, which has now been tried out on every type of track the series visits, and has decided to debut the device at Martinsville. It has supplied teams with a number of spoilers fixed at 70 degrees with a 4in height to be used at all tracks but superspeedways. The ruling body had yet to determine the final configuration of the spoilers for the biggest and fastest tracks at the time of writing.

Speaking at the test, NASCAR vice president of competition, Robin Pemberton, said: 'The feedback was the cars were stable [in drafting] but the closure rate was a little too much at certain points.'

The shark fin strip the cars run with at Daytona, and at the Talladega test, will also be mandated this year to help stop the cars getting airborne should a car get sideways.

Teams also tested a variety of restrictor plates at Talladega in response to excessive speeds – some reports claiming cars hit 210mph when in the draft.

BRIEFLY...BRIEFLY...BR

LOTUS TO ENTER INDY, TOO

IndyCar team KV Racing now has announced a commercial and technical tie up with the Lotus brand and will run its Takuma Sato-driven car in the famous green and yellow livery that has recently returned to Formula 1. 'It's only fitting that as the Lotus Racing name re-enters Formula 1, we will also race and innovate again in IndyCar,' said Group Lotus CEO Dany Bahar. 'The Lotus name will, once again, compete in the top two open-wheel racing series for the passion and enthusiasm of car fans around the globe.' The Lotus name was last seen in high-level US single-seater racing in the 1960s, when Jim Clark won the 1965 Indianapolis 500.

GARAGE SALE

The assets of the A1 GP Championship, which collapsed due to financial problems in the autumn of last year, have been put up for sale by the administrator and liquidator acting for the championship's bosses. The sale includes 20 of the Powered-by-Ferrari cars, as well as 10 of the first generation Lola-Zyteks. Maserati and Ferrari course cars are also to be put under the hammer, along with spare parts and team equipment. For more information go to www.go-dove.com

MERCEDES-BENZ SLS 63 AMG

LAT

The racing might have been dull at F1's season-opening Bahrain Grand Prix but the safety car was anything but. The new Mercedes-Benz F1 course car is based on its gullwing SLS 63 AMG, and the 571bhp supercharged V8 supercar is said to be the fastest F1 safety car ever. Maybe scrambling this once or twice during a race might spice things up a little...?

SEEN GP3'S FIRST TEST

LAT

The new-for-2010 GP3 car has been testing at Paul Ricard, with each of the 10 teams running its racecars for the first time. So far, the teams' response to the car has been positive. Trevor Carlin, team principal at Carlin Motorsport, said: 'It's been a really encouraging first step for us in GP3. We've been very impressed with the car – GP3, Dallara and all technical partners have done a fantastic job. The feedback from our drivers has been [that] the car is well balanced with a lot of high-speed grip and very driveable.'

Good Things Come in Small Packages

After extensive on-track and laboratory testing, Tilton Enginering have developed brake fluids that endure the most rigorous racing conditions. In fact, TSR-1's extremely high 328 Celsius dry boiling point is unmatched by any other brake fluid currently used in racing, virtually eliminating the possibility of vapor lock.

TSR-1 and TBR-1 racing brake fluids are packaged exclusively in small 250ml bottles. Besides being easy to handle, the convenient 250ml bottle helps to reduce the amount of wasted fluid. Unlike 500ml and 1 litre bottles, where unused fluid is left to absorb moisture from the atmosphere and lower its boiling point, Tilton's 250ml bottle insures that little fluid is left over after filling brake system. As a result, brake fluid expenses are reduced significantly over a racing season.

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Typical Dry Boiling Point: 328˚ C (622˚ F)

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FORMULA 1

Bahrain breakdown

The much-anticipated 2010 Formula 1 season started with several legality issues and a batch of new parts not yet seen in testing. Here's some of what we saw

LOTUS

As the newest of the new teams on the gird, with just six months to prepare the cars for the first race, Lotus made a good showing at the Bahrain GP. The team was alone the amongst the new teams, having both reliability and new developments for the first race. Throughout the weekend the T127s ran with mini winglets added to the rear wing. These 15cm wide winglets sit in a zone with the rear wing regulations that allows more than two closed sections. As such, the middle span of the wing comprises both the winglet and a slot in the main plane, totalling five sections in this area. Lotus did try a shark fin attached to the winglet briefly on Friday in practice, but did not continue with it on track.

FORCE INDIA

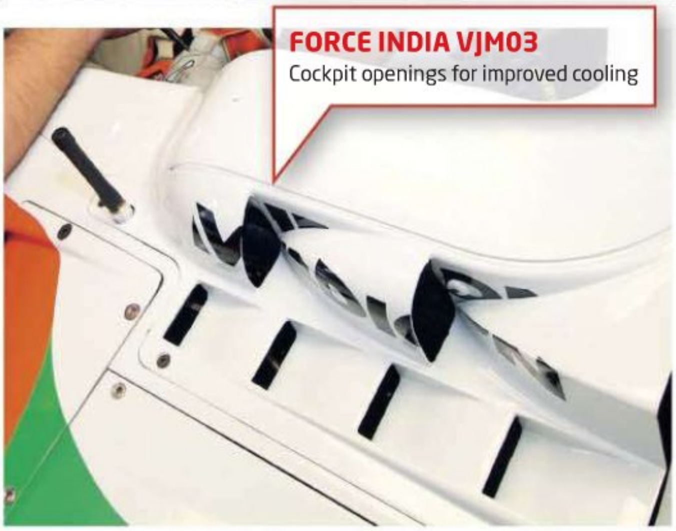
Force India completed the Barcelona test with a completely revised diffuser and beam wing set up. The beam wing was no longer split in the middle, but instead hooked up and over the crash structure to align it with the tall double diffuser. This combination was raced at Sakhir and was joined by a variety of cooling options: outlets in the shark fin; holes around the rear suspension; openings in the front of the sidepods and the increasingly popular cockpit openings. These cockpit openings sit outside the exclusion zone for sidepod openings and, being close to the radiators, provide an efficient outlet for hot air. In Force India's case, these openings comprised both a rear facing vent and a series of louvres.

WILLIAMS

Friday's practice session saw Williams conduct further testing of its blown rear wing assembly. This wing takes the 15cm slot inlet in the front of the main plan and diverges to span the full width of the wing. The team even went so far as to conduct tests with flow visualisation paint applied, to show the complex surface flow under the wing.

Neat features abound on the FW32, one being the way the rear wings connect to the diffuser. Rather than using a simple plate, the team have developed a series of five small vanes shaped to allow the airflow passing between the wheel to expand behind the car. Elsewhere, the snowplough turning vane is far more complex than the launch version, or indeed the Brawn 2009 device it is inspired by. The vane is mounted to the front splitter and has an opening in the middle to allow airflow to pass through it, while still creating the vortices that are directed under the floor to feed the diffuser.

LOTUS T127
Mini winglet on the rear wing



FORCE INDIA VJM03
Cockpit openings for improved cooling

WILLIAMS FW32
Slotted rear wing

+ TECH EXTRA
www.racecar-engineering.com/f1

Further insight on the opening round of the 2010 F1 championship can be found on the *Racecar Engineering* website at racecarengineering.com/scarbsf1

Read more on the following:
- McLaren's F-vent
- Renault's diffuser
- Mercedes' new nose
- Ferrari's sidepod openings
- Red Bull's exhaust

ELECTRONICS

BOSCH DASH DISPLAY AND LOGGER

BOSCH HAS RELEASED its new DDU8 dash display and C60 logger. The DDU8 display integrates a programmable full colour dashboard display with a data logging system designed specifically for motorsport applications. The device allows for synchronised acquisition and visualisation of engine data from the ECU, and chassis data from up to 24 analogue and four digital input channels. Recorded data from the internal 2GB flash memory can be downloaded via either high-speed ethernet or wireless connection, with the BT60 burst telemetry system. The C60 data logger offers all the advantages of the DDU but without the visual display.

See www.bosch-motorsport.de for more information

HARDWARE

TOOL BOX

F1 TOOLS LIMITED has over 20 years experience in the sale of tools and motorsport merchandise to professional technicians, race teams and motorsport enthusiasts. The company's range includes: limited edition branded toolsets, tool boxes, branded merchandise, motorsport merchandise and collectable technicians tool boxes and tool storage solutions. All the F1 tool boxes come with quick release ball bearing track slides, gas-filled cylinders for easy opening, double-wall construction and all products have either a extended or lifetime warranty.

See www.f1tools.com for more information

ELECTRONICS

ELECTRONIC RAIN LIGHT SWITCH

CARTEK HAS RECENTLY released a new dedicated rain light switch, offering three pre-defined modes of operation. By utilising a small microprocessor in the toggle switch drivers are able to select whether the light is off, on or flashing, the flashing option allowing drivers to warn cars behind if they are stationary on track. The switch will work with any FIA-homologated LED rain light, and is easily integrated into existing wiring systems.

See www.cartek.biz for more information

HARDWARE

DIMENSION UPRINT

STRATASYS HAS RELEASED its latest 3D printer, the Dimension uPrint Plus, which offers cost-effective rapid prototyping in a compact package. With a footprint of 635mm × 660mm and weighing 70kg the printer can be accommodated in most office workspaces, making it ideal for design offices or small engineering firms. The printer has increased capacity over previous models, with an available build envelope of 203mm × 203mm × 152mm, whilst two resolution settings, 0.254mm and 0.330mm, are available.

See www.dimensionprinting.com for more information

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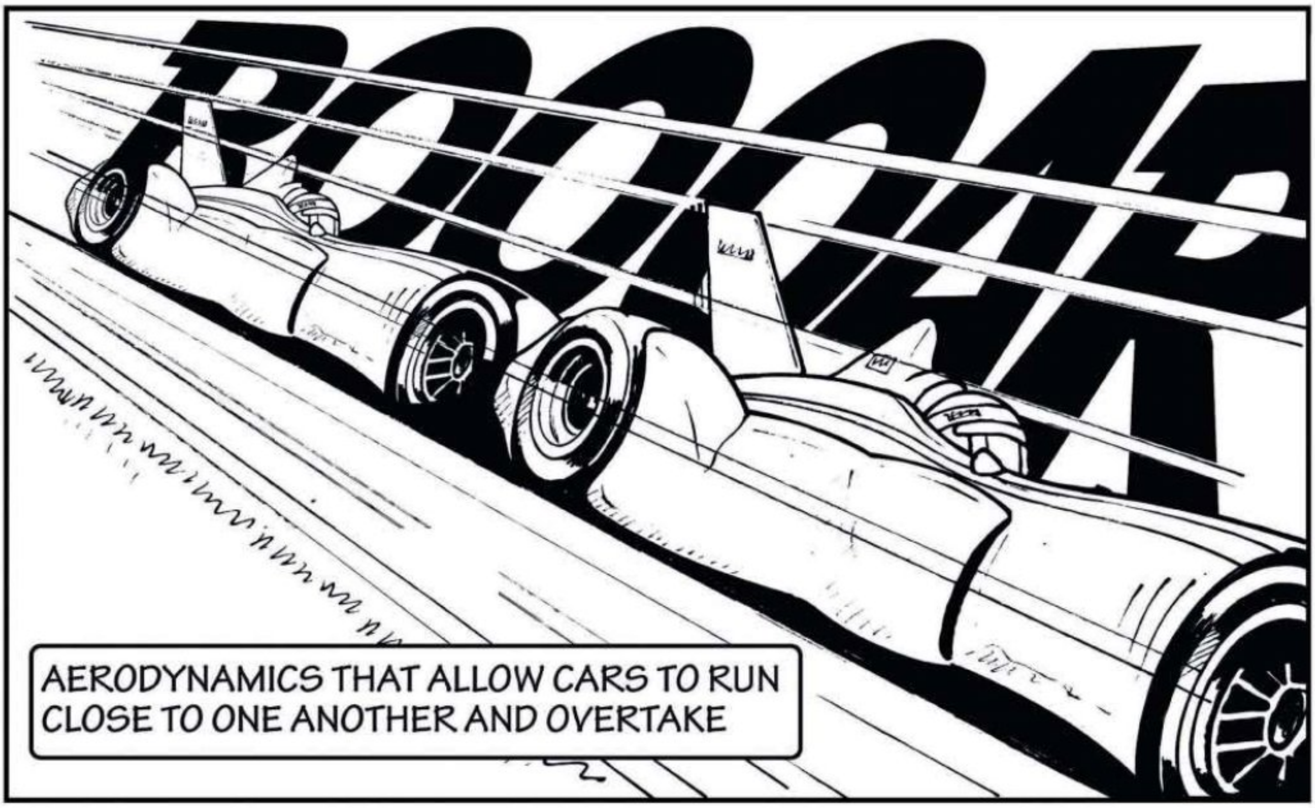
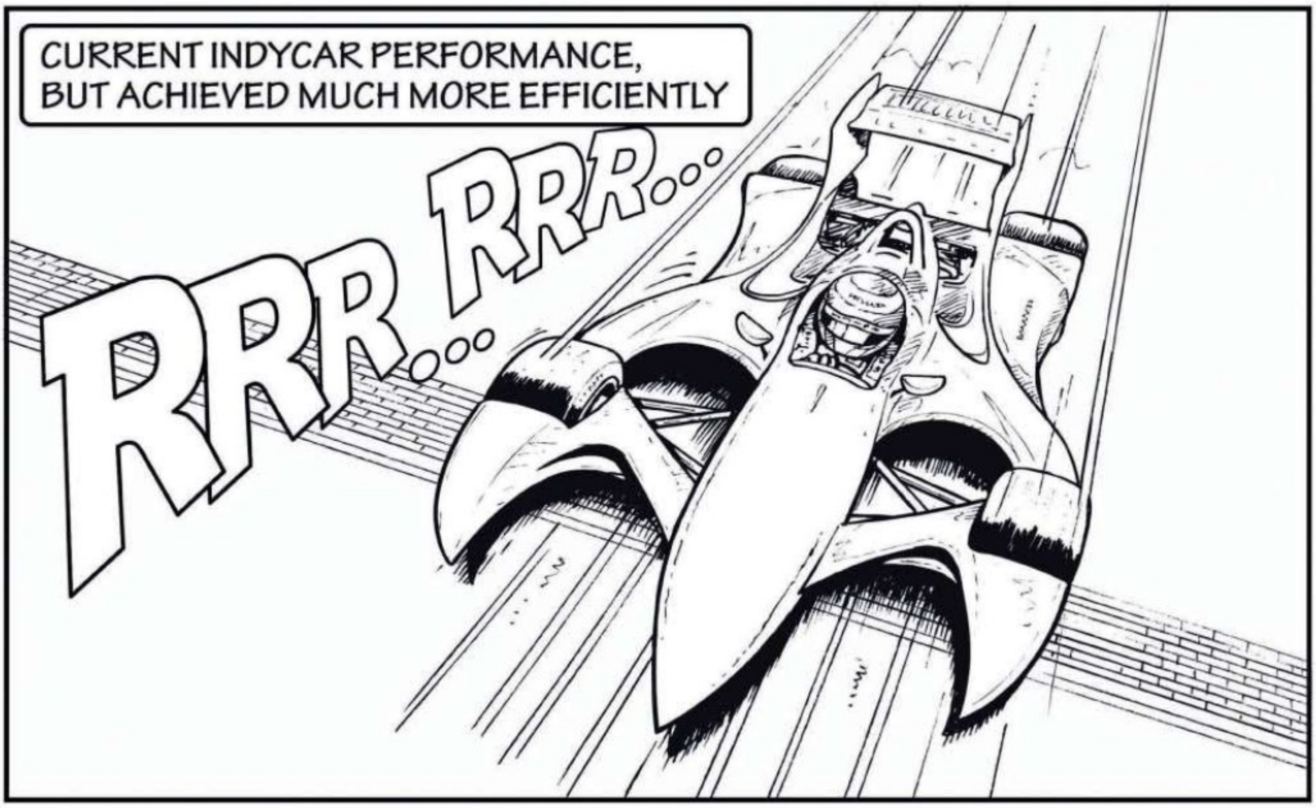


Indy cars of tomorrow



Artwork: Jim Bamber

IndyCar is heading for the most radical shake up of its life. We look at the current concepts being put forward for its 2012 re-birth

BY IAN WAGSTAFF

Dallara, Lola, Swift, DeltaWing, BAT and maybe even others – if all the companies pitching to create the next Indy car were to appear on the grid together then the glory days could be back. However, economics dictate that is not going to happen and what seems imminent is a competition between the evolutionary and the revolutionary to decide what the future holds.

The publication by the Indy Racing League of its requirements and subsequent announcements from Dallara, Swift and Lola in early February were followed by the news that former Indianapolis-winning designers Bruce Ashmore, Alan Mertens and Tim Wardrop were combining to present their own bid – the BAT project. If the IRL decides wrongly between them, the Indianapolis 500 itself could be in jeopardy. Get it right though and its currently maligned series could indicate the way ahead for much of motor racing. At the time of writing the League was not going to indicate which way it was leaning, although the word around Indianapolis was that it probably favoured staying with what has been described as the 'comfort zone' option ie a new Dallara-Honda V6.

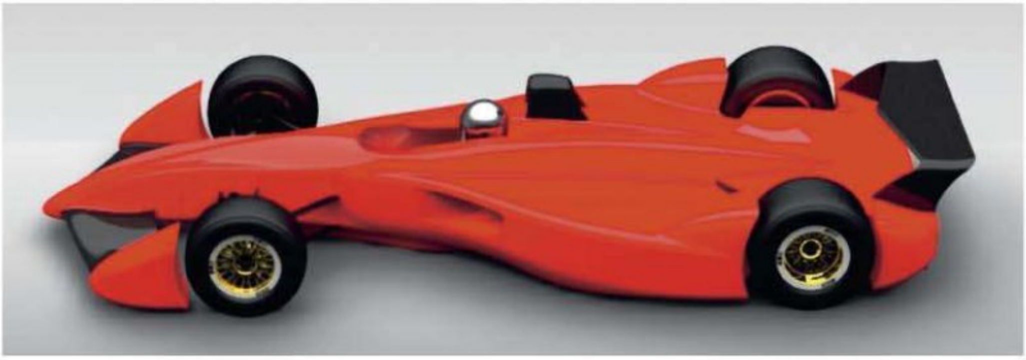
ONLINE POLLS

The fans seem to favour neither Dallara nor DeltaWing. Online polls issued before the BAT announcement indicated a close run thing between Swift and Lola. DeltaWing was the next most popular, but only favoured by just over 10 per cent, whilst Dallara – perhaps unfairly blamed by fans for the current sterile conditions – was the least popular.

The IRL acknowledges the desire for a multi-chassis formula although, of the current bids, only the DeltaWing project (described in *Racecar Engineering* V20N4) would allow for this. Swift's chief design engineer, Chris Norris, believes that current economics do not support anything other than a spec formula. 'We would welcome the opportunity to compete in a series with multiple chassis and multiple engine manufacturers. However, this would bring an increase in the cost of participation.'

'I hope that there could be more than one supplier,' adds Dallara chief designer, Andrea Toso, 'but I think the economy is not strong enough.'

Each of the bids has its pros and cons. Dallara is the incumbent and has enjoyed a good working relationship with the governing body, but people are looking for a change. Swift is an indigenous supplier and is highly experienced in manufacturing for spec series, if that is the way it must go, but it has never built a car for the Indianapolis 500. Lola, which has the longest Indy car history of all the bidders, has both its original idea of two bodywork styles and the fact that its chassis could also be used for Indy Lights. BAT has an unrivalled team of Indy-winning designers and a plan to bring more than just Indy car work to Indiana, but it must be able to persuade the IRL that it can establish itself as a manufacturer. Then there is DeltaWing, which has the backing of the teams and the possibility of multiple chassis suppliers and would get away from the spec series concept, but would perhaps be a step too far.



Dallara's three concepts range from a mild update of the current car (top) to a version with a DeltaWing-style rear end (bottom). The third design (middle) is thought to be a serious candidate, despite disapproval from fans

DALLARA

The Italian company has shown three very different designs, indicating that it is prepared to be conservative or radical. One is simply an evolution of the current car with the same, distinctively pointed nosebox and architecture, although the rear bodywork is wider than the wheels, offering increased protection. With this suggestion, the constructor is obviously playing safe with a nod to improvements in safety. The front wing end plates would also appear to provide greater protection for the front wheels. Arguably, the main visual difference between this and today's car is the lower engine cover with its 'shark's fin'.

The second design is, observes Toso, 'more edgy. It has a sharp look, but again with increased protection for the driver.' Gone is the pointed nose of the existing car but, like the first design, the front wings are being used for protection. The sidepods, which slope outwards, dominate the design, guarding

Swift's designs are all based on the proven 017.N Formula Nippon monocoque and feature a number of popular design elements such as an exposed engine and information lights, which let fans know car position and fuel load. One thing that may go against Swift is its intention to build the cars in California instead of Indianapolis

against interlocking wheels and with a sculptured feature that protects the rear tyres. It certainly looks different, but whether it is attractive to the fans is open to question. The polls would suggest not.

The third design is more revolutionary. With the delta shape of its bodywork it has echoes of the DeltaWing but, unlike Bowlby's design, the front wheels are exposed in the conventional manner, but with pods at the end of the front wings for wheel protection. Likewise, there is protection for the rear wheels that is sculptured into the enveloping bodywork.

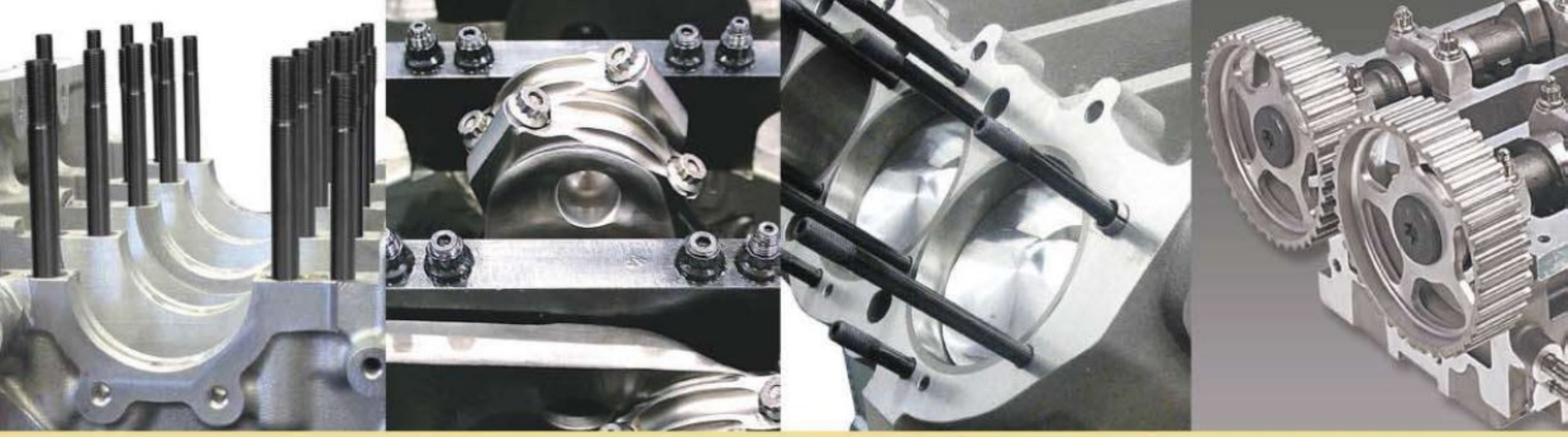
Toso has long pointed out that something had to be done about the increasingly evident problem of interlocking wheels. In response to this, all three Dallara proposals have bodywork that is slightly wider than the outer wheel rim. In order to prevent lift off in a straight line, caused when a car touches the one in front of it, the shape of the underwing has been designed to so that an 'attacking car' is forced down, not up. By properly shaping the upper body, Toso also plans to avoid cars tipping over when they hit the wall after a loss of control or having been hit by another car. 'With an existing design you can only do a patchwork, but with a new one you can take into consideration all the past experiences,' he said.

Whether the engine should be a stressed member or not has become a point of contention for most concerned. Toso is adamant that it should: 'If the engine is not stressed you have to connect the transmission to the monocoque in another way, so you need a frame – and why do that?' He does not, though, discount the use of a turbocharged in-line four, as long as it is a stressed member. He believes this would have to produce at least 570bhp (considerably higher than DeltaWing designer Ben Bowlby believes would be needed for his concept), meaning high turbo pressure and the consequences that has on the life of the engine. Alternatively, he sees a V6 with a lower turbo pressure.

SWIFT

'We are open to working with the series organisers to develop not only the car that they want, but also the car that they need... and on previous projects we have found that sometimes these are not always the same thing,' says the company's chief design engineer, Chris Norris.

Swift seeks to reduce the amount of downforce coming from the wings. Whether this means an overall reduction in downforce or a change in the balance of where the downforces is created (wings or underwings) is still open to debate. The most conventional of its concepts features a downforce-reduced



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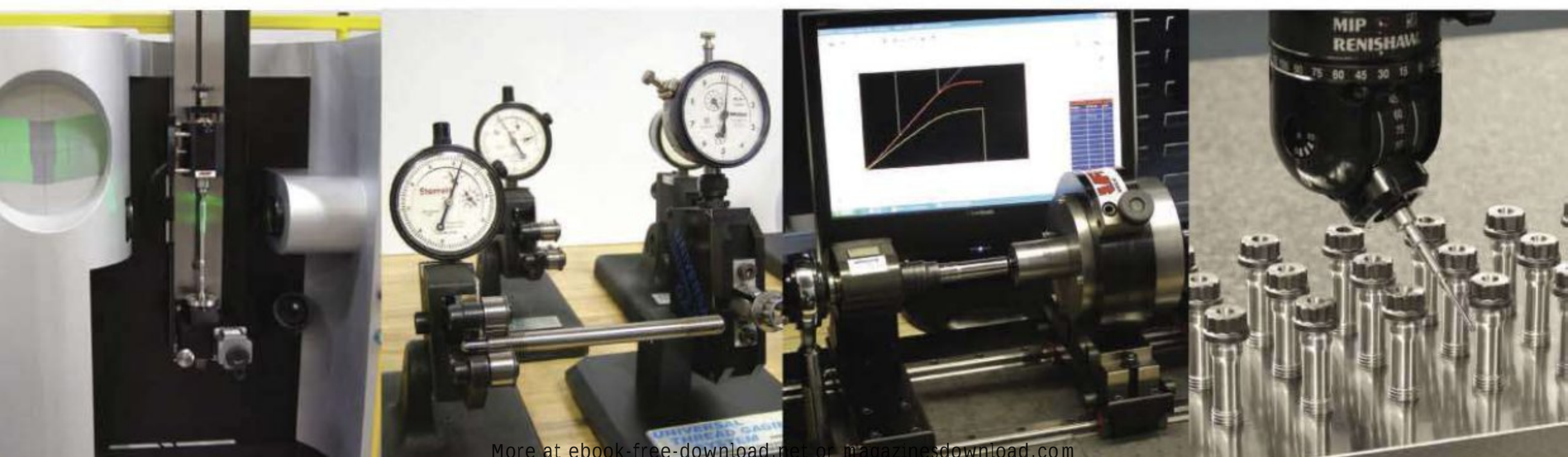

front wing. Some concession has been made to protecting the tyres, but not as much as with the other concepts. 'With this concept we wanted to bring back interest in the mechanical pieces,' says Norris. 'Nobody ever sees the wonderful engines we use. We felt it might be good to display some of the engine, perhaps the cam cover and the rear suspension.' On all three designs show so far, the engine is easy to see and one of the discussions at Swift is whether it needs to be quite this visible. A 'downside' to this approach would be that sponsorship area would be reduced.

One of Swift's concepts has a front wing approach designed to reduce drag, and also to reduce the lift generated by the front wishbones. One idea is to have wheel pods that attach to the uprights so they will turn with them. For future concept developments, Swift is now looking at further drag reduction, wheel protection and coming to a conclusion about its wing studies. Norris confesses that the design group has considered many wing ideas, but has yet to decide on which direction it wishes to head.

Swift's ideas also include bodywork that extends beyond the wheels, one concept more so than the other. 'The guard behind the front wheel is at a high level and the sidepod underneath provides an exit for the air to spill down the side of the car and from the radiator intake, similar to LMP cars with their exit ducts for the forward venturi behind the front wheels,' explains Norris. The aft body surface as it approaches the rear wheel deflects the air upward and provides a level of drag reduction. Likewise, the pods forward of the front wheels are a drag-reducing device, as well as being there to prevent tyre-to-tyre contact. Swift is also looking at guards behind the rear tyre for future developments.

One of Swift's ideas to improve the racing is what the company calls 'mushroom busters' – referring to the mushroom shape of the car's aerodynamic wake signature. These, which are already found on its Formula Nippon design, sweep away the vortices to create cleaner air for the following car. The effect achieved for the Formula Nippon was small and Swift believes it can be developed further for its Indy car. On the Formula Nippon the mushroom buster takes the form of a blade device mounted on the underwing to create a vortex that sweeps the upwash to the middle of the car and upwards with a view to leaving cleaner air for the front wing of the following car. Ongoing developments, however, could mean something very different for the Indy car.

Swift has joined the entertainment debate further with its proposal for 'Swiftlights' – an idea that takes the position lights of Le Mans cars a stage further. Light panels, made from 1mm thick clear plastic, that can be pixel addressable and able to indicate where the car is running. Other information can also be displayed, such as how much fuel is on board, or how much throttle or brake is being used.

As regards potential powerplants, Norris feels it is the engine manufacturers who will have to have their say on the installation, saying, 'this needs to be driven by them.' He points out that Swift has built cars with stressed, semi-stressed and non-stressed engines, but believes the IRL will call for a stressed engine installation.

LOLA

Lola has come up with a different approach in that it has suggested two aero performance-balanced cars that would be able to compete in close formation. The company has also has targeted a weight reduction to 1380lb (626kg) against the current 1540lbn (699kg). 'We have tried to understand what is important to the IRL. During our early discussions it was talking of having two engine suppliers within a one (chassis)-make series,' says Peter McCool, head of special projects at Lola Cars. 'When two chassis manufacturers lock horns, development costs go through the roof. The IRL wanted to cap costs, but it still wanted visual differences.' Lola, therefore, came up with the idea of a different body type for each of the two engine suppliers it was hoped would compete. Whichever engine manufacturer a team chose would then dictate the body style it could use. Although how many engine suppliers there will be is currently an unknown, Lola has stuck with the two-body idea to provide at least some visual variety.

Both bodies appear a logical step forward from current designs without appearing too wayward. Indeed, from the side the B12/00 brings back memories of CART in its heyday and Lola's IndyCar DNA is clearly apparent.

In theory, the only reason for choosing one bodywork over the other would be a preference for the look. 'We will match them in the wind tunnel across the entire ride height range,' explains McCool. 'If I were an engineer on one of the teams, I would try very hard to get an advantage

Lola has a proven track record at Indianapolis, and would set up a new facility in Speedway if it won the contract. However, feedback from fans suggests they feel the joint IRL and Indy Lights concepts are visually too conservative

> **"When two chassis manufacturers lock horns, development costs go through the roof"**

from one kit or the other, but there are ways of policing that.' Lola is proposing a series of aero blockers that the governing body can stipulate be run at certain races. These will be able not only to limit speeds where required, but also ensure that one body design does not gain an advantage over the other.

Lola intends its chassis to be suitable for both Indy Lights and IndyCar, with simple upgrades from one to the other. This would allow drivers and teams to step between the two championships and potentially to flood the Indy 500 with teams for qualifying. The current plan is that the Indy Lights cars would be supplied for the start of the 2013 season.

McCool: 'We believe what we have come up with is a step forward, but it may not be all that is required. Our solution is to have a wider front wing, so this is likely to be the first thing that is damaged. There is also a structure at the back that the following car will connect with. In effect these are bumpers to limit wheel-to-wheel contact.' The front and rear wings are also less aerodynamically important, so if a driver does damage his front wing or end plate, this will not destabilise the car as much it would have done previously. Structures in front of the rear wheels should limit front wheel to rear wheel contact, and the front leading edge of the sidepod has been moved forward for the same reason. However, as McCool says, 'It is hard to maintain the concept of open-wheel racing and not have the possibility of wheel-to-wheel contact.'

Close racing is another IRL requirement. 'We satisfy this,' claims McCool, 'by having the reduced effect of the front and rear wings. The majority of the downforce is generated by a large central underbody, which is less susceptible to downforce variations when following another car.' The Lola aerodynamics team has been working to find a minimum wake solution to promote more overtaking. Its concepts are designed to eliminate the vortex rings that fall off the back end of a car through the underbody and the rear wing endplates. According to McCool, 'Our CFD study already shows [these] will minimise the wake and makes its effect more manageable.'

McCool's scheme will accept both stressed and non-stressed units, but he underlines that it is always a problem to fit a road car-based engine into a racecar. 'There are a host of issues with oil systems, levels of fluid, the load going through the block etc. I'm not a fan of racing unstressed engines,' he concludes.

Lola admits it has also looked at a number of futuristic possibilities and has suggested that the best may be deferred to appear as a 'next iteration option'.

"It is hard to maintain the concept of open-wheel racing and not have the possibility of wheel-to-wheel contact"

BAT

The obvious feature of the BAT project is the experience of its partners who, over a 16-year period, were among the most influential of Indy car designers. The skills of Mertens and Ashmore are said to be complementary, the former being best known for his mechanical design ability, the latter for his aero work.

BAT's initial move was to meet with Indianapolis surgeon, Dr Terry Trammell and IndyCar's safety and technical directors. This enabled the team to establish the safety features of its design, in particular the cockpit and driver position. The goal has been to produce the safest cockpit available, while at the same time positioning the driver in such a way that he can drive the car in a more aggressive fashion. The design features the strength to sustain minor knocks, as well as stable aerodynamics to allow the cars to run closer together.

The wheels are protected from interlocking, although the design still retains a Coke bottle shape in the sidepods. The airflow path is directed underneath what Ashmore describes as 'sponsor-friendly' rear decking and towards the centre of the car, in order to facilitate overtaking manoeuvres. The downforce, meanwhile, is generated more from the stable centre body profile than the turbulent sensitive front and rear wings as on current single-seater designs.

The BAT design is one of the smoother flowing of the bids. Take Ashmore's 1990 Indianapolis 500-winning design, move forward 20 years and perhaps this is it. All the wheels are well protected, the forward ones between the end plates of the sculptured wings and a guard that protrudes from the front of the sidepod. The rear is enclosed front and back by the rounded bodywork, from which flows the integrated rear wing.

BAT has said that, if successful, it will design and build its entire car within a 30-mile radius of the Speedway. It already has a drawing office using the latest in CAD and CFD software, while an agreement has been reached with ChassisSim, which has developed a user-friendly Adams-type modelling simulation program. The team is also working on a further plan to expand the racecar industry that once thrived in the area. In this it hopes to offer more than just the factories that both Dallara and Lola have said they will establish in Indiana to meet the IRL's criteria and take advantage of a state subsidy that governor Mitch Daniels has indicated he may offer (Lola intends still manufacturing safety-related items such as the chassis and nose box in England). Swift, being a US company anyway, has fewer constraints, but does have relationships with Indiana-based suppliers, including Mark One Composites, which it would use for much of the composite manufacture.

The BAT design team is highly regarded, but the firm would have to outsource to produce the cars

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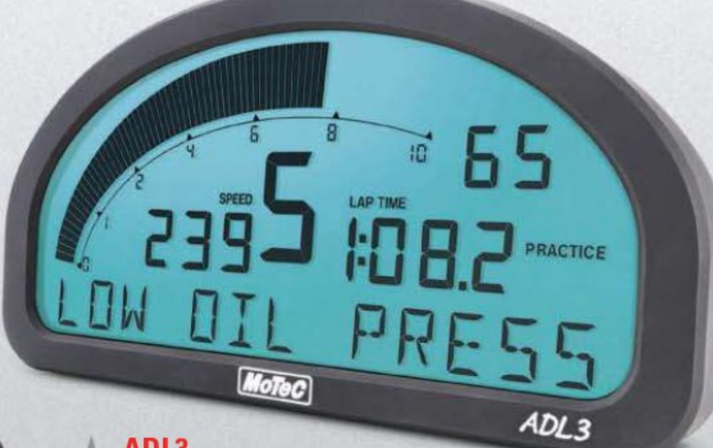

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Simon McBeath is an aerodynamic consultant and manufacturer of wings under his own brand of The Wing Shop – www.wingshop.co.uk. In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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Mapping the front end

A closer look at the Mannic's aero package reveals some surprisingly effective solutions

Photos: S McBeath

The front section of the test car may not look extraordinary but proved to be a very potent downforce generator

It helps to understand the effects of aerodynamic changes at either end of a racecar, whether the aim is to achieve maximum downforce, minimum drag or best efficiency. This month we continue our study of Nic Mann's home built Mannic hillclimb sports libre car and encounter some very interesting effects at the front end...

The Mannic arrived at the wind tunnel with a suspected forward downforce bias, something the first baseline run confirmed (see table 1 below).

The overall aim with the car was to increase downforce but improve the balance so that around 48 per cent of the total downforce was exerted on the front end, the car having a 50/50 static weight split with driver aboard. Last month we saw how a range of modifications at the rear enabled an overall downforce increase, along with achieving the desired balance. This month we look at the mapping carried out on the front end of the car. Although most of the changes involved either strengthening the front end or losing overall downforce to achieve a better balance, they all added to the understanding of the car.

The front end of the Mannic looks superficially like a Classic Clubmans' class nose, but the lower surface of the nose section is actually shaped like the underside of an inverted aerofoil section, so is in reality a wide diffuser running the full width of the car. Clearly, the flow from this will be affected by what is immediately downstream. In the centre is the chassis, and at the outer ends are the wheels, with a reasonably clear path between wheels and chassis, although suspension is outboard and driveshafts are present, too. To try to augment the flow through

TABLE 1

Baseline aerodynamic coefficients on the Mannic hillclimber, based on an estimated frontal area of 1.6m²

CD	-CL	-CLfront	-CLrear	% front	-L/D
0.764	1.507	0.855	0.653	56.71	1.97

TABLE 2

The effect of blocking the front louvres (results expressed in 'counts' relative to the baseline case), where a coefficient change of 0.100 = 100 counts

CD change	-CL change	-CL front change	-CL rear change	% front change	-L/D change
+20	-62	-a132	-69	-6.67	-0.13

FRONT DIFFUSER
This terminates at the rear of the nose section, with a vertical infill above that

PASSAGE OF AIR
These large louvres in the centre provide an exit route through the chassis for some of the air that has passed under the front splitter and diffuser

the centre section, attached to the chassis is a secondary splitter with a radiused leading edge and a faired cowling channelling air sideways and upwards. Small trim tabs on the upper trailing edge of the nose are also present, offering three adjustments: high, low and absent.

To test the effect of the central louvres in the front panel, they were blocked off with a piece of card taped underneath, and the changes to the coefficients are shown in table 2 on the previous page. It would appear that the louvres did indeed help the front end to generate more downforce and also to reduce drag slightly, despite the compartment beneath being cluttered with front differential, inboard brakes and springs and dampers.

PROFOUND EFFECTS

The little trim tabs were checked out next, and for such small devices these had profound effects. The baseline configuration featured the tabs on the 'low' setting, so table 3 (below) shows the effects of fitting them in the 'high' position, and of removing them altogether. Of all the configuration changes made during this session, this one was the most surprising, and the effect of these seemingly small adjustments deserves some thought. Essentially, the trim tabs were incredibly efficient at increasing front downforce, causing a commensurate decrease in rear downforce and a substantial shift in balance, with an increase in overall downforce. Not only that, they produced a decrease in drag. All plus points.

The only downside at this point was that the rear end could not be strengthened enough to balance the front with the trim tabs on maximum, but time will no doubt produce remedies to that. However, as was shown last month, it *was* possible to balance the car with the components available if the trim tabs were set to the baseline 'low' setting.

TRIM TABS
The front trim tabs are set to 'high' here

So what were the likely mechanisms by which these plates proved so beneficial? It seems probable they caused an increase in local static pressure on the upper surface of the nose section ahead of themselves, which would contribute to the increase in downforce. But one might expect this to be accompanied by some extra drag, too. However, we saw how downforce gains from the front wings of an F1 car did not affect drag at all (see V19N9) and, as such, generated useful increases in efficiency (-L/D). So, with this in mind, we might have expected minimal change in drag from the tabs. But in this instance there was an actual drag decrease. Perhaps then, an explanation for this is they reduced the mass flow over the car's upper surface, increasing the flow underneath. This mass flow increase under the nose section would explain the increase in front downforce and would also mean less mass flow encountered the rear wing, which could in part explain the reduction in rear downforce and also the net reduction in drag.

The final configuration change for this session was an alteration to front ride height, and table 4 (left) shows the results. The fairly large increase produced a marked decrease in front downforce, together with a significant balance shift. So at least we finished with no surprises!

Many thanks to Nic and Jason Mann for access to the Mannic, and to Chris Lewis and Ling Xiao for their assistance.

TABLE 3

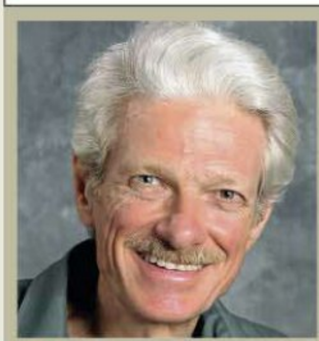
The effects of altering the front trim tabs (results expressed in 'counts' relative to the baseline case), where a coefficient change of 0.100 = 100 counts

	CD change	-CL change	-CL front change	-CL rear change	% front change	-L/D change
Remove trim tabs	+13	-60	-169	+108	-9.32	-0.11
Trim tabs to 'high'	-20	+30	+121	-91	+6.76	+0.10

TABLE 4

The effects of altering the front ride height (results expressed in 'counts' relative to the baseline case), where a coefficient change of 0.100 = 100 counts

	CD change	-CL change	-CL front change	-CL rear change	% front change	-L/D change
Raise front ride height by 14mm	-1	-121	-129	+7	-5.34	-0.16



FIRST PRINCIPLES

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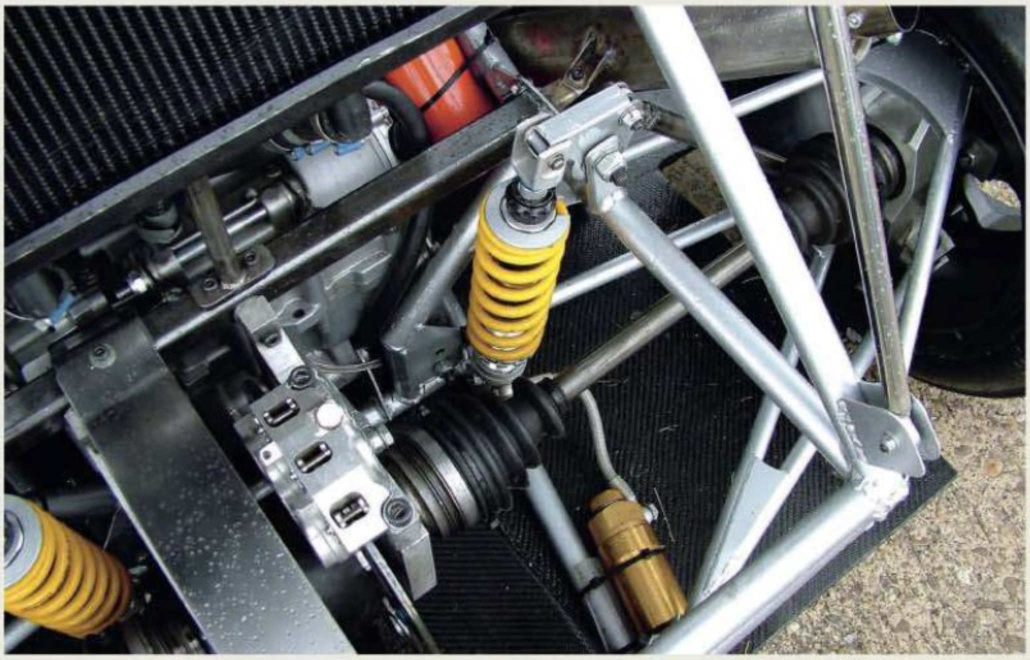


LAT

Off your rocker?

THIS MONTH:

Q1 Is rocker arm suspension with a 1:1 shock-to-wheel ratio a good idea/

A It depends on how it integrates with the rest of the car

Q2 What's the best way to locate a DeDion tube?

A With parallel arms

Q What is your opinion of rocker arm front suspension, where the top A frame continues inboard beyond the pivot point and has the shock vertical at the inner end? Space permitting, it seems a simple and effective system that minimises joints, levers and rods, while possibly achieving nearly 1:1 shock-to-wheel ratio.

In its traditional form, the layout does eliminate some parts and some wear points compared to push rod or pull-rod layouts. However, it requires a long piece loaded in bending, and doesn't lend itself to rising rate as readily as push rods or pull rods. Also, in most of the old cars using it the coilovers and the box structures containing them were situated by the drivers' ankles and would trap feet and legs in crashes. Coilover accessibility and shock cooling were also often not very good.

In most cases, getting a 1:1 motion ratio involves making the upper arms shorter than is really desirable from a geometry standpoint, although this will depend on the particular design.

It is possible to improve the structural efficiency of the control arm / rocker by making it a truss rather than a beam, usually with the truss structure below the pivot axis. In an open-wheel car, the car would then have similar appearance and aerodynamics to a pull-rod car.

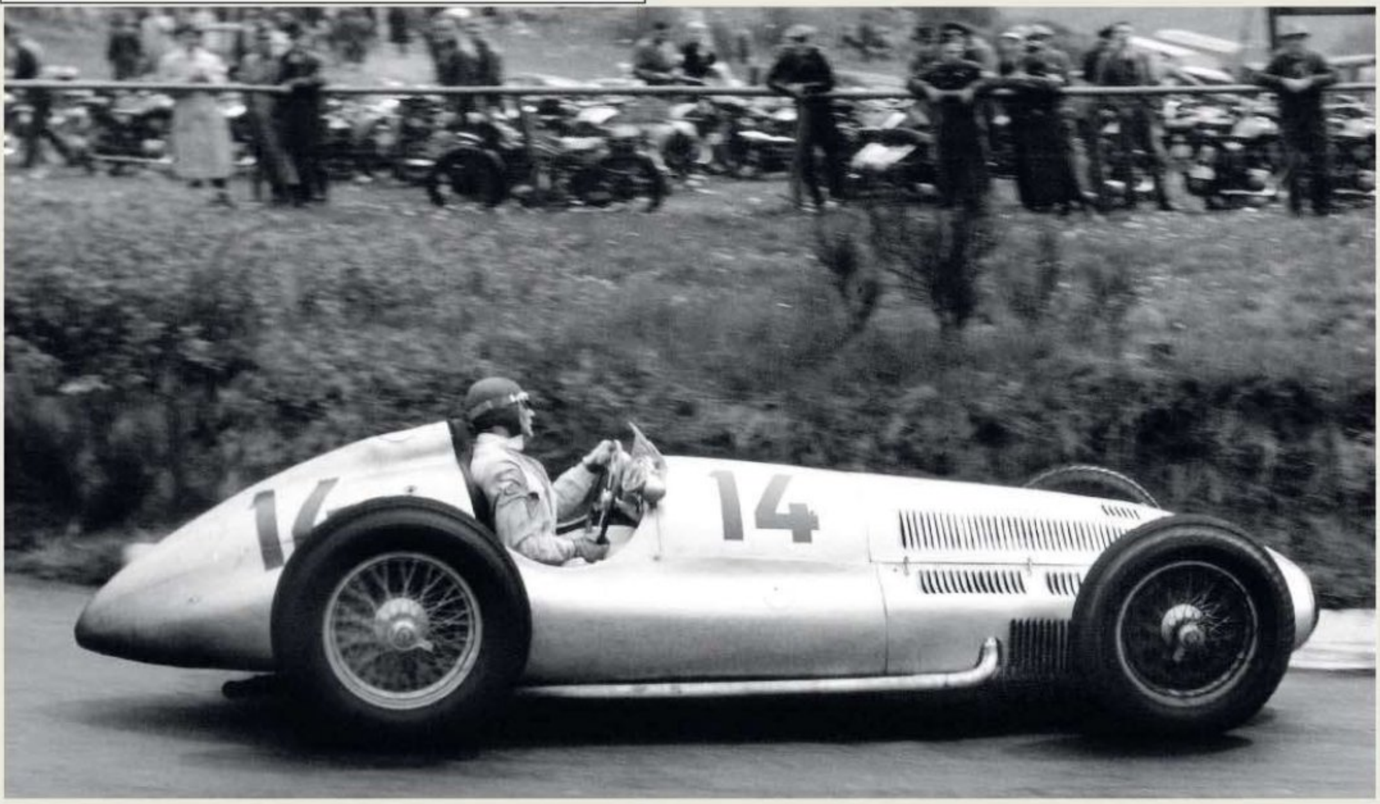
Or, if we want rising rate geometry, and if the upper arms are inclined considerably to get camber recovery in roll, and if we have room above the pivot axis, we will have a markedly v-shaped rocker in front view. We may then be able to add a compression member across the top of the v, from the upper ball joint to the upper coilover end, and have a truss structure that way.

> "doesn't lend itself to rising rate as readily"

It would even be possible to incorporate adjustability into such a design, rivalling that available from a conventional pushrod and rocker. The compression member would effectively be a push rod, of adjustable length, and the system could then perhaps be considered a push-rod system, but with the push rod and rocker more or less integral with the control arm, rather than separate.

This might offer a reduction in the number of wear and load points compared to conventional rockers, and maybe a small weight reduction, too. The reduced number of load points on the frame would be particularly attractive for tube frame designs.

Whether the whole concept would be advantageous depends on how it integrates with the overall design of the car.



DeDion tube design and location

Q I am trying to decide on the arrangement to locate a DeDion axle in an Autocross car with a transverse engine / transmission mounted directly in front of the axle. I plan to use a Watts linkage for lateral location. A single trailing arm on each side with a third central link does not seem appropriate because the transverse engine would dictate a very short centre link, so I am considering parallel trailing arms on each side. However, I have seen applications that converge the arms on each side to a single front mount. It seems to me that in this situation there might be bending forces applied to the arms when one wheel rises and / or the other falls. Perhaps these are not significant because the axle will have quite limited vertical movement. Any thoughts?

The simple answer is to go with parallel arms. Converging arms or hairpin-style ones with a single pivot will bind in roll, unless the DeDion tube has a swivel in the middle.

A swivel in the middle complicates the DeDion tube, but this was actually a feature of many designs when DeDion suspension was popular in F1 cars – for example the Mercedes W154. That car used a tube assembly that was rigid in bending and tension / compression, but not in torsion, and single trailing arms, with outboard brakes. Lateral location was provided by a roller in a slot machined into the back of the differential housing.

The Rover 2000 / 3500TC on the other hand used a tube that both swivelled and telescoped, so it was rigid only in bending. Lateral location was then provided by fixed-length halfshafts, eliminating the need for any plunge accommodation at the shafts, and the need for any additional lateral locating mechanism. Single trailing arms were used, and brakes were mounted inboard.

> **"Converging arms or hairpin-style ones with a single pivot will bind in roll"**

Both of these designs offer somewhat more than 100 per cent camber recovery in roll (ignoring tyre deflection), and a roll centre a bit higher than the halfshafts or the roller.

The Mercedes design afforded very ample anti-lift in braking, due to the combination of outboard brakes and single trailing arms. The Rover design does not have comparable anti-lift, despite similar side-view geometry, because on that the brakes are inboard.

Either of these designs could also have used four trailing links, and they wouldn't have to be parallel. With outboard brakes, that would permit having any desired anti-lift in braking, without significant bump steer, which is not possible with parallel trailing links.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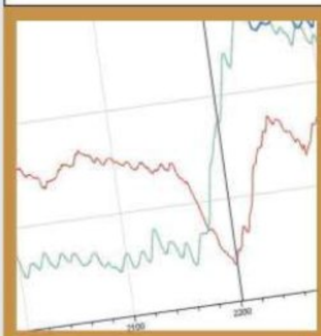


FIRST PRINCIPLES

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

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

Further speed anomalies

Part 2 of our insight into speed-derived data

In last month's Databytes we saw how an ill-positioned hub speed sensor can lead to spurious readings in the data. This month we will look at the area highlighted B in image 1 below. Here we see that the speed as derived from the hub speed sensor takes a large dip in this period relative to the GPS unit, but then suddenly jumps up to a non-believable speed, double what it previously was.

To investigate this, firstly we will fix the data trace such that we can compare the two speed traces in relative terms. We came to the conclusion last month the hub speed was exactly double within a certain speed range, so we can create a maths channel based on these conditions that results in an almost corrected speed trace, as shown in image 2. Note that this will not produce an absolute cut-off value due to the effects of logging rate and the sensor having the problem within a tolerance band. A more sophisticated algorithm to correct for this could possibly use this, combined with rate of change of signal, to correct the signal.

Following this mathematical conditioning of the channel allows us to overlay the traces from the GPS and hub speed and to see in more detail what the problem is. In image 3, overleaf, we can see the speed trace from the hub drops off the moment the power is released and then gradually tends towards the same value as the GPS signal over the course of the deceleration.

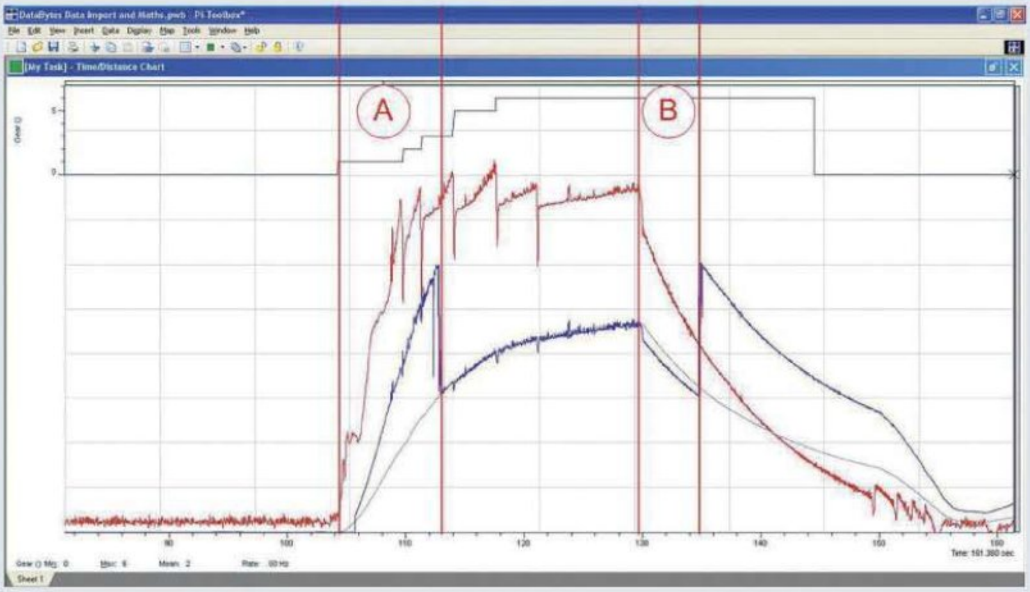


Image 1: trace showing speed derived from two sources – a GPS unit and a wheel speed sensor. in section B we can see a major misalignment under deceleration

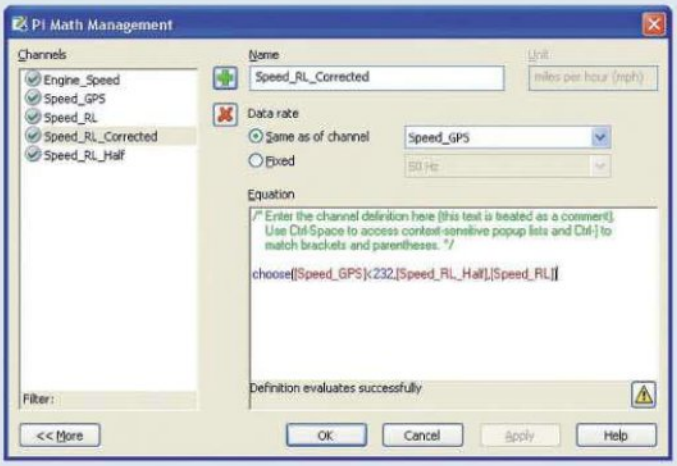


Figure 2: using a maths channel to correct the anomaly in the speed trace seen in the trace above

THEORY

In its most simplistic form, hub speed is calculated by counting the time between triggers on a toothed wheel and knowing how far the wheel has travelled (from the loaded radius) in that period between triggers. With a race tyre being a non-rigid body, this means that the loaded radius changes as a function of speed and load. The data that is the subject of this article is from a drag motorbike, so we can assume that the tyre loaded radius changes quite a lot. From that we can quote an equation to calculate speed of a hub to be given as:

$$\frac{TyreDiameter(m) * Pi}{WheelTriggers * SpeedRaw(Seconds)}$$

where: $TyreDiameter$ is double the loaded radius; $WheelTriggers$ is the number of triggers in one complete revolution of the hub and $SpeedRaw$ is the time between triggers.

This means that:

- An increase in wheel diameter yields a higher speed
- A decrease in wheel diameter yields a slower speed

POSSIBLE EXPLANATION

If we assume the front wheel as an un-driven wheel is not subject to as much tyre growth and deformation as the rear we can make an assumption that the GPS speed is equal to the front hub speed, and that front hub speed is very similar to vehicle speed.

On this assumption, we can calculate a percentage slip of the rear wheel relative to the front. This is simply expressed as:

$$\frac{RearWheelspeed}{FrontWheelspeed}$$

This would nominally return a value greater than 100 per cent when the rear wheel is slipping. In this example, we see that the slip value is almost exactly 100 per cent during acceleration before falling away under deceleration.

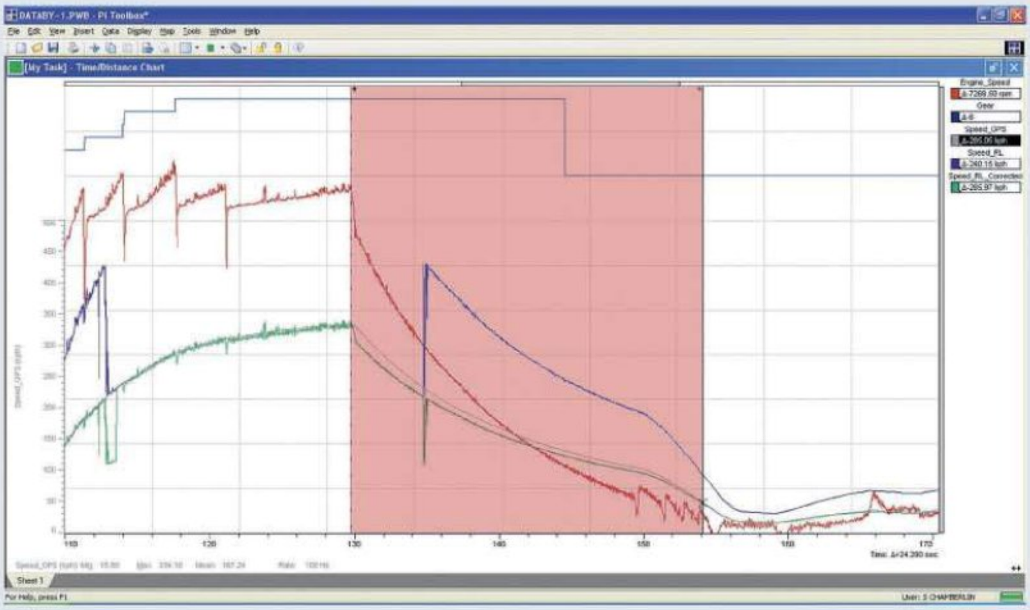


Image 3: overlaying the two traces we can see the speed trace from the hub drops off the moment the power is released and then gradually trends toward the same value as the GPS signal over the course of the deceleration

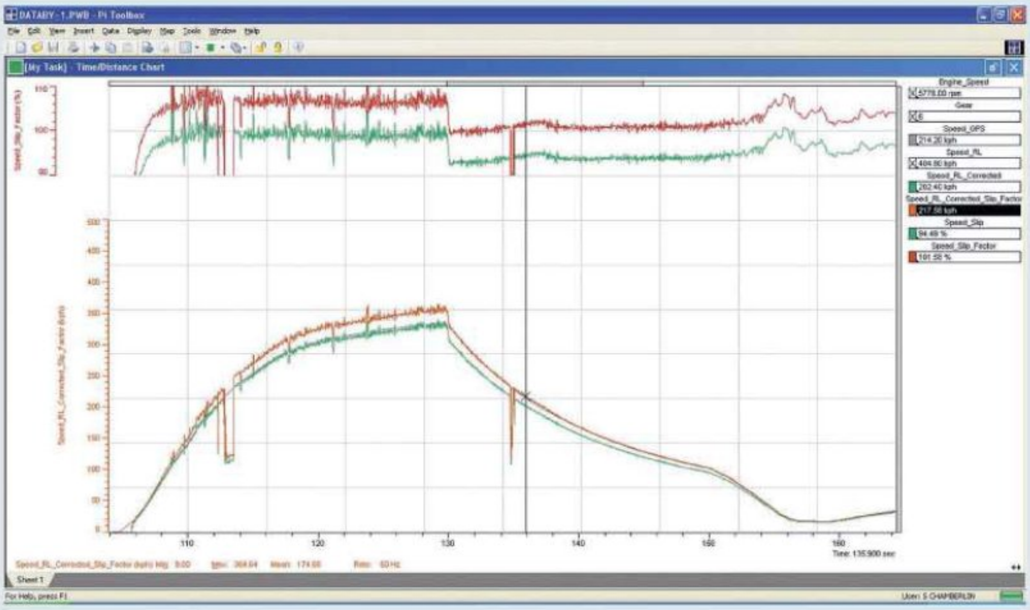


Image 4: expressing the two traces as a slip shows a percentage slip rate, which better explains what is going on

In the case here, this implies the loss in hub speed with respect to the GPS speed is caused by a reduction in radius. This is strange behaviour, as we would expect in a drag vehicle for the rear tyre to be slipping.

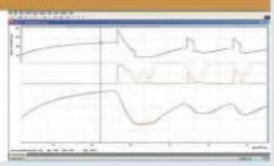
Investigating further, if we normalise the rear wheel speed to that of the GPS speed under deceleration through a multiplication factor, we see that the rear wheel speed is now greater than the GPS speed under acceleration, which is more likely to be the case. Expressing this as slip again, using the same equation as before, we see this is now a very reasonable 7-8 per cent slip, which begins to make sense (see image 4 above).

CONCLUSION

This method shows how logical thinking can be applied to a problem utilising the power of the mathematical functions of a data analysis package, and prevent the all too typical immediate thought that as the data system is not providing the answers *you* expect that it must be incorrect.

CHALLENGE

Test your own data analysis skills by going online at **www.racecar-engineering.com/databytes**
Here you will find a monthly challenge set by Cosworth, together with an explanation of the answer by one of its data engineers.



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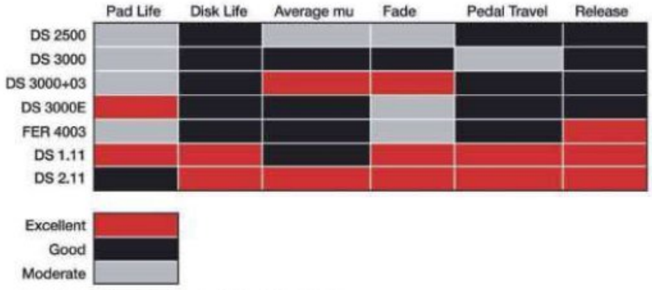

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The last word on technology

Reflections on 20 years of unrivalled motorsport engineering coverage

BY RACECAR STAFF

To say that *Racecar Engineering* is 20 years old is a bit misleading. The magazine itself may be 20 years old this issue, but the brand itself has been around for a little longer. *Racecar Engineering* was created by journalist and author Ian Bamsey in the 1980s, the Englishman having previously founded *Automobile Sport* magazine. 'It was around 1985 when the idea for a technical magazine really started to form in my mind,' Bamsey explains. The idea was simple: to cover the technical side of the sport and document it. At that time nobody was doing that. In the old days you would find technical pieces in titles like *Autocar* but, in the 1970s, all the technical coverage seemed to dry up and in the '80s there was nothing. So the need was clear.'

In 1986 the *Racecar Engineering* brand appeared for the first time, not on the front of a magazine at all but on the title verso of a book, Bamsey's *Ferrari 312 & 512 Sports Racing Cars, The Porsche Hunters*. It was very much a history book, but focussed on the technology of the cars. Bamsey was using his books, published by Haynes, to develop the magazine concept.

But Bamsey was not completely decided on the name, having toyed with the correct English version of *Racing Car Engineering*. 'That just didn't sound right, so I settled on *Racecar Engineering*, and when I found out that Paul Van Valkenburgh had used it I realised that I had got it well.' Bamsey also experimented with another brand in some of the lower end practical motorsport books, *Race Tech*, which eventually became the name of a section of the magazine focusing on individual technologies and components.

> **“The idea was simple: to cover the technical side of the sport, and document it”**

In 1986 *Racecar Engineering* received its first press accreditation for an event, the San Marino Grand Prix, and later the Le Mans 24 Hours, starting the title's long-running coverage of the sport's most challenging race. The brand has been represented at that event every year since, and still features unrivalled technical coverage.

By 1990 event press officers decided it was high time they saw this magazine that they were giving passes to. Bamsey, who by then had been joined by Alan Lis, was asked to show the FIA an issue of *Racecar Engineering*. So the two set about making one. It was based on the format of Bamsey's 1988 book, *International Race Engine Directory*, and featured no advertising whatsoever. Just 500 copies were printed, making it extremely rare today, but there was now a magazine to show to the FIA. Two subsequent issues were produced, but Bamsey was now looking for a publisher.

At the 1991 Autosport show, he teamed up with former *Autosport* editor Quentin Spurring and, after a short delay whilst Bamsey and Spurring worked together on another project, Q.Editions published

The men who have brought you *Racecar Engineering:* (from left to right) Tony Tobias, Quentin Spurring, Charles Armstrong-Wilson and Graham Jones

the fourth issue of *Racecar Engineering*. 'We called it Volume 2 No 1 because it had more pages, more colour and adverts!' explains Bamsey.

The arrival of adverts meant that someone would have to sell them and that man was Tony Tobias. 'It was his energy and enthusiasm that made it work,' adds Spurring. 'He managed to sell 9 adverts into V2N1 – AP Racing, ATL, Castrol, Earl's, F1 Racewear, Instron, Lola, Minister and Rapid Movements.'

That issue arrived in time for the staff to take it to the 1992 British Grand Prix at Silverstone, where Patrick Head commented that it had 'too many pictures' and Max Mosley said it was 'hard to get into'.

Two issues later there were 45 advertisers and, by 1995, the magazine was in profit (largely thanks to having a stand at the PRI Show in the USA). Things were going well, despite the fact that Bamsey had now left the company, and soon a bigger publisher started to take notice. The result was *Racecar Engineering* was sold to the publisher of *Cars & Car Conversions*, Link House Magazines in 1996, with V5N5 being the first issue under the new regime. Link House was later absorbed into IPC Media, the UK arm of Time Inc, and remains the title's publisher.

Spurring's leadership gave way to Charles Armstrong-Wilson in 2000, and the following year the magazine benefited from a new look. Armstrong-Wilson left the magazine in 2008, with former Minardi F1 press officer Graham Jones taking the controls later that year. From 500 copies of the first issue to more than 65,000 readers today (combined with the website) Bamsey's idea is ageing very well indeed!

THE MAGAZINE'S EDITORS

1990
IAN BAMSEY (FOUNDER)
V1N1–V1N3

1991
QUENTIN SPURRING
V2N1–V10N4

2000
CHARLES ARMSTRONG-WILSON
V10N5–V18N8

2008
SAM COLLINS
V18N9 (caretaker)
GRAHAM JONES
V18N10–present

The best of the best

AWARD WINNER: THE AUDI R8 / R10

GREATEST CAR OF THE LAST 20 YEARS

All photos: LAT; Audi Sport

If there's one thing everyone involved in European motorsport seems to agree on, it's that Audi has built the greatest racecars of the last 20 years

THE AWARDS

To celebrate *Racecar Engineering's* first 20 years we decided to ask a number of people concerned with the magazine to select some particularly notable events and persons from the last two decade, with the intention of revealing *Racecar Engineering's* choice of **Greatest Engineer**, **Greatest Car** and **Greatest Innovation**.

Our panel included, Ian Bamsey, Charles Armstrong-Wilson, Graham Jones, Peter Wright, Lawrence Butcher and Sam Collins, with further suggestions made by a number of contributors.

Predictably, the results of the deliberations over who and what has contributed the most to racecar engineering over the last 20 years were varied in many areas, but nearly everyone agreed on one thing – the greatest racecar was an Audi.

'Audi has always tended to go its own way when it comes to motorsport, from the early days with its highly successful turbocharged, four-wheel drive Quattro rally cars, through its TransAm and IMSA racing programmes,' explains Graham Jones. 'However, winning the 12 Hours of Sebring and the 24 Hours of Le Mans with the R10 Sports Prototype in its first year of competition (2006), making it the first diesel-powered car to win either of these blue riband endurance events, was an amazing technical achievement.' And that sentiment is echoed by *Racecar Engineering*'s technical consultant, Peter Wright, who cited the R15 TDI as his choice.

Charles Armstrong-Wilson,

BY RACECAR STAFF

Sam Collins and Lawrence Butcher, meanwhile, all plumped for its predecessor, the R8. 'People forget the sheer dominance of the R8 in Sportscar racing,' explains Sam Collins. 'The car was not just fast, it was innovative, too. Look at the FSI engine, the way the car was designed to be easy to work on, and its solid design. It was the perfect endurance racer.'

> **"The car was not just fast, it was innovative, too"**

So the decision was taken that the joint winners should be the Audi R8 and R10.

The Audi R8 was first introduced in 2000 as a successor to the previous year's R8R. Sportscar design commentator Mike Fuller of www.mulsannescorner.com observed at the time that 'Audi has produced a thoroughly detailed machine. This was further witnessed at Le Mans when the Joest Team was able to complete an entire swap of the rear end of the car in just over four minutes. But there is no one 'trick' item that differentiates the Audi from its competitors, it is the subtle details that make the difference...'

Following the R8's crushing victory in the 2000 Le Mans 24 Hours *Racecar Engineering* took a closer look at the new Audi. 'The manufacturer returned for a second year with a car bearing the R8R type number, but here the similarities with the 1999 project ended. The Audi Sport chassis design team, headed by Wolfgang-Dieter Appel, produced a striking new chassis based around an all-new, Dallara-manufactured monocoque. Its dimensions kept to the minimum requirements of the ACO LMP

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RECOLLECTIONS BY TT

They say history is what happens while you are quietly trying to get on with your life. Well, in my case, not so quietly.

One day I got a call from my old pal 'Q' aka Quentin Spurring asking for my opinion. Knowing I had started run the advertisement and circulation departments on *Cars and Car Conversions*, Q wanted to know whether I thought launching *Racecar Engineering* would be a viable business venture.

We concluded the motorsport industry did not have a B2B publication to assist suppliers find a market for their products, or for racecar manufacturers to read about them.

Q asked if I would be prepared to assist him. I had faith in the project, so agreed and, after three successful issues, became a permanent part of 'the family'. The rest is history, but the last 20 years have been the happiest times of my life. To have worked on every single issue of *Racecar Engineering* has been a privilege and it has been an honour to serve and be a part of one of the greatest industries in the world.

None of this would have been possible, however, without my wife Dixine, to whom I owe a debt of gratitude, both for supporting me and for marketing subscriptions at every overseas show we exhibit at.

Reminiscent of the Ford GT40s in 1966, Audi R8s took first, second and third on their debut at Le Mans in 2000

The R10 set a precedent for other manufacturers to follow, by becoming the first diesel-powered car to win Le Mans

900 rules, to such a degree that drivers taller than 1.8m found the cockpit a tight fit. Every effort was made to reduce the c of g height, concentrate mass within the wheelbase and reduce the frontal area of the racecar. To this end, the front and rear suspension systems were re-designed to place the coilover units lower in the car. Changing to side-mounted water coolers resulted in a narrower tub, which allowed the engine to be fully stressed, improving chassis rigidity and saving the weight of the tubular steel A-frames used previously.

The aerodynamic test programme, carried out in conjunction with Fondmetal Technologies, resulted in upper body panels that fitted far more tightly to the running gear beneath than on the previous design. The underside of the car was closer to the limits of the regulations than it had been, particularly in the area of the front diffuser, which followed the principles first seen on the Toyota GTONE racecars in 1998.

A 20 per cent reduction in frontal area was claimed along with a 10 per cent improvement in the lift-to-drag ratio.

Outwardly the R8R engine appeared unchanged from 1999, although the layout of the engine bay was revised to cater for a closer fitting tail section. The twin turbocharged Audi V8 engine was designed around a flat plane crankshaft, in deference to exhaust tuning and fuel economy advantages. The 2000 engine weighed around 12kg less than it had originally, a significant part of the saving coming from a lighter exhaust system. Engine project leader Ulrich Baretzky claimed major gains in torque output and driveability with an eight per cent improvement in fuel efficiency, enabling him to state before the race that the R8Rs would be able to routinely run a full 13 laps on a tank of fuel.

A revised version of the 1999 longitudinal gearbox, produced in conjunction with UK company Ricardo, featured a new magnesium alloy casing and updates to the internals that saved more than 15kg.

RECOLLECTIONS BY CHARLES

To anyone with a passion for motorsport technology, editing *Racecar Engineering* is surely the dream gig. I never ceased to be amazed by the access the job brought. Whether it was the chance to spend time with Gordon Murray or Adrian Newey, the opportunity to work with the likes of Peter Wright and Paul van Valkenburgh, or the friendships with writers Allan Staniforth and Carroll Smith, it was all a dream ticket. Even the engineers who work within the sport are unlikely to see behind quite so many locked doors as I had access to.

There is a thrill in holding a fragile-looking Formula 1 piston in your hand, while being quoted the forces it will be subjected to. Likewise, watching a brake being loaded on a rig until it glows white hot, or an engine being run to its maximum in a test cell. This is where races are won or lost, yet enthusiasts who pay a fortune for a grandstand seat never get to see it.

Above all, my lasting memories are of the inspirational conversations with some truly brilliant minds. Editing *Racecar Engineering* was a very special opportunity – often frustrating, infuriating and exhausting, but certainly never boring.


LAT

Audi introduced its FSI technology in 2001, reducing fuel consumption and improving performance in the process

In keeping with Audi philosophy the rear end of the 2000 R8R was configured to allow rapid replacement in the event of not only transmission problems, but also suspension and brake issues. The revisions allowed this process to be carried out even faster than in 1999. Having qualified in the first three positions, the Audis were similarly dominant in the race. As the opposition dissolved, the silver cars extended their advantage over the field and, at the finish, the winning R8R was no less than 24 laps (326km) clear of the first non-Audi finisher in fourth place. Two of the R8Rs required new rear-end assemblies, an operation achieved in a jaw dropping four minutes in one instance. The winning car's avoidance of this necessity proved decisive.

According to Michael Pfadenhauer, Audi Motorsport's chief aerodynamicist, when you start to develop a car for a new race series you start with the regulations, just like you do in Formula 1. This gives you the basis for a design. 'Normally, you don't have a car already existing when you do this for the first time, as was the case for the R8,' said Pfadenhauer. 'Thereafter you base your developments on the old car. Unless you find that the old car was uncompetitive in some ways, then you have to re-design these things more extensively. Similarly, if you have an existing car and the regulations change significantly, you have to go through the whole design process again. At the moment the changes are rather moderate, so the current car is an evolution of the existing car.' So the R8 was only changed slightly over its first two years. 'These changes are probably unnoticeable to the general public,' continues Pfadenhauer. 'But a big step was made from 1999 to 2000 because the '99 car was not at the optimum and we needed some experience with it to find out where the optimum was under the current regulations. In 2000 there was a big step, which was visible to the outside.' After the initial scheming was done for the '99 car from the regulations, Audi turned to CAD for the design, accompanied by wind tunnel tests at 25 and 40 per cent model scale. The current design process, however, is different. 'Now that we have a good basis for the car and the fact that CFD technology has developed considerably in recent years we are now including CFD in the design process, but this is only a recent innovation. The 2002 car is the first car that has been designed with CFD as an integral part of the design process.'

> **"The FSI process injects the fuel directly into the combustion chamber"**

For the 2001 Le Mans 24 Hours the R8 was fitted with a direct injection engine, which Audi branded Fuel Stratified Injection (FSI). This gave the R8 a significant reduction in fuel consumption (around eight per cent) and a boost in performance. The FSI process injects the fuel directly into the combustion chamber, timed to the millisecond. The necessary pressure of over 100 bar is provided by a piston pump, which supplies fuel to the electromagnetically-actuated injectors in the cylinder.

The system was capable of two different charge modes: stratified charge operation and homogeneous operation. Stratified charge operation allows particularly economical fuel consumption at part throttle because an ignitable, rich mixture is only necessary around the spark plug. The rest of the combustion chamber contains strata of air / fuel charge with a high air excess.

FSI technology makes this so-called stratified charge possible


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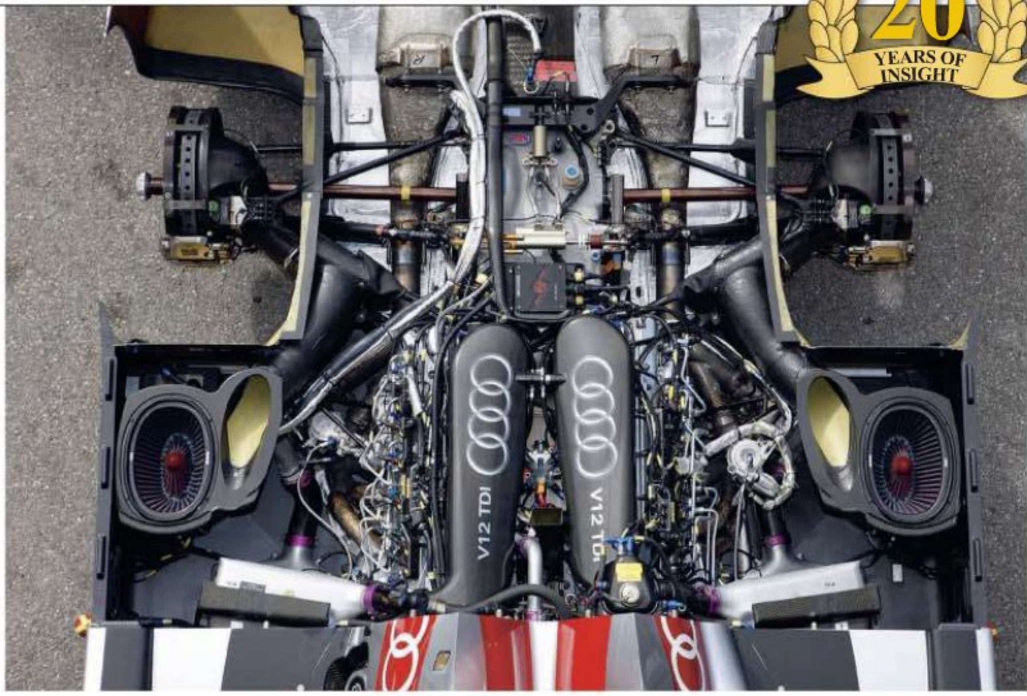
The R8 won Le Mans in 2000, 2001, 2002, 2004 and 2005. It was only beaten at the race once, in 2003, by its very close relative, the Bentley Speed 8, which was fitted with a 4.0-litre version of the R8's engine.



LAT

The TDi lump that appeared in the R10 was the world's first purpose-built diesel race engine. And boy did it work

THE DIESEL REVOLUTION

By 2002, though, the Audi Sport engineers had their sights set on the next project – the R10 TDI, a diesel-engined successor to the R8. 'We'd been involved with discussions on the rules since the very beginning. We sat down with Daniel Poissenot and Daniel Perdrix from the ACO in January 2002 in Ingolstadt and, over a beer in the evening, talked about racing in the future… and the idea came out that we should build a diesel. That's where it started,' explained Audi's head of engine technology, Ulrich Baretzky. 'The next step was in Sebring in 2002 where I had a list of questions from the ACO and went off to think about them. The ball played backwards and forwards until the rules took shape.' And while the idea obviously appealed to Audi marketing, Baretzky's eyes twinkle when he says, 'Oh yes, I *wanted* to do it. It's as simple as that!'

Both parties wanted this new idea to work. Unsurprising really, as currently every second Audi sold is a diesel, and Audi invented direct injection for road cars – introducing the five cylinder, 120bhp, TDI engine, with direct injection and electronic management, at the Frankfurt Show in 1989. It also knows that diesel needs a major change in image to bring acceptance in the USA. The ACO, meanwhile, is actively promoting responsible, useful technology, and last year introduced the Ecology Trophy at Le Mans – created by the Automobile Club de France, and won by the R10's predecessor, the R8.

When the ACO framed the equivalency rules in 2003 (for 2004) they offered a carrot for a diesel to challenge for outright victory – also attracting interest from Peugeot, who were slated for a return in 2007. The carrot was that a diesel, either supercharged or turbocharged, could displace 5.5 litres, as opposed to the 4.0 litres for forced induction petrol engines, or 6.0 litres for naturally-aspirated petrol. Maximum boost for a diesel is related to displacement, and for the R10 is 2.94bar absolute, while a single-turbo diesel must run a single 55.9mm restrictor and a twin turbo (like the R10) is allowed two 39.9mm restrictors.

> **"the only racecar in the world to combine turbocharging and direct injection"**

Baretzky acknowledges the rules were framed to give an incentive: 'The ACO knew they had to give a theoretical advantage at least. Any company looking to move into diesel would have to take an enormous risk, because making a diesel race engine is very different from making a gasoline (petrol) race engine.' He also knew there was no future in trying to adapt a production diesel engine for racing, as the under-funded Taurus Lola-Caterpillar effort had done in 2004. 'No, I didn't see any potential in that at all. The way they did it and the money they had gave them practically no chance. You just can't take a road engine and go into LMP.' But in one respect, he did see the Taurus effort as a threat, if only to diesel's credibility: 'My concern was the way they did it, with all the smoking and all the problems in Le Mans [it lasted 35 laps] doing more to destroy the potential image of a race diesel than to move it forwards.'

He did have another benchmark though: 'our TFSi engine and the R8.' Which, it must be said, has been everyone else's benchmark too, because although the R8's 610bhp, 3.6-litre, twin-turbo V8 introduced the petrol direct injection TFSi format as long ago as 2001, it is still the only racecar in the world to combine turbocharging and direct injection. Or at least it was until the R10 arrived, and translated both to diesel, in the programme that now evolved. The schedule was fixed by September 2003 and the hard points of engine layout were agreed by early 2004 – including the number of cylinders, bore, stroke and external dimensions. 'That,' says Baretzky, 'was the most important stage, because it affects everything that follows. You can make the biggest mistakes at the beginning – get it wrong here and it's almost impossible to correct it later. Which is why we thought about it all extremely carefully before we fixed the basic parameters. It was clear we had to take maximum advantage of the capacity for example, because more than anything a diesel engine depends on capacity. That was why it became 5.5 [litres], and a V12 gave the best compromise between what we wanted from an engineering point of view and what Audi wanted to do from a marketing point of view.'

ENGINE SPECIFICATION

So they started experimenting with a single-cylinder mule, and modified production engines, but what emerged as the definitive R10 TDI engine is a 5.5-litre, dry-sumped, 90-degree V12 (offering smaller, stronger piston crowns than engines with fewer cylinders), with four camshafts and four valves per cylinder. There are two Garrett turbochargers with maximum boost and restrictors as per regulations, as well as air-to-liquid intercoolers. It is the first ever Audi diesel

RECOLLECTIONS BY GRAHAM

Much to my amazement, this is the 19th issue of *Racecar Engineering* for which I have been responsible. Even so, I am very aware of being the new kid on the block. It is impossible to have accumulated the fund of anecdotes and stories from which Quentin and Tony can draw, given their time served with the publication, but there are a couple of events that stand out for me in the last 18 months. One such was my first visit to the Performance Racing Industry show in Orlando. The initial impression on walking into the main hall of the Orange County Convention Center was the sheer scale of the event, followed by a mild case of panic: how were we going to see everything in the space of just three days?

The lasting impression was of a show as only the Americans can do, from the spectacular gala breakfast on the opening morning, complete with a NASCAR Cup car being driven into the hall, to the Happy Hour that brought each day to a close.

However, perhaps the most amusing interlude of the Florida sojourn occurred one evening a short distance from the Convention Center, when a few of our number decided to go to BB King's club for dinner and to listen to some live blues music. As it transpired, it was 'singles night' at the venue, there were precious few blues songs played and the evening culminated with a majority of the locals climbing up on stage for a mass line dance. It was certainly entertaining, but not quite what we had been expecting…

The other memory that sticks with me involves a visit to Warneton Speedway, in Belgium, last summer, along with editorial assistant, Lawrence Butcher, and deputy editor, Sam Collins. We were there to fit data-logging equipment to a couple of European Late Model Stockcars for a feature we had planned for the magazine, and also to provide some moral support for Sam, who was competing that weekend.

The Late Models were very much the 'star turn' of the programme but, at one point between races, Lawrence and I decided to venture to the outer paddock in search of frites with mayonnaise and the local beverage. The sight that greeted us resembled a scene from Mad Max, as the large number of bombers and bangers that were also competing that day were being 'fettled' before their next races.

In one particular case, a young lad, who could have been no more than 10 or 11, was knocking eight bells out of a very dented bonnet with a sledgehammer about the same size as him. As we were taking in the scene, an adult member of the team wandered over and, although my French is a little rusty these days, I think suggested that it might be more productive in terms of the bonnet's overall fit and finish if he hammered on the inside rather than the outside…

All of which I think goes to prove that you can't be around motorsport for any length of time, and the people who work and compete in it, without amassing some great experiences – a point with which I feel my fellow editors, and TT, would undoubtedly agree.

with an aluminium block and, although it is probably about 50 per cent heavier than the R8's V8, there are links. 'Apart from the combustion process,' says Baretzky, 'we tried to take over as much as we could, because we don't have to re-invent the wheel every time. There are differences because of the demands of diesel, but look at the structure of this engine and you'll see it's very similar to the structure of the R8. Most of the similarities are in the bottom end, most of the differences in the top end. For example, the oil system is adopted from the R8. We'd proved it worked so why do something new?'

making electronic management systems for petrol engines for 25 years, to make a system for a diesel race engine was a big challenge for both companies.'

Injection pressures of around 2000bar are far greater even than the 1600bar now seen in production, with combustion pressures way above anything previously seen in any Audi engine. 'Of course you have much, much higher combustion pressure compared to a petrol engine and that affects the stress on the piston heads, con rods, crankshaft and many other things. You try to make everything as light as possible, just as you would with any other engine, but the loads

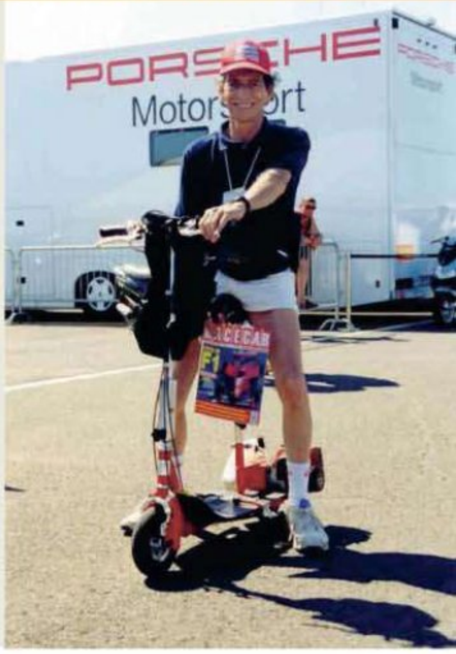
"hopefully we've given them some inspiration for the next generation of road engines"

The all-important fuelling regime uses Bosch common rail injection with multiple orifice nozzles and Piezo injection valves. Management is Motronic MS14, and the system was a completely new design. As Baretzky explains: 'we really started from zero to make a system for diesel, and to fulfil the demands of racing. Those are demands you find nowhere else, and although Bosch has been

are there and there's no use trying to deny it. You have to make it as close as possible to minimum weight while respecting the stresses'. But watch this space: 'This technology will come into Audi road cars within about a year and a half. Let's say we're doing a very hard test on the technology now.'

There will be other road car lessons, too. Strength without weight prompted the

BLAST FROM THE PAST



In the beginning, a youthful TT peddled (scooted?) *Racecar Engineering* around the paddocks, direct to those who it was aimed at

all-aluminium construction, and Baretzky admits, 'Some of our colleagues in production said it would never work, so now we've proved that it does, hopefully we've given them some inspiration for the next generation of road engines.' Metallurgy has broader synergies, too: 'We're using alloys that are used in production engines, because Audi's philosophy is to make all its race engines in a way that could be used sooner or later in production form. For me the whole purpose of racing isn't just to have fun (or stress!) at the weekend, it's to give customers the knowledge that we're working for them, too.'

The R10 TDI engine first ran on a test bed in July 2005 and produced so much torque that Audi Sport's F1-spec engine dynamometers had to be re-configured with special gearboxes to accommodate it. 'It was incredibly interesting,' says Baretzky, 'because we really have explored completely new territory with this engine.' It then ran almost 1000 bench hours before its first track roll-out on 29 November 2005, and Paris unveiling on 13 December. Before it arrived in Le Mans in June it had done more than 3000 bench hours, thousands of kilometres, and of course everything it took to win in Sebring.

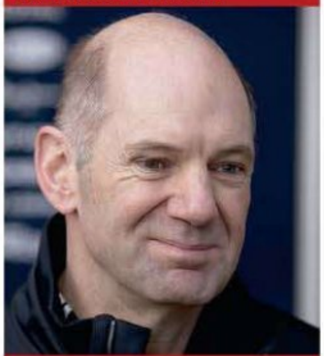
Quoted outputs were 'more than 650bhp and over 1100Nm of torque', but even those figures are reckoned to be conservative. The meat is between 3000 and 5000rpm, but they say it has useable torque and power virtually from idling speed. And the power band isn't significantly narrower than the R8s, it's just in a different place from the petrol V8's 5000-7000rpm range. This is specifically the most powerful diesel engine in the world, but by racing standards it is smooth and quiet. It uses a pair of Dow Automotive diesel particulate filters because it is very important for Audi that it is also seen to run clean. And it doesn't even flame out on the overrun...

The Audi R10 TDI took victory at Le Mans in 2006, 2007 and 2008. In 2009 it was replaced by the R15 TDI, but continues racing to this day in the hands of privateers.

Innovative minds...

...produce innovations. Here's what the *Racecar Engineering* team picked as the most significant of the last 20 years

AWARD WINNER: ADRIAN NEWEY



GREATEST ENGINEER OF THE LAST 20 YEARS

Nearly everyone involved with putting this piece together agreed on one thing – the greatest engineer of the last 20 years was one of two men whose work has dominated motorsport at the top levels for the last two decades – Ross Brawn and

NEWEY'S CHAMPIONS

1992
Williams FW14B
1993
Williams FW15C
1994
Williams FW16
1996
Williams FW18
1997
Williams FW19
1998
McLaren MP4/13
1999
McLaren MP4/14 (Drivers' title)

LAT

1992 - Williams FW14B

LAT

1993 - Williams FW15C

LAT

1994 - Williams FW16

1996 - Williams FW18

1997 - Williams FW19

1999 - McLaren MP4/14

2010 - Red Bull. Not a championship winner, yet...

Safety advances, such as the HANS device, have undoubtedly saved lives

Adrian Newey. Brawn can claim involvement with the greater number of World Championships, including that amazing run of titles with Ferrari and Michael Schumacher between 1999 and 2004, and the fairytale result with Jenson Button and Brawn GP last year. His great strength seems to have been his ability to assemble great teams around him and to motivate them. By comparison, Newey has always been more of a 'lone wolf', but cars of his design have won multiple F1 World Championships for Williams and McLaren, and one has to imagine the Red Bull Racing 2010 challenger, the RB6, will be a strong contender for this year's World Championship, given the performance of last season's car.

Peter Wright plumped for Ross Brawn explaining, 'I would say that Ross Brawn is the top engineer of the last 20 years - a) for his record in three different organisations, and b) because he is the only technical director I know who was responsible for manufacturing, as well as the rest - that makes him more of an engineer than most.'

In the end though the decision went to Adrian Newey (*see page 65 for Newey's own thoughts on motorsport engineering today*).

“many of these advances have since filtered down to other levels of the sport”

TECHNICAL INNOVATIONS

Finally, we attempted to decide what the most significant technical innovation of the last two decades had been, and in this category no two people said the same thing, making it impossible to name a single winner. Graham Jones said that the FIA's advances in safety over the years was his choice: 'It is arguable whether any of the current array of safety provisions in Formula 1 could have saved Ayrton Senna's life in 1994, but the most significant legacy of his untimely death has to be the improvements to car, driver and circuit safety subsequently driven forward by the FIA. These include cockpit design, rollover protection, front, rear and side impact structures for the cars,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Spoilers, CoT, fuel injection... NASCAR will never be the same again

True innovation at its very best - McLaren's slotted rear wing concept

large run-off areas and, notably, improved medical capabilities at the circuits, plus highly effective racewear. Significantly, many of these advances have since filtered down to other levels of the sport. Yes, motor racing remains a dangerous activity, as we were reminded by the accidents that befell Henry Surtees and Felipe Massa last season, but it has to be that the odds are now stacked much more in favour of drivers than they were prior to Senna's fatal crash.'

Meanwhile, deputy editor Sam Collins couldn't even decide on a single concept. Ganassi's Laurel Hill tunnel facility was his first suggestion, which sees an abandoned highway tunnel converted into a hi-spec straight line testing facility. 'How could we not mention that?' he cries. 'The only real question in my mind would be who would get the award for that though – Paul van Valkenburgh for suggesting the concept, *Racecar Engineering* for publishing it or Ben Bowlby for building the thing.'

Peter Wright took a different

WIN 20 models to celebra

Racecar Engineering has teamed up with *Model Collector* magazine interesting cars from the last two decades. Everything from the 19 Brawn BGP001 are represented. All you have to do to enter is visit

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20 YEARS OF INSIGHT

Racecar engineering

MODEL Collector

LAT

The trouble with KERS...

The IndyCar DeltaWing concept is one of the most radical re-thinks of motorsport technology for years

direction again, suggesting 'the top innovation really depends on definitions. The DeltaWing concept could be this. Or the McLaren slotted wing. This is brilliant on so many fronts: good aero details; clever reading of the regulations to realise that the only way to make moveable aero legal is to use the driver and to build it into an homologated component (the monocoque). The fact that it is so difficult to copy is the real essence of innovation.'

Ultimately, it was too difficult to pick out one single innovation from a period that saw fully active 3.0-litre grand prix cars give way to the current tightly restricted 2.4-litre V8s, NASCAR change forever, diesels win Le Mans and drawing boards and wind tunnels starting to give way to computer chips.

As for what lies ahead in the next 20 years – Kinetic Energy Recovery Systems and alternative fuels hint at the direction the next batch of innovations may take. Rest assured, *Racecar Engineering* will be there to cover it.

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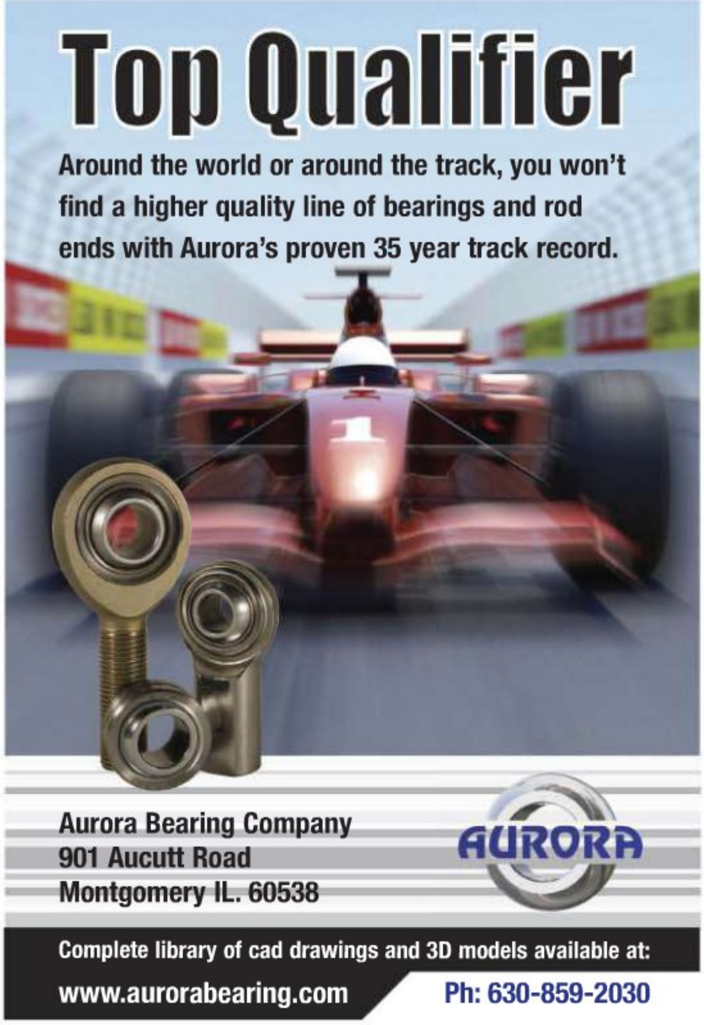
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The mechanics of acceleration

More thoughts on the anti debate, this time taking it right back to the beginning, using pictures and purely graphic technique

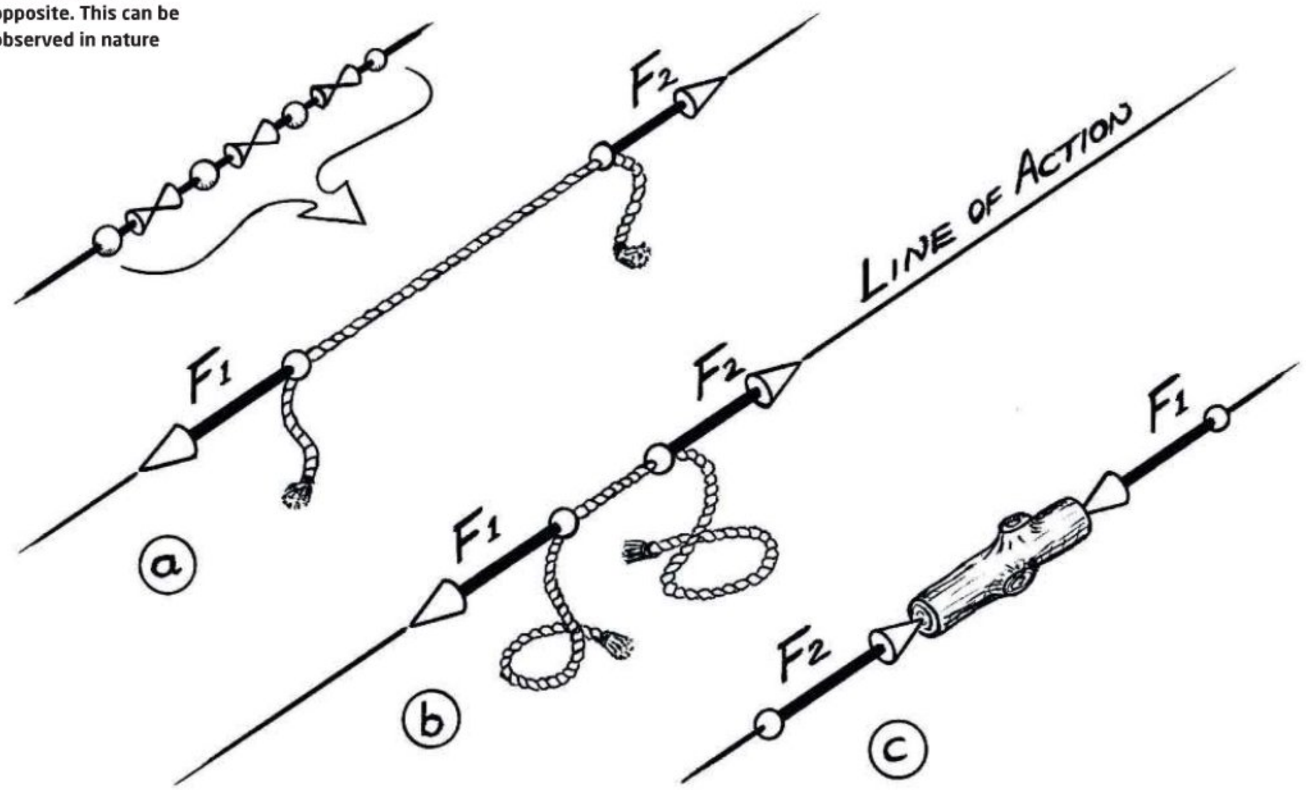
BY ERIK ZAPLETAL

When a car accelerates hard, the rear usually squats down, with the body pitching backward. Conversely, when the car brakes hard the nose dives, with the body pitching forward. And when cornering, which is acceleration toward the inside of the corner, the body rolls outward. Changing the suspension geometry can cause these body motions to increase or decrease, or even reverse. Recently, Danny Nowlan in V19N3, V19N9 and V19N10, and Mark Ortiz in V19N9, explored the suspension properties that give anti-pitch and anti-roll, under the general heading of 'The anti-controversy'. Prior to this, William Mitchell provided a similar article in V17N7 entitled 'Roll centre myths'.

FORCES IN STATIC EQUILIBRIUM

Figure 1

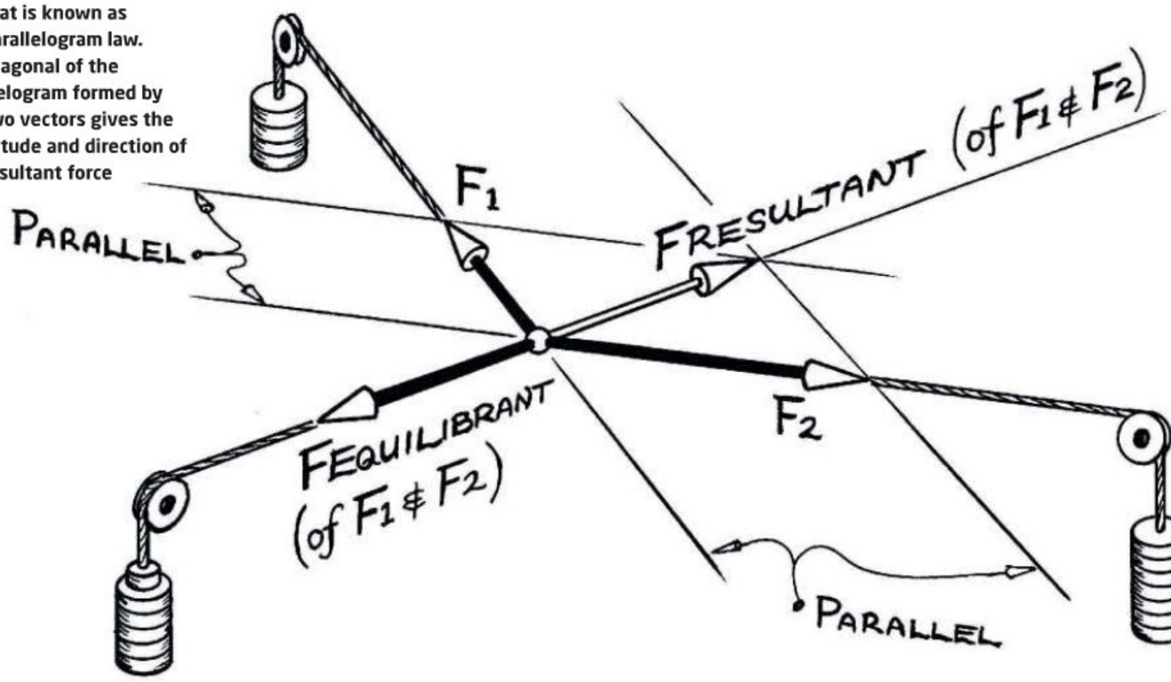
Forces always come in pairs, equal and opposite. This can be observed in nature



THE VECTOR PARALLELOGRAM

Figure 2

Forces can be represented as vectors and the combined action of two forces can be obtained by what is known as the parallelogram law. The diagonal of the parallelogram formed by the two vectors gives the magnitude and direction of the resultant force



Those articles used the standard method for solving mechanical problems that is taught in most modern technical schools. Put simply, this involves writing down a number of algebraic equations describing the unknown forces and moments in the problem, and then solving those equations. In this article we shall address the same problem using an older method of analysis. Our method would have been familiar to a competent draughtsman from at least 300 years ago, right up until the time computers became commonplace. Our method requires the drawing of a picture of the problem using the known information, and then finding the unknowns via purely graphic techniques. In this author's opinion this graphic method makes what is a controversial, and hence apparently difficult, problem really quite easy.

The main advantage of the graphic method is that by necessitating a reasonably accurate picture of the mechanism and its forces, the user gets a better kinaesthetic feeling for the problem than they can possibly get from lines of algebra. This kinaesthetic sense is what a small boy develops as he follows his father around the workshop. As the old man pounds away with a big hammer, the boy taps away with his small hammer, and so, with no words or equations, gains some understanding of how things work.

> "a much better kinaesthetic feeling for the problem"

MECHANICS PRIMER

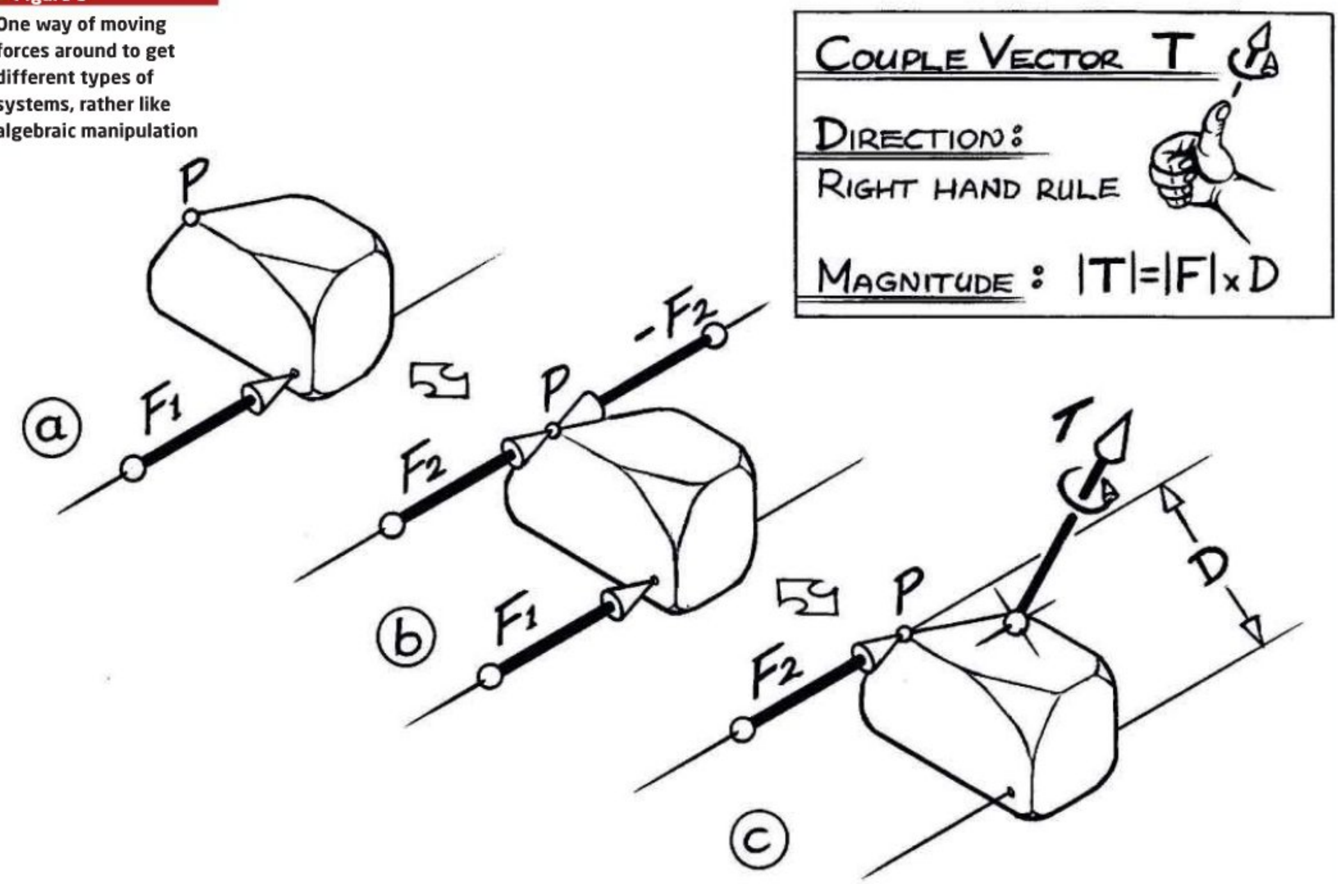
Before we can use the graphic method though we must understand mechanics. It seems that in recent times shortcuts have been taken in teaching this subject and some of the fundamentals have been forgotten. So a brief review is in order. Mechanics, a field of applied mathematics, is traditionally divided into three sub-fields: statics – the study of forces in balance; kinematics – the study of massless bodies in motion; and dynamics – the study of forces causing motions of massive bodies. We could start our review about 2500 years ago when the ancient Greeks knew all the geometry that we need. They probably also knew most of the mechanics that we will discuss next, but then most of this was lost in the Dark Ages. So we move on to the Renaissance, or re-birth, of the 1500s, and find some natural philosophers re-exploring forces.

STATICS

Figure 1a depicts a rope at the centre of a tug-of-war, and suggests two of the most obvious properties of forces that were re-discovered. Firstly, forces appear to be 'directed quantities', in that along with each force having an overall size, or 'magnitude', it also has a 'direction', that is at least as important as its size in understanding its behaviour. Today we call these arrow-like quantities 'vectors', and we use vector theory to describe both forces and motions. On a drawing we use an arrow to represent a vector, with the length and direction of the arrow representing the magnitude and direction of the vector. Many other quantities, such as

Figure 3

One way of moving forces around to get different types of systems, rather like algebraic manipulation



length, area, volume, mass or density don't seem to have any particularly important direction, so they only require a single number to describe their size. We call these quantities 'scalars'.

Secondly, if a force acts on a body, such as one of the forces acting on the rope in figure 1a, then it seems that the force can only come into being if it has an equal and opposite partner. We can only pull on the rope if the rope pulls against us in the opposite direction. Without the second force we just walk backward holding a loose rope. This notion that 'to every action there is always opposed an equal reaction' was eventually formalised by Isaac Newton, the English mathematician and natural philosopher of the middle to late 1600s, as his Third Law of Motion. When two forces like F1 and F2 act on a body and the body remains stationary, then the forces are said to be in 'static equilibrium', and we are working in the field of statics. Each force then is called the 'equilibrant' of the other force.

It is important to understand that in figure 1a there is a long chain of equal and opposite force pairs acting along the rope, with a pair of forces acting between each adjacent pair of sections of the rope. There is also a similarly long chain of force pairs going back along the ground below the tug-of-war, closing the loop. More pedantically, we might suppose that there is a pair of equal and opposite forces acting between each and every particle, or quantum, of the rope and ground. But, in simple terms, we take the forces F1 and F2 as two representative forces taken from this multitude of force pairs.

> "the force can only come into being if it has an equal and opposite partner"

Figures 1b and 1c illustrate another property of forces. Considering only the static equilibrium of the two forces in the tug-of-war, it doesn't seem to matter whether these forces are acting at the ends of a very long rope, or if they are brought closer together toward the middle of the rope. In fact, if the two forces swap positions so that rather than pulling on a rope they are pushing on the ends of a wooden pole, then they are still in static equilibrium. Again, this property can be understood in the context of the long chain of force pairs acting along the rope or pole. Since all the force pairs are essentially the same, it doesn't matter from which pairs we pick the representative forces F1 and F2.

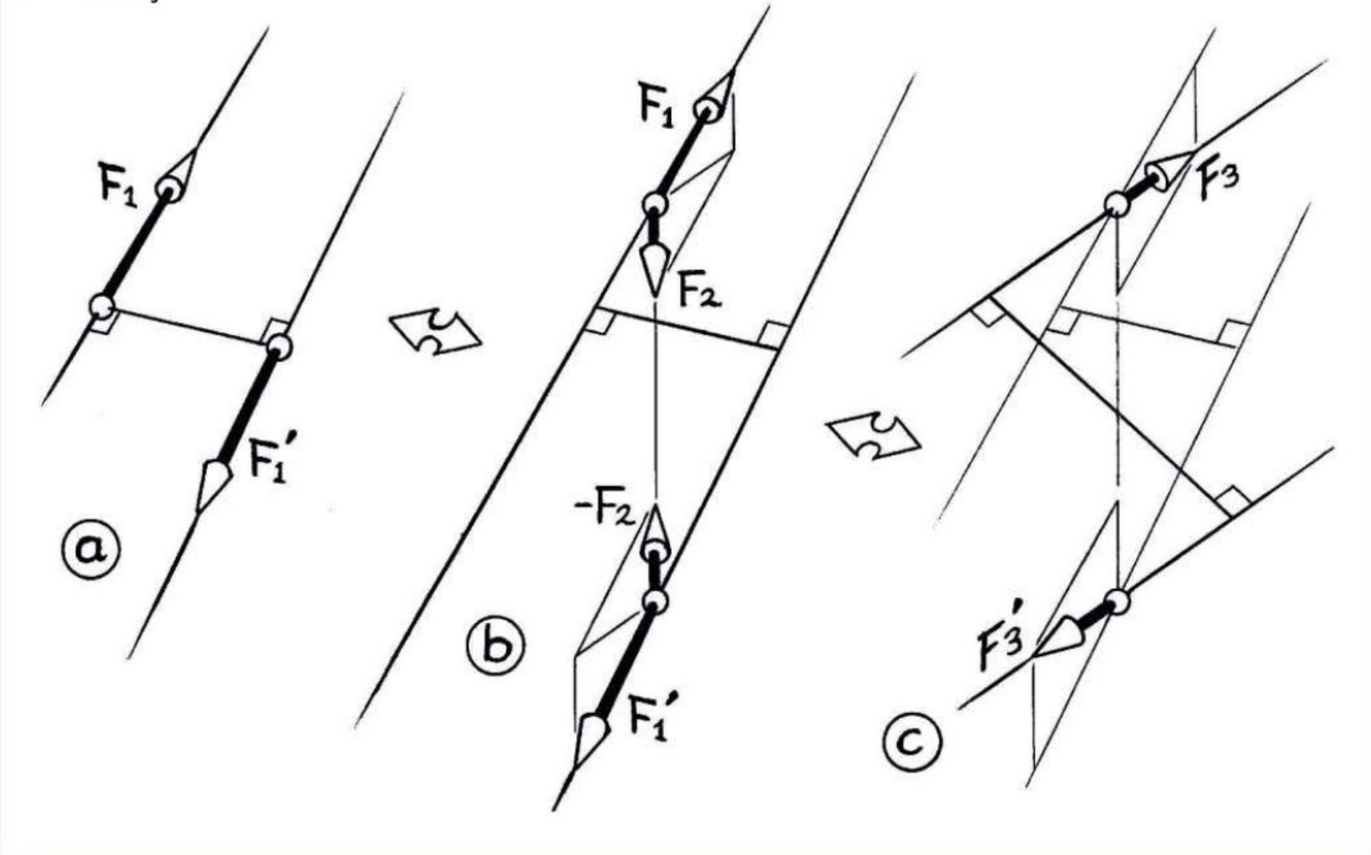
SLIDING VECTORS

Today we describe this property by classing forces as 'sliding' vectors. Here the force, or the arrow depicting it, can be slid anywhere along its 'line of action' with no change to the mechanics of the situation. Not all vectors share this property, as we shall soon see. Also, this property most certainly does not apply if we are doing a structural analysis of a body, since the stresses vary hugely according to where the forces act along their lines of action. So when considering load paths, the forces should be slid to their realistic positions.

The last important property of forces to be discovered, or re-discovered, required some

COUPLES ARE 'FREE' VECTORS

Figure 4
Looking at the free nature of couples in an informal way



experimentation. Simon Stevin, the Flemish mathematician and engineer of the late 1500s, used arrangements of strings, pulleys and weights to come to the conclusion that forces can be combined or decomposed using the 'parallelogram of forces' rule. For example, in figure 2 the two forces F1 and F2 are combined, or added together, to give the 'resultant' force fresultant. The method is to slide F1 and F2 along their lines of action so either both their heads, or both their tails, are at the intersection point. The parallelogram is then completed, as shown, and the diagonal represents the result of the addition. Using the parallelogram rule in reverse we can then decompose any single force into a pair of forces, each having any direction we choose. We can then decompose those forces into further 'components', *ad infinitum*.

There is much more to statics than given here but, quite remarkably, for our investigation of accelerating racecars these simple properties of forces are almost all we need to know. So, to re-cap, the three main 'axioms of statics' are:

> **forces can be combined or decomposed using the 'parallelogram of forces' rule**

1. Forces are directed quantities that come in equal and opposite pairs
2. Forces can slide along their lines of action
3. Forces can be combined or decomposed using the parallelogram rule

All that remains is to become proficient in the use of these axioms, and that takes practice.

We note here some of the conventions used in the figures. We draw forces that are actively pulling or pushing on the bodies as solid, black arrows. These black arrows don't represent all the forces in the problem, just the ones of interest at the time. We often also draw some white arrows to represent the resultants or components of the active forces, or to represent copies of the active forces that have been slid to other positions along their lines of action. These ghostly white arrows are drawn only in the manner of construction lines, to help the reader follow the calculations.

One subtle aspect of statics we must address is how, in three-dimensional problems, do we add two forces that are on non-intersecting, or 'skew', lines of action? In figure 3a we show a force F1 acting at the right side of a body. Towards the left side of the body is a point of interest P. We want to know what sort of force system acting at P is equivalent to that of figure 3a.

COUPLES

In figure 3b we add two forces, F2 and -F2, acting at P. These have opposite directions, but are equal in magnitude and parallel to F1. We can add these two forces to the body because we are, in effect, adding nothing to the body. In figure 3c we combine F1 and -F2 into what is called a 'couple of forces' or, more simply, a 'couple' T. As such, the single force F1 acting at the right side of the body is equivalent to an equal magnitude and parallel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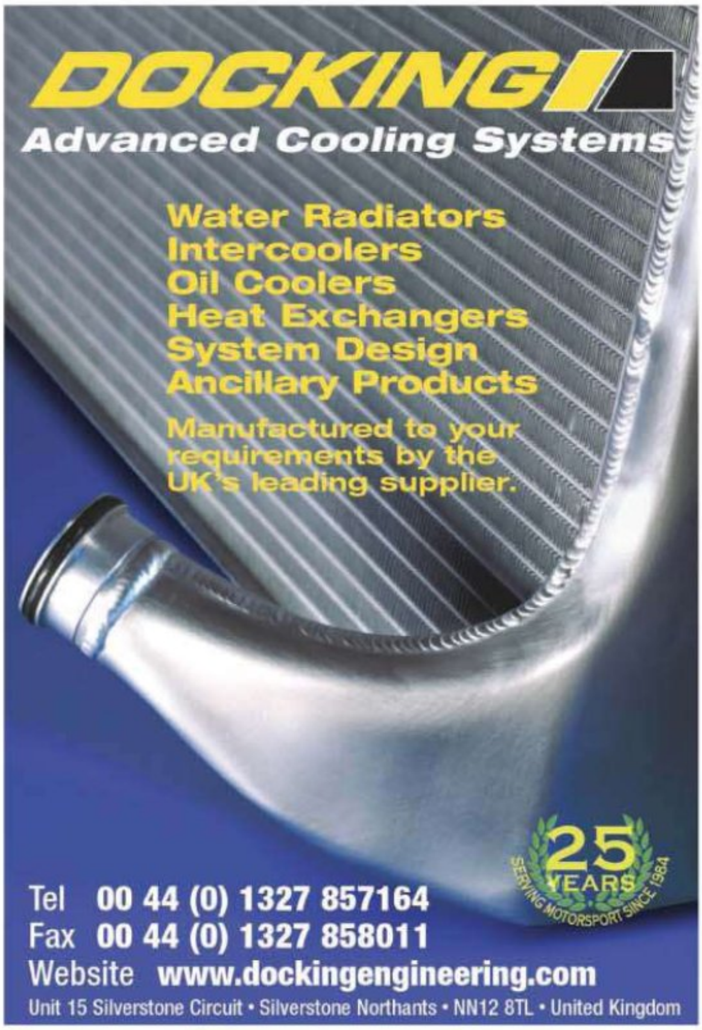
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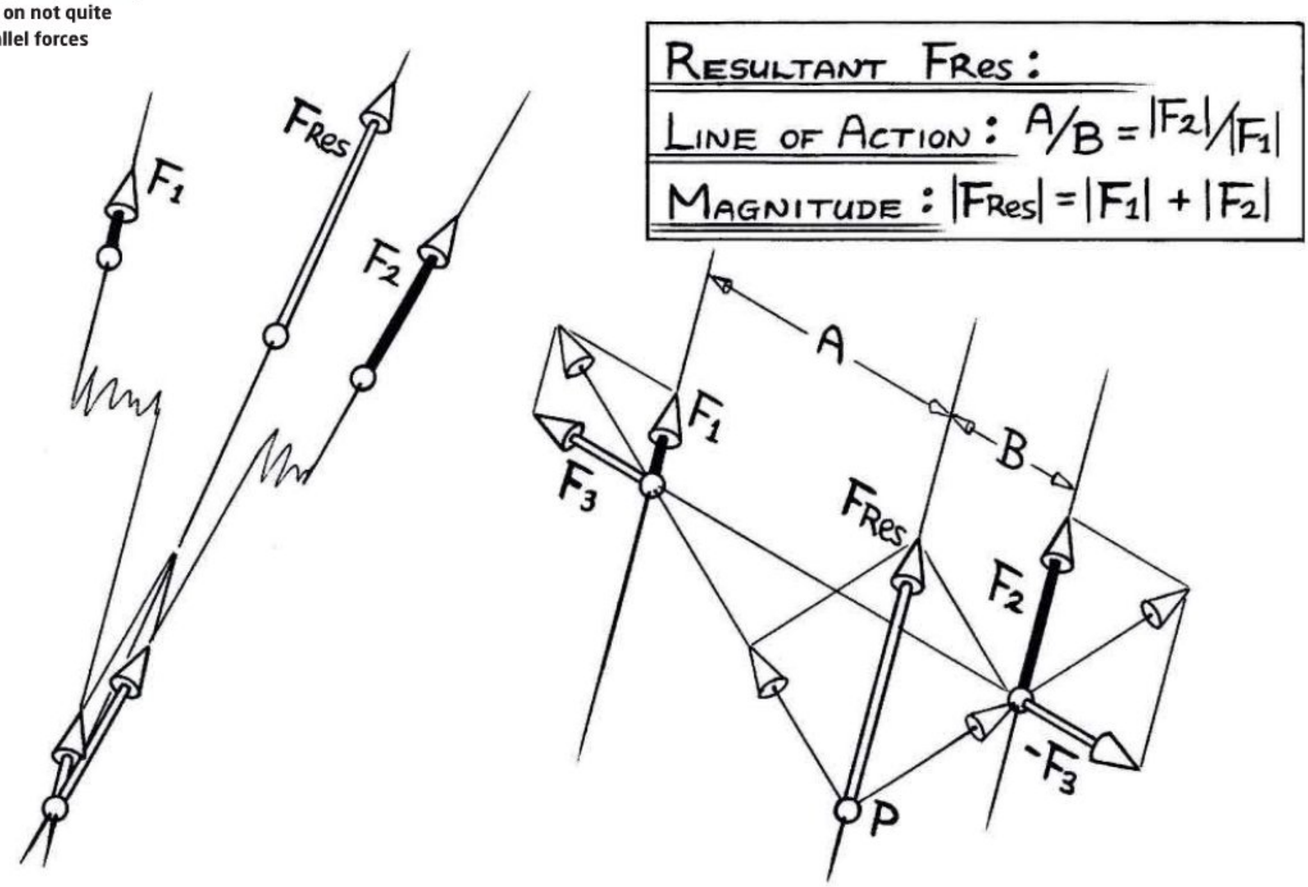
ADDING PARALLEL FORCES

Figure 5

Using the parallelogram rule on not quite parallel forces



force F2 acting at P, together with the couple T. Loosely speaking, we have moved the force F1 sideways to P and added the couple T to compensate for the move. So if there is another skew force at P we can now add F1 to it. We can also do this manipulation in reverse, moving from figure 3c to figure 3a.

The couple T represents a purely rotational force, and is sometimes called a 'torque', hence the symbol T. It is not a 'moment', as we explain later. It exists whenever two forces of equal magnitude, opposite direction, and non-coincident lines of action exist. Its magnitude is given by the magnitude of either force multiplied by the perpendicular distance between the two forces' lines of action. Its units are thereby force by distance, such as Nm, or lb.ft. It is a vector, and like other vectors it is depicted as an arrow, often with an arrowed ring around it, or sometimes a double arrow head, to distinguish it from the linear forces. Its line of action is perpendicular to the plane containing the two linear forces and its direction is given by the right-hand rule, as shown in figure 3.

Figure 4 shows the free nature of couples in an informal way. Here a couple of large but closely spaced linear forces is converted into an equivalent couple of smaller but more widely spaced forces with arbitrarily different lines of action.

> "the most interesting property of couples is that they are 'free' vectors"

Perhaps the most interesting property of couples is that they are 'free' vectors. Unlike linear forces, which can slide along their lines of action but must not move sideways off them, couples can act at any point in a body with always the same effect. However, the same caveat regarding structural analysis mentioned earlier applies equally here.

Finally, on the subject of adding forces, how do we add two forces on parallel lines of action? We could use the parallelogram rule at infinity, where parallel lines intersect, but that would be a long walk. At the left of figure 5 we use the parallelogram rule on not quite parallel forces to give an indication of how it might work.

At the right of figure 5 we use a method similar to figure 4. We simply add to our parallel forces, F1 and F2, two forces with equal magnitudes and opposite directions, F3 and -F3. This allows us to bring the resultants of the additions together at point P. We then add these resultants, effectively eliminating the F3s, and we have the answer Fres.

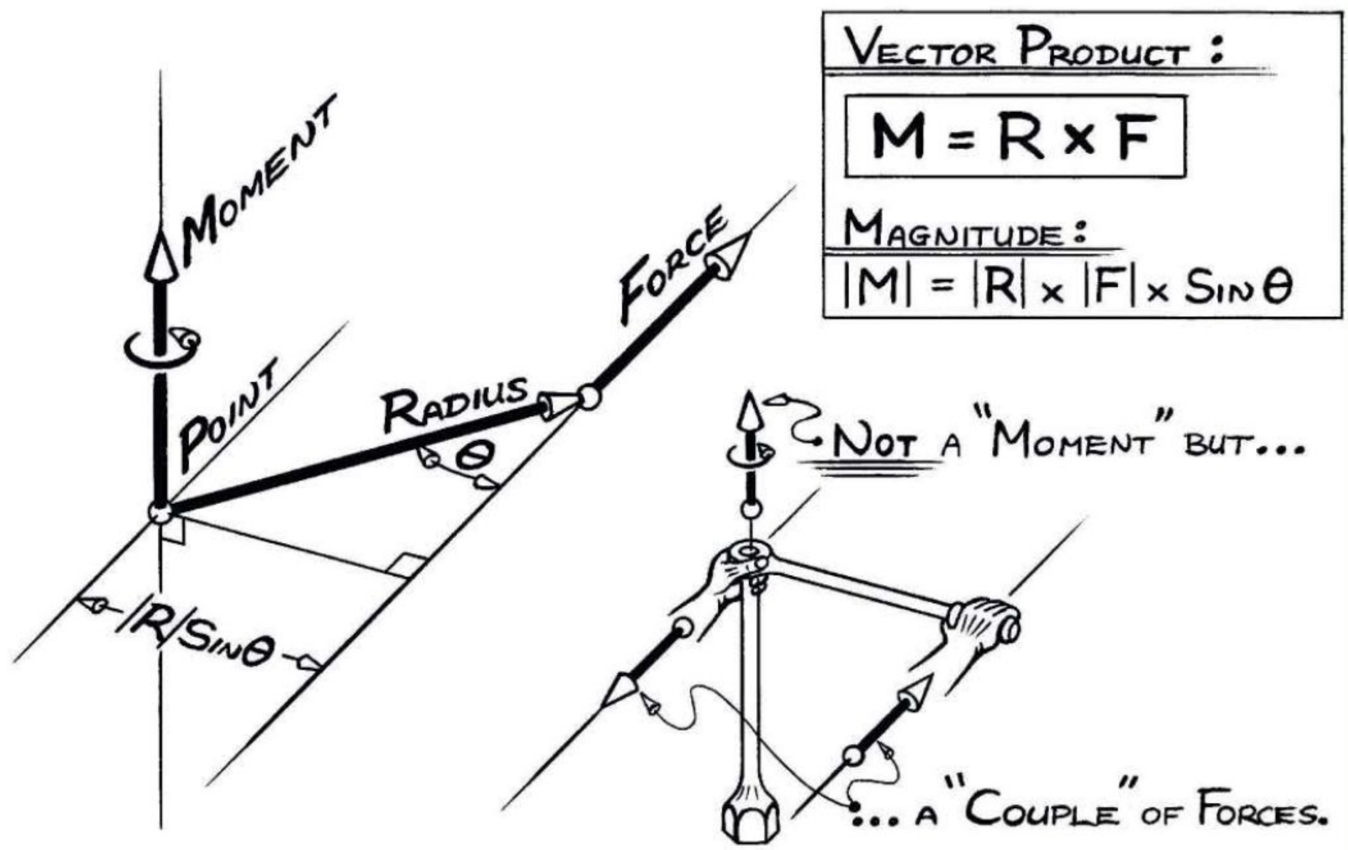
MOMENTS

For completeness we need to briefly consider moments here, even though we don't need them later. Figure 6 gives the modern definition of a moment. We get moment vector M when we perform a certain type of operation, the 'vector product', on two other vectors, R and F. It turns out that modern vector theory can be constructed very neatly if we use the vector product as one of the building blocks. For example, in figure

THE MOMENT OF A FORCE AT A POINT

Figure 6

The moment of a force at a point



6 we see that wherever we slide force F along its line of action, it always gives the same moment M at the arbitrary point P. The vector product and its moment can replace the second axiom of statics given earlier. Modern vector theory is used in many different fields besides mechanics, such as structural engineering, aerodynamics, electrodynamics, quantum theory and more. So moments are at the core of much of modern engineering and science.

However, the practical understanding of moments is not what it could be. This is partly because the word 'moment' is used with different connotations in the different fields. We suggest that in mechanics a moment should be considered a potential *effect* of a force at a particular point. As such, it is a 'bound' vector that only makes sense when fixed to its particular point. This contrasts with a couple, which is a rotational *action* applied anywhere on a body. The reader can discover the difference by trying to loosen an over-tightened nut using only one hand at the end of a wrench with a long extension shaft. It is not possible to apply a purely rotational force using only a single linear force!

It may help the reader, when they hear the phrase 'the moment of a force at a point', to think of the couple that must be applied to the body when the force is moved away from its original line of action to the point, as in figure 3. This is how 'moment' is used in many engineering circles. However, with this usage it is important to specify which forces are moved, and where they go. Different moves give very different moments. It may be that the subject of suspension antis is considered controversial because different authors move different forces to different places, without clearly stating which forces go where. We will discuss this in more detail later.

> **moments are at the core of much of modern engineering and science**

Erik Zapletal started school when motorsport was slowly recovering from WWII and man had not yet flown above the highest clouds. He was still at school when Porsche's 917 turbo had over 1000bhp, Chaparral's 2J 'Sucker Car' was cornering at unheard of gs, and man was walking on the moon. He has spent the last 40 years wondering if anything interesting will ever happen again.

IN THE NEXT ISSUE

Zapletal turns his attention to Kinematics as he continues his look at the fundamental principles of vehicle dynamics.

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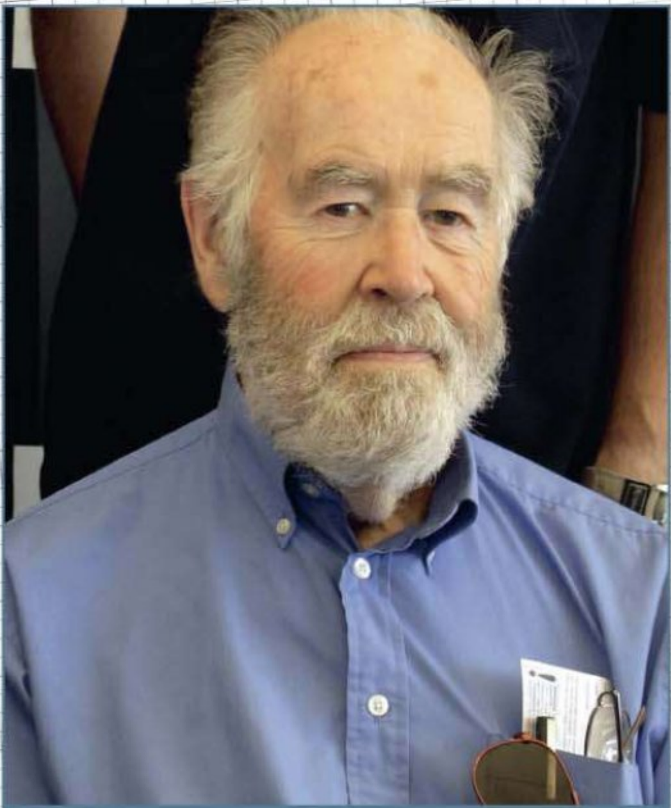
THE DESIGNERS

ERIC BROADLEY



> I wasn't really thinking of getting into commercial racing...

A quantity surveyor by training, an engineer by intuition, Eric Broadley may not have set out to change the face of motor racing, but that's exactly what he and his company, Lola, did

BY IAN WAGSTAFF

In doing interviews for this series, one designer's name seems to be mentioned over and over again, that of Eric Broadley. Perhaps that it is not surprising. This is the man who created what was to become the most versatile of all racecar manufacturers, and certainly one of the most prolific production chassis suppliers. 'I wasn't really thinking of getting into commercial racing,' he says. 'It was just a dabble, but it took me over.'

Lola has now been operating for over half a century, the first 40 years having been run by Broadley. During that time it won just one Formula 1 grand prix and that was disguised under the Honda name, but victories in a wide variety of formulae and wins in classic races such as the Indianapolis 500 and the Daytona 24 Hours mark it out as infinitely more significant to the motorsport industry than many of those who have multiple Formula 1 wins to their name.

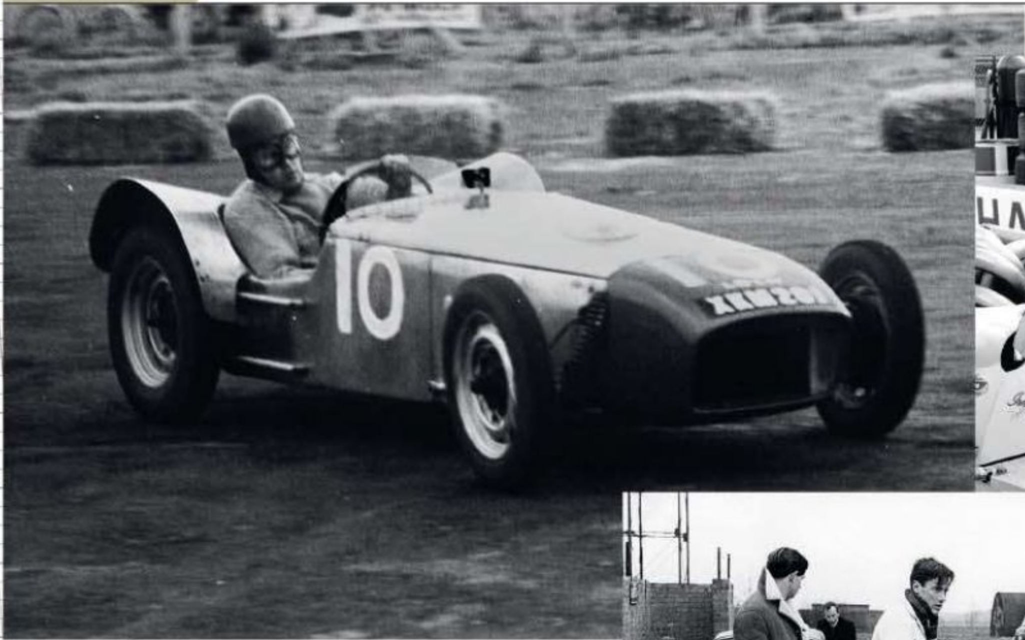
Quality surveyor Broadley's start in the sport was the classic one of an 1172 Formula car. Having tried his hand with his cousin Graham's Austin 7 Special, 'I became keen to drive, but I was also very interested in the engineering and design,' he explains. The 1172 Broadley Special dominated its class in 1957. For his next car Broadley again went head on with Lotus, this time in the 100cc Sports Racing category. Again, the car was incredibly quick, even in Broadley's inexperienced hands. In all, around 40 of what became known as the Lola Mk1 were made. Lola had become a production car manufacturer. Formula Juniors and then a 1.5-litre Climax-engined Formula 1 car that John Surtees put on pole for its first world championship round followed and Lola was on its way.

On being asked which of the around 240 cars that Lola has built stands out, Broadley smiles and answers, 'The older I get the more I think my first car is my favourite.' The iconic T70 Sportscar obviously stands out in his memory (a recent industry poll showed the Mk3b GT version as the favourite Lola) but he thinks that it is the Formula 5000 cars that stand out. 'It was an interesting and difficult period, caused by extreme tyre development. By the mid-1970s, when we were running the T332, we had got to the stage where we had huge rear tyres, massive rear rims and very small front tyres. We were making our own wheels because nobody else could keep up and we got to 20in wide. This made the cars extremely difficult to handle. You need to use the front of a car to support it but the front tyres were so small they weren't capable of taking much load. There was also a massive cast iron engine in the back and you had to control the car from the back, which is very difficult to do. We managed, more or less, to get over this but the cars were still difficult to drive. It was not until the FIA in its wisdom – it's not always wrong – decided that the rear tyres were too big that this improved. Then the tyre companies said we'll make the front tyres much bigger. They had not thought of that before!'

> We could be pretty accurate in those days, but no two cars would be absolutely the same

Mention of the FIA leads Broadley to recall the decision of the organising body to 'dump the big engine rule' and reduce the size of endurance racers to a mere 3.0-litres. 'Our main direction at the stage was GT racing and they killed it stone dead overnight.'

The interest in GTs went back to the Lola Mk6 GT of 1963 – a car that Broadley says was 'the sort that anyone could have jumped into and driven quickly' – and another problem with authority. The hurriedly finished car arrived at Le Mans only to fail scrutineering. A rule stated that



Above: like many of the great racecar designers, Broadley started his career behind the wheel, seen here in 1957 in one of his early 750 Motor Club excursions

Right: Broadley (middle right) discussing the latest in pit lane fashions in 1961

the drivers had to be able to see behind through a rear view mirror. However, the air ducts to the carburettors made it impossible to see through the steeply raked rear window. Tony Southgate, who was working for Broadley at the time recalled, 'We had made this fantastic effort to get there and the bloody car was not even going to start.' Much hacking away, and with the induction system re-routed through the sides, saw the car eligible for the race. 'It was probably our own stupidity,' recalls Broadley today, 'there was a rule that said you had to have a certain size rear vision and I said it didn't have to be all in one piece. That should have been all right, but it wasn't. The organisers at Silverstone (where the car had made its debut) and the Nürburgring accepted it, but the ACO did not.'

The Lola Mk6 GT led to an unhappy involvement with Ford on the GT40, and from there to the GT versions of the T70. Broadley reflects on how technology has changed since those days: 'We went from a stage when I could pretty much design the car by myself to the computers that have effected both the design and manufacturing process. We could be pretty accurate in those days, but no two cars would be absolutely the same. Now everything is 100 per cent accurate and all cars are the same.

'When about to design a car, the obvious first thing to do is to look at the rules... the second thing is to see how far you can bend them to your advantage.

> **What is important is that a designer should have a natural ability to visualise the car he is working on**

All cars have two front and two back wheels to start with so you are starting off with quite strong limitations. Very often you don't have much room to move and sometimes you are carrying on from a previous design so you are just dealing with modifications. Where the engine is located, where the fuel is going and the various bits and pieces around it forms the basis of the design. Then you have to think about such as the torsional stability and the dynamics and, of course, the aerodynamics. You gradually bring them all together.

'There is then the question of how much priority you give to each area of the design. This should not be a personal preference thing, it should be a functional judgement.' What is important, says Broadley, is that a designer should have a natural ability to visualise the car he is working on. He says it was out of the question to start working on the drawing board before this. He also feels that those who now work on computers may have lost this ability. 'They get their vision from the computer, not the other way round. A designer has got to be a designer.'

Broadley admits he 'never really became computer literate, at least not to the extent that I could design a car on a computer, so I had to stand behind somebody else. In my day, CAD was not very quick. In fact, it was quite time consuming and you could not afford that much time, there were too many other things to do.' So Broadley, who feels he was personally good at structures, found himself increasingly having to delegate. However, he believes that he has had some excellent people working for him over the years. 'You get very good results working alongside the same people. You begin to understand them and they begin to understand you.'

The first mechanics that Lola employed came from Aston Martin off the back of its 1959 Le Mans win, men like Laurie Bray and Terry Hadley. 'We threw some real problems at them and they got on and solved them.'

Broadley believes the best combination of designers employed by Lola was in the post-Ford GT40 period. 'We had Patrick Head out of university and John Barnard. Head, particularly, was very good, a

Left: Graham Hill in the Lola T90 Ford Indy car in which he won the 1966 Indy 500. This period in time was very good for Lola

Right and below: The Honda-badged 'Hondola' was the only Broadley-designed car that ever won a Formula 1 race

Above: always one to speak his mind, here's Broadley in candid mode in 1980

Photos: LAT

hands-on natural engineer. He would get straight to the root of a problem. His drawings weren't very good, though!' adds Broadley with a grin. 'Barnard was very different. He had his own ideas. They weren't always right, but he was brilliant as well.'

Of more recent Lola designers, Broadley topically, given the DeltaWing, says that Ben Bowlby 'was good in his own way, a hard working guy who liked quirky things.' Broadley also singles out for mention Mark Williams (now with McLaren) and current Lola designer Julian Sole, before continuing, 'All designers are critical of other designers, and I am probably very guilty of that. You will find a designer will lean heavily in one direction and, very often, according to the bullshit of the day. Often aerodynamics can be the be all and end all, as can be minimum weight, when there should also be concentration on such as structural and suspension requirements, c of g and cooling. All these things are equally important. There are very few designers who actually understand the basics. In fact, I often lost them myself!

'When I started, there was plenty of scope for innovation. Now the design is railroaded and there is very little room to move. Designers are straight jacketed. The problem is that the design process is more or less laid down and all they can do is just massage how much you can vary the tiny bits and pieces. When there is a lot of innovation, that can be a driving force in itself, but there is not much innovation now, everything just drops into a groove and that makes it difficult for people to think creatively. The cars are all very good and one may be just fractionally better than the others. It's all very boring!'

One of the problems that Lola had with designers was 'we could not keep them out of Formula 1,' explains Broadley. 'Some of our own excursions into F1 were more about keeping the people and some of the finance rather than actually wanting to be in it. They were after the glamour and the money and you can't blame them for that.'

Broadley also has something to say about drivers' input. 'I found out that you can't rely on their analysis, generally speaking a car is quick or it isn't and it is up to you to find out if it is the latter. Sometimes drivers can help but you just have to regard their observations as one of the inputs.' Having said that, Frank Gardener he does single out as 'good', while he also mentions Al Unser sr in this context. By contrast, Broadley believes that Mario Andretti was 'not particularly analytical, so he made things up. You never knew whether the guy was simply being political!'

“ you can't rely on [driver] analysis... a car is quick or it isn't and it is up to you to find out if it is the latter ”

He also mentions how certain drivers helped raise Lola's profile, in particular the Indianapolis 500 appearances of Nigel Mansell, Graham Hill and Jackie Stewart. The heyday of supplying Indy cars, 'when there was plenty of money about', was particularly good to Lola. 'But these things don't last for ever. You have to realise that it's a rolling business.' At one point Lola was building over 30 Indy cars a year, with a peak of 38 T91/00s.

Lola first appeared at the Speedway in 1965. George Bignotti, the legendary mechanic, had approached Broadley to build cars for the 500. 'We had plenty to do, but you grabbed what you could. Indianapolis was a strange place, still old fashioned, which was rather nice. It also still had a roadster mindset, with the teams going there in May, putting a car together, building the engine and then going racing. Then we Europeans arrived and screwed everything up for them by making it expensive.

'We approached the design of an Indy car in the same way we would have that of a road racing car, except in 1965 we had offset suspension. That was a waste of

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Left: undoubtedly the most evocative of all Broadley's designs is the iconic Lola T70 Sportscar, seen here high on the banking at the Monza 1000km in 1969

LAT

Right: in terms of sheer numbers built, the 1991 T91/00 Indy car was Lola's most prolific creation, with 38 chassis built that season

Broadley today, mid-way through the interview conducted by Waggy for *RE*

time, but that was how it was. Theoretically, it should have been an advantage, but nobody ever exploited it as they should have done. It was banned before anyone really understood its full potential.'

In 1966 Lola returned with a car, the T90, that incorporated lessons learnt from what had been a difficult debut. 'I found those first two years very interesting,' muses Broadley, who was present as Graham Hill brought his Lola home to victory.

Lola won the Indy 500 again in 1978 and 1990. Broadley was also there to see ground effects introduced to the Speedway. 'It was rather rule of thumb but it seemed to work, but then there is a lot of bullshit talked about wind tunnels...'

The advent of the Indy Racing League undoubtedly 'spoilt the business' for Lola. Although the company pitched to become one of the IRL's chassis suppliers for 1997, Broadley came under much opposition from his US distributor Carl Haas, who was firmly in the CART camp. 'So I backed off. You grab what you can in racing.'

By this time though, thanks to business in Champ Car, as well as Can-Am and F5000, Broadley must have crossed the Atlantic between 200 and 300 times.

It was in the 1990s that Broadley feels one of the biggest mistakes to have been made in recent motor racing was made. 'I think the flat bottom rule introduced by the FIA in the 1990s was a disaster. The big problem with Formula 1 is overtaking, but the thing is a show and you want to put the best one on you can. So you get the cars to overtake, but how to do that is not easy. The basic fact is that the underside of the car should be used to give as much downforce as possible to reduce the dependence on wings. It appears the wings are what screw things up but, until somebody does some good research into it, which I don't think anybody really has, we don't know precisely why overtaking is so difficult. If you use the underside of the car, exploit the venturi theory, you can get a lot of downforce without disturbing the air.'

“ the flat bottom rule introduced by the FIA in the 1990s was a disaster ”

He admits it is doubtful whether it would be possible now to get away with rear wings, but feels the FIA's ruling has meant almost 20 years of wasted research. 'The cars would be totally different now. There could be more overtaking... but we don't know that. The introduction of the flat bottom showed a total lack of understanding of aerodynamic theory. It's not right for Formula 1, which should be the leading technological challenge.'

What about Broadley's own mistakes though? 'How long have you got?' he asks impishly, before singling out 'one Formula 3 car at the beginning of the ground effects period, which we designed with so much downforce it could barely drag itself along. It was a disaster.'

However, it is not for such as this that Broadley will be remembered. You only have to think of the Mk1 Sports Racer, Mk4 F1, the T70s, the Indy-winning cars, the fleet 2.0-litre Sportscars, the Hondola and the dominating F5000 cars to realise why his is the name that so many fellow designers refer to.


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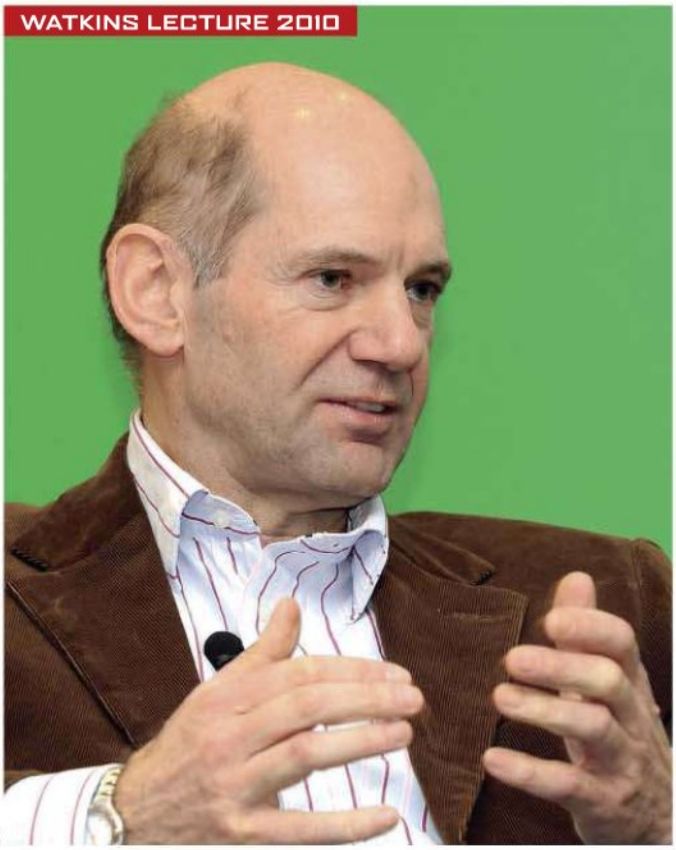


LAT

Newey on Newey

The legendary Red Bull designer was both frank and controversial when he stepped up to support the Motorsport Safety Fund

BY CHARLES ARMSTRONG-WILSON

Professor Sid Watkins, the venerable retired neurosurgeon who did so much for Formula 1, has a record of pulling some powerful names out of the hat for his lectures. Past speakers have included Ross Brawn and Bernie Ecclestone and this year's Watkins Lecture – held in support of the Motorsport Safety Fund – didn't disappoint. Adrian Newey is undoubtedly one of the greatest F1 designers of the last decade and endorsed his abilities with the 2009 Red Bell, which was arguably the best package of that season.

The term lecture has become a bit of a misnomer in recent years as the event is now conducted as an interview and this year the 'victim', as the professor described him, was put through his paces by evergreen F1 journalist Maurice Hamilton. But this seemed to hold few fears for Newey, who looked fit, relaxed and happy to talk.

DOUBLE DIFFUSERS

His inquisitor opened the questioning with, 'If the double diffuser had been banned in 2009, would you have won the world championship?' Hesitating slightly at being hit with such a blunt question at the start, Newey composed himself before delivering a very diplomatic reply. 'We had the quickest car before everyone went double diffuser,' he noted, 'so I think we would have stood a very good chance. But unfortunately that's the ifs and buts of motor racing.'

Not to be fobbed off, Hamilton pursued the theme and asked whether permitting the double diffuser had compromised the objectives of the rule changes, particularly in encouraging overtaking. 'I don't think it affected the overtaking. It gave us more downforce, so it made the cars around a second a lap quicker. That doesn't change whether a car is going to overtake or not. There's no difference in the aerodynamic wake that affects other cars.'

Newey then explained how the 2009 rules, good or otherwise, were the result of the Overtaking Working Group. 'It's questionable whether they worked or not but the process was correct. What's now happening is everybody is saying overtaking is still not as good as it should be, and we've now gone back to piecemeal modifications. I find it very frustrating because it's not thought out, it's a fiddle and dick mentality without a clear goal and proper research.' And what about banning double diffusers for 2011? 'I'm ambivalent whether it's a good or bad thing. What I don't like is the way it's done.'

THE NO REFUELLING RULE

Then he was asked about the no refuelling rule, and how that would impact on the design of the car? 'The initial problem is packaging. We've gone from a fuel tank that holds 85-90kg to needing one that holds 160kg. That's almost double the size. That means it has to be longer and wider and will reduce the radiator area.' He then pointed out that it was more difficult to

> "it's a fiddle and dick mentality without a clear goal and proper research"

gauge how that affects the car's dynamics in terms of ride height change. 'From qualifying on low fuel to the start of the race where we are on 160kg of fuel there's a big ride height change. Also tyre degredation in the early part of the race brings us onto another factor where the cars are normally quicker just before a pit stop. The weight reduction outweighs the degradation of the tyres, so under the old rules you can overtake cars by running longer. Under the new rules the car is always going to be quicker after the pit stop because you have the same fuel weight but new tyres. So, on the face of it, whoever pits first is then going to overtake.

'Then there will be all the games of bluff and double bluff with everyone standing out in the pit lane saying they are going to pit and the cars driving straight past. Potentially it means overtaking through pit stops will become more difficult. Does that mean drivers will take more risks because that's the only way they can get past? We'll have to wait and see.'

PRE-SEASON TESTING

At the time of the lecture, the media was making a big deal of Red Bull missing the first pre-season test. How did Newey react to that? 'I'm always an advocate for spending as long as possible on research and the design of the car and hopefully having a better product, which will more than compensate for the lack of development. No mid-season testing makes pre-season more important for reliability and learning about the car, and we compromise ourselves on both of those, but I believe it is the best way to go. Part of that is how confident you are in your simulation tools. One thing that surprised me last year was that with no testing, most of the teams were still able to put on huge upgrades to their cars.'

Was it delayed because the team was hoping for the Mercedes engine? 'Yes, and no. The Mercedes engine enjoyed a good advantage last year. Lap time-wise it was significant – several tenths of a second. When you have to find that back in the chassis it's a big ask. We looked at the Mercedes engine and we looked at the Cosworth engine very carefully. In the end, Brawn and McLaren blocked us from having the Mercedes engine. Also we became very satisfied with staying with Renault because Mercedes developed very heavily through what was supposed to be a frozen engine, while Renault was very honest and they fell behind. They now have a good programme to redress that. We've had a very good relationship with them and they've been a fantastic company to work with. If we can maintain that good working relationship and they can bring that product up then that's the ideal working scenario.'

MARSHALL SAFETY

And what are his views on safety? 'Marshall safety is something we are guilty of not thinking enough about. Things like KERS. I'm hugely relieved that we got through last season without anyone being hurt by it. In many ways I would be concerned if battery KERS came back into Formula 1. A lot went on behind the scenes that people don't know about with exploding batteries. If a car goes into the barrier, the driver is probably hurt, there's wreckage scattered everywhere, and you are meant to stop, put on your rubber gloves, approach it carefully, push the KERS button, stand back, wait for it to go green, and only then can you go and approach the car. That's not human nature. You are all trained to go and assist somebody, not wait for the light to go green. Those sorts of things we do need to think about more carefully.'

> “I would be concerned if battery KERS came back into Formula 1”

ON CRASHGATE

Questioned about the Crashgate saga at the 2008 Singapore GP, Newey admitted he was, 'surprised at the time but not surprised a year later when it finally came out. It was pretty obvious.' But then revealed an unexpected take on the issue: 'Flavio [Briatore] I have a lot of respect for. He is one of the few senior figures in the sport who actually does genuinely care for it and has a good business picture for the sport and a good vision of where it should be going. I think it is poorer without him, despite that incident, which we can only condemn.

'Having said that, to some extent it has been over-hyped, journalists saying "this is awful, we're endangering a young driver". Because the cars are so safe he wasn't endangering himself, he wasn't endangering any marshals or spectators where he did it, he was fixing a race. Frankly, I think that what Michael Schumacher did crashing into Damon [Hill] and Jacques [Villeneuve] is actually more dangerous because not only could he have hurt himself, he could have hurt the drivers he was hitting deliberately, but he got off scot free.'

Hamilton then drew him on perhaps the darkest chapter in his career – Imola 1994. 'The court case didn't do any good,' reflected Newey. 'I don't think we'll ever know exactly what happened. What we can see from the data was the car didn't understeer off, which would be consistent with a broken steering column. It actually oversteered off. In motorcycle terms, it high sided. The rear stepped out, Ayrton [Senna] corrected, then the rear gripped, spat him to the outside, at which point he got onto the brakes.

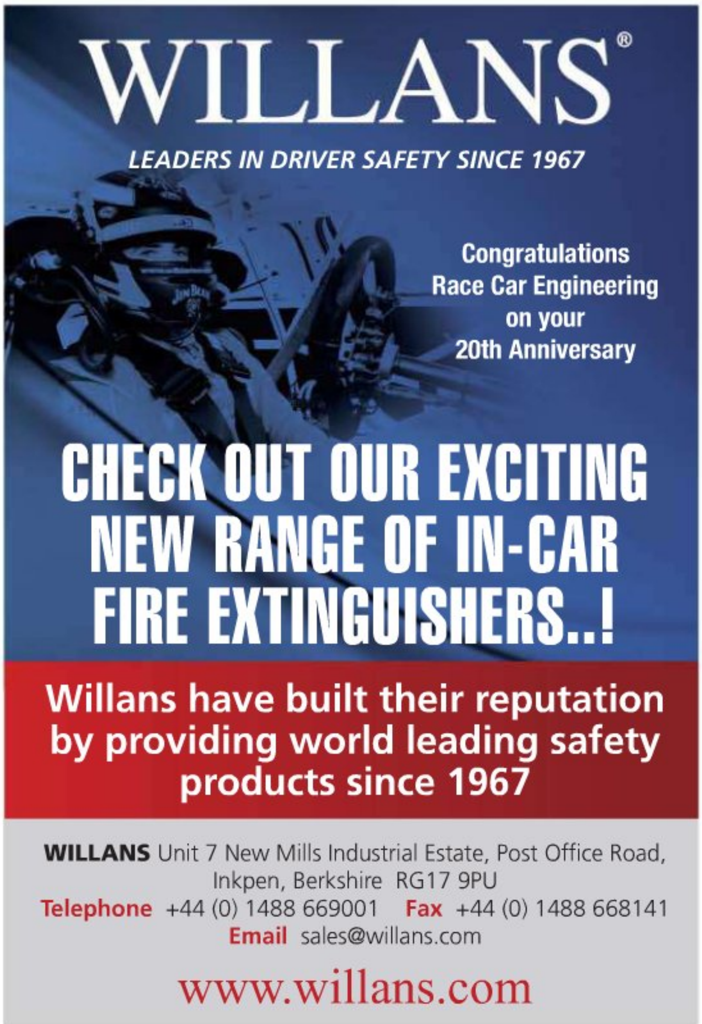
'It served no purpose. Instead of remembering Ayrton for how great he was, we got dragged into this court case that lasted for almost 10 years. Unfortunately, in the case of the prosecutor, greed and self interest got in the way.'

With respect to the 1994 car, he was candid about its issues. 'The tragedy was, the car at the start of the year was a pig. We had been on active suspension for two years and developed the car aerodynamically to suit. When we went back to passive, I'm afraid I completely mis-read it. I didn't get the sidepod shape right and they were stalling and causing all sorts of handling problems. So that car, at the start of the year, was a very difficult car to drive, and Ayrton used his incredible ability to manhandle it around at a speed it frankly shouldn't have ever gone at. We sorted that out by Magny Cours, and through the second half of the year we had a car that was where it should have been at the beginning, but that car unfortunately Ayrton never had a chance to drive.'

By the end of the lecture, Newey had acquitted himself as a likeable man who the audience clearly warmed to with their enthusiastic applause.

LAT

After an intensive programme of research, the Renault-powered Red Bull RB6 is Newey's latest F1 creation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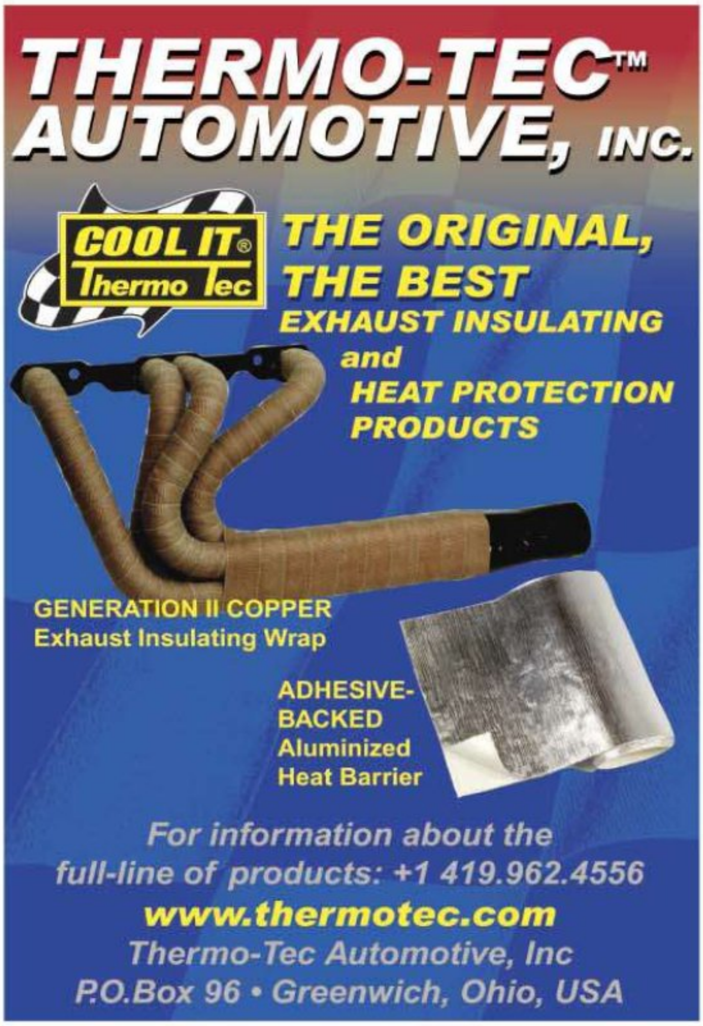
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Racecar damping

LAT

How damping ratios can be used to better understand how to control a racecar

BY DANNY NOWLAN

A number of issues ago I wrote an article on exploring approaches to specify a racecar damper. This article is the second in that series and we shall be following on from where we left off. In particular, we will be exploring the use of damping ratios – what they tell us and how we can use them.

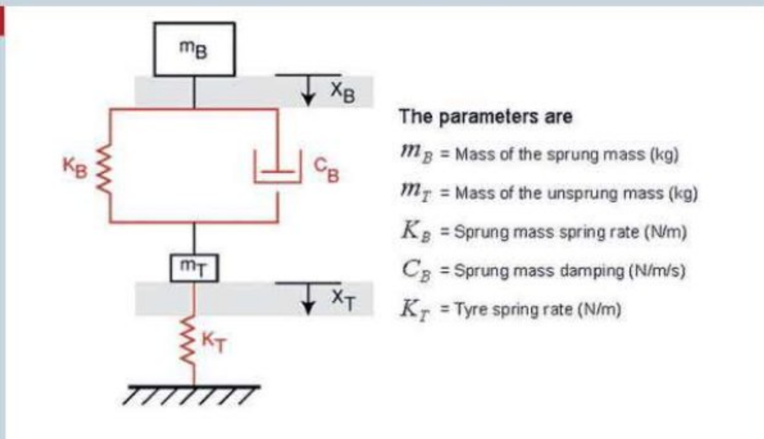
Before we get into this though, let's re-cap where we left off with the first article. In that I presented the example of controlling a quarter car mass being subjected to a sinusoidal road input. We explored what damping would have to be used to control this and what we could do via an inerter. The conclusion drawn was that damping alone wouldn't get the job done and an inerter would only work at a specified frequency. However, we did leave the article on the note that we could approximate what we wanted to do by approximating the job with damping ratios. This is where we will take up the discussion.

As a precursor to what we will discuss, let me go through the two schools of damping I have encountered over my career. The first school dictates all the damper does is control the oscillation of the wheel, that's it. The second school regards the damper as an essential element of the set up of the racecar and, in addition to controlling the oscillation, it is used as a vital tool to control chassis attitude and tyre loads. I have varied between both schools of thought and I trust what we will discuss here might provide some answers to this conundrum.

Let's talk about how we can characterise dampers through damping ratios. As before, we will be using the quarter-car model approximation to draw our line in the sand. I realise that a real car functions with a chassis and

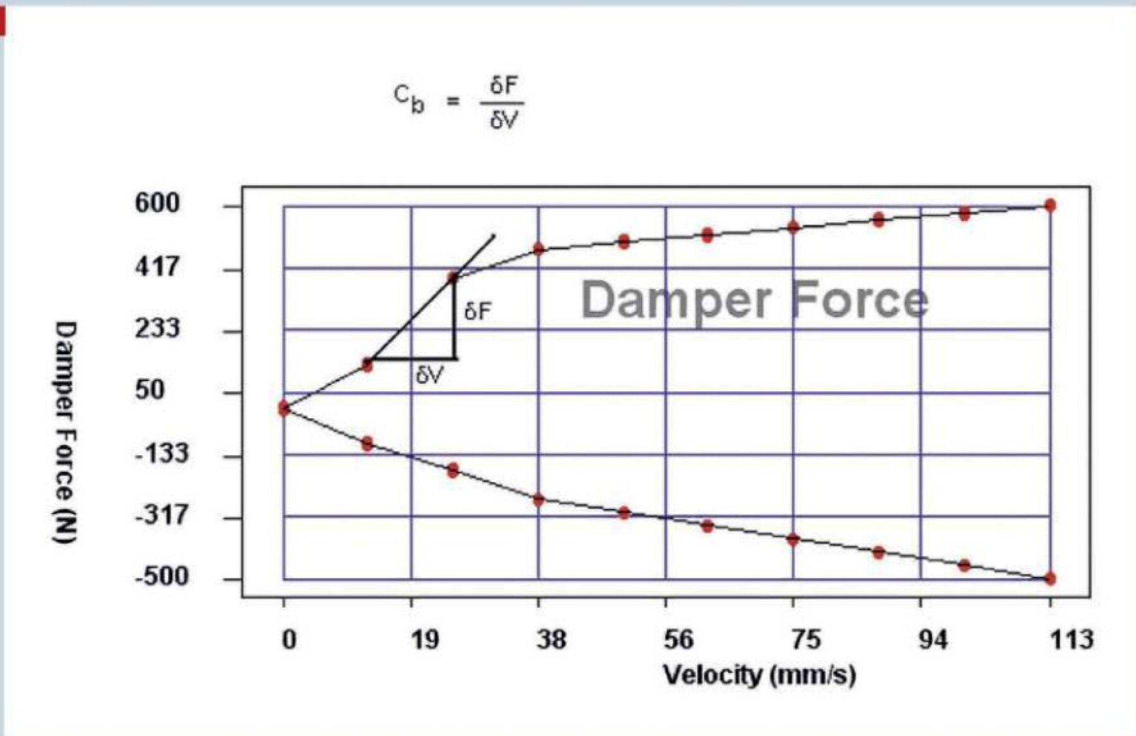
THE QUARTER-CAR MODEL

Figure 1



DAMPER SLOPES

Figure 2
Evaluating a damper slope from a typical force vs damping curve



four contact patches, but bear with me as this is still a very useful approximation. To refresh our memories let's look at the quarter-car model in figure 1. Here we have a system with four degrees of freedom - body movement and velocity and wheel movement and velocity. To solve this properly we need to start solving eigenvalues and eigenvectors but this doesn't readily lend itself to nice hand calculations.

Instead we need to make some approximations. The approximation that we are going to make is,

$$K_B << K_T$$

$$m_t << m_B \qquad (1)$$

Please note, all the rates we are about to quote are going to be in wheel rates. The astute reader will instantly recognise that this is perfectly valid for a road car, but we could run into trouble with an open-wheeler application where the spring rate of the chassis are of the same magnitude as the tyre, or in a V8 Supercar or NASCAR, where the unsprung masses are quite high. Bear with me though, for what we are constructing is a rough rule of thumb. You'll see its power as we carry on.

In this case, the governing equations of the sprung mass reduce to,

$$m_B \cdot x_B'' = -K_B \cdot x_B - C_B \cdot x_B' \qquad (2)$$

In layman's terms, what this means is that the acceleration of the sprung mass is the sum of the spring rate of the damper times the damper movement and the damping rate times the damper velocity. The damping rate is the slope of the damping curve at that particular damping velocity. Let me illustrate this in figure 2.

The beautiful thing about equation (2) is that we can now do a laplace transform on this. The end results are shown below,

$$0 = s^2 + \frac{C_B}{m_B} \cdot s + \frac{K_B}{m_B} \qquad (3)$$

If we compare this to the ideal second order system with natural frequency ω_0 and damping ratio ζ it is seen that,

$$0 = s^2 + 2\zeta \cdot \omega_0 \cdot s + \omega_0 \qquad (4)$$

When equations (3) to (4) are compared we know have the tools to specify our desired damping rate in terms of damping ratios and natural frequency,

$$\omega_0 = \sqrt{\frac{K_B}{m_B}} \qquad (5)$$

$$C_B = 2 \cdot \omega_0 \cdot m_B \cdot \zeta$$

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_B} \qquad (6)$$

This is the first point of the analysis. Equation (5) specifies the natural frequency in rad/s of the system (to convert to Hz divide by approximately 6.283185), and equation (6) means a damper rate based on the damping ratio that is desired can be specified. It's at this point when calculating you need to be really precise with your units. Everything here needs to be in strict SI units. That is masses in kg, Spring rate in Nm and damping rate in Nm/s. Also all rates are in wheel rates, not at the damper. I make absolutely no apologies for this. Besides, as far as I am concerned, any measurement that has the slug as its measure of density is intellectually flawed.

Before we get into this in further detail, let's do a worked example of this. For this particular case, I've outlined the following variables in table 1. The damping rate was actually calculated from figure 2 and I would invite the interested reader to repeat the calculation. Let's now work through the calculation of the natural frequency and the damping ratio shown in formula (7) below.

As far as I am concerned the real power of this is that

$$\omega = \sqrt{\frac{MR^2 \cdot K_B}{m_B}} = \sqrt{\frac{1^2 \cdot 175000}{157}} = 33.386 rad/s$$

$$\zeta = \frac{MR^2 \cdot C_B}{2 \cdot m_b \cdot \omega_0} = \frac{1^2 \cdot 21333}{2 \cdot 157 \cdot 33.386} = 2.03 \qquad (7)$$

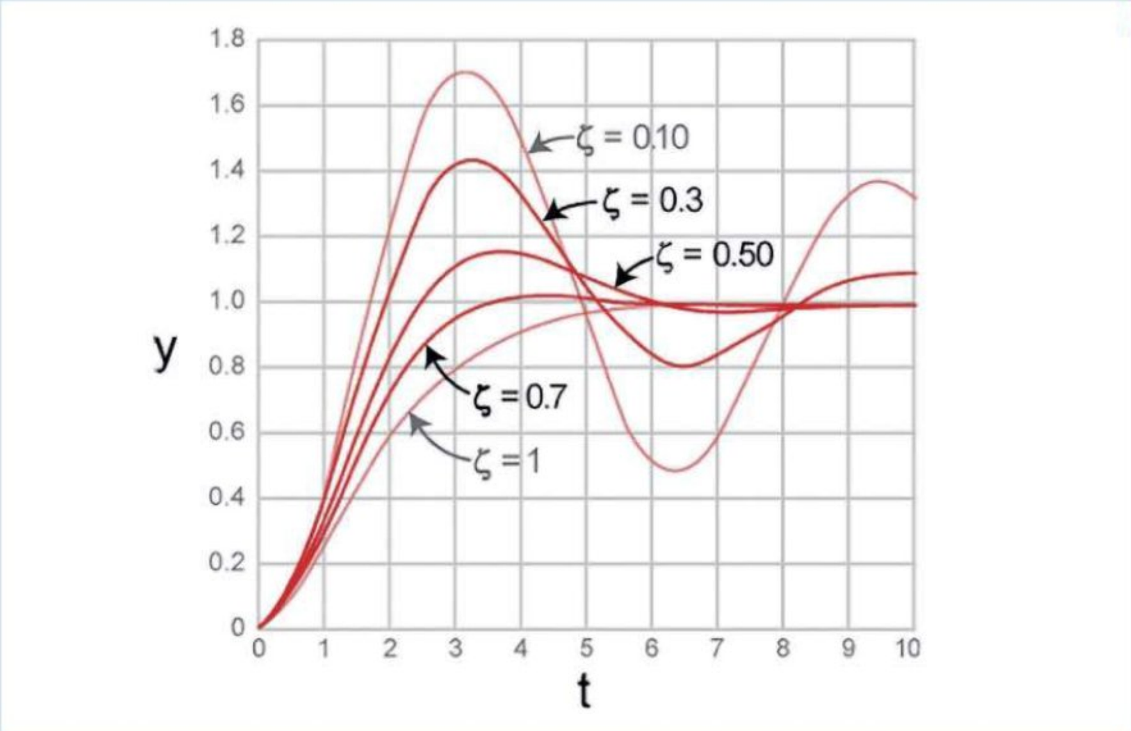


Figure 3
Second order system response to a step input

it gives us a powerful way of non-dimensionalising what is going on with a damper. If you characterise a damper this way the moment you do a spring change you can specify a damper, which in theory has identical characteristics. I should also add this applies both in bump and rebound. Obviously, when back calculating for rebound when re-working your numbers remember to multiply the slope by -1, if using a standard force vs damper curve, that shows bump positive and rebound negative.

Now that we have gone to all this trouble to calculate damping ratio what does all this actually mean? To get to the heart of the matter we need to return to what our quarter car is going to do when we apply a step input to it. The damping ratios will actually tell you this, and it is illustrated here in figure 3,

Reviewing this graph is very interesting. At low damping ratios the quarter-car model is decidedly underdamped and it takes a long time to return to an equilibrium state. However, think about what this is ideal for. If we are hitting a bumpy bit of the circuit we actually want the car to do this. When the damping ratios hit about 0.5-0.7 the car's oscillation is remarkably decreased. That's not so great at dealing with bumps, but is ideal for controlling the body when we are pitching and rolling. Damping ratios greater than this are ideally placed to force the car to almost act like a spring, as we discussed in our previous articles. However, be warned there are some consequences for overdoing it.

On the back of this I came up with a rough damper guide that I actually outlined in my first article. Now that we have discussed this in further detail let me outline this more closely. Armed with this knowledge, let's look at the first damper curve we saw in figure 2. Assuming the same numbers from table 1, I'll work out the damping ratios for both bump and rebound. This is presented in table 3.

Table 3 presents some enlightening insights into what this damper is trying to do. First things first, the damping ratios from 0 tell me immediately this is a high-downforce car (the high

TABLE 1

Values for quarter-car example

Item	Value
Motion ratio (damper / wheel)	1
Spring rate	175000 N/m (1000lbf/in)
Damping rate	21333 N/m/s
quarter-car mass	157 kg

TABLE 2

Rough outline to damping ratios

Damping ratio range	What this applies to
0.3 – 0.4	Ideal for filtering out bumps
0.5 – 1.0	This deals with body control
1.0 +	This deals with extreme body control / driving temperature into the tyres

TABLE 3

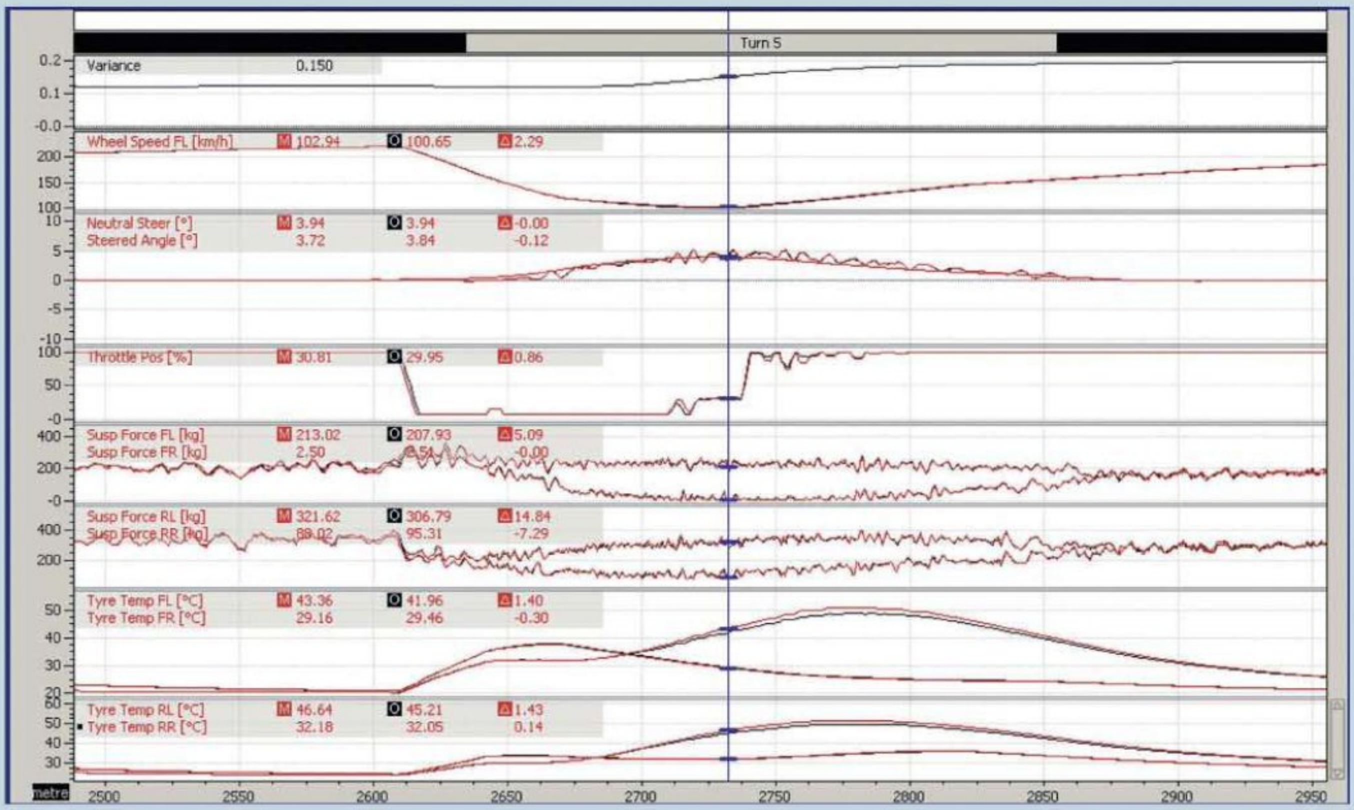
Damping ratios for damper presented in figure 2

Velocity (mm/s)	Damping ratio in bump	Damping ratio in rebound
0	1.24	0.95
13	2.03	0.6
25	0.616	0.707
38	0.175	0.31
50	0.167	0.286
63	0.174	0.31

MOTEC SIMULATED TRACES

Figure 4

Results for two totally different dampers



damping ratios are telltale signs this is a high downforce car). The high damping ratios immediately suggest that body control is paramount. Looking at the bump at 13mm/s the damping ratio jumps to 2.03. This indicates the damper engineer is trying to give some feel to the car, as well as load the tyres. Beyond this range the dampers blow off to a low ratio to allow the car to ride the bumps. In rebound from 13-25mm/s the damping ratio is 0.7. This tells me body control is still paramount. Beyond the damping ratios blow off to 0.3. This tells me this is designed for the bumps.

I think the reader is fast starting to get the idea that damping ratio is not just a useful parameter, but can tell you an awful lot about what you want both the chassis and the tyre to do. As a rough rule of thumb, the higher the damping ratio, the better it is for both controlling the chassis and putting temperature into the tyre. The lower it is, the better it is for riding bumps.

However, the question has to be asked how do we determine what we want and need? One is experience and a bit of informed intuition. Let me illustrate with an example. Say you have a low-downforce car going over a circuit with a lot of undulations. In general terms, for a car without a lot of downforce you would actually like low-ish

> **"the higher the damping ratio, the better it is for both controlling the chassis and putting temperature into the tyre"**

damping numbers in rebound – say, damping ratios in the order of 0.3-0.5. However, let's say you are rounding out a turn with an undulation – could it be desirable to actually have a higher damping ratio in rebound to keep the car connected with the ground? I'm not saying this *is* what you need to do, I'm just asking the question so you can think about it.

The second method is to use simulation software to aid us in determining this. Indeed, it was this very question of evaluating the appropriate dampers that lead to the creation of ChassisSim. When I was evaluating what lap time algorithm to use it was because of this I dismissed the pseudo static lap time approach. To illustrate what I am taking about, let me evaluate two totally different types of dampers for the front of an F3 car. The results of the simulation are shown in figure 4.

This is a bit of an obvious example because this was a very bumpy circuit and I set the second damper particularly stiff in both bump and rebound, but nonetheless, this shows how you can use simulation to look at different configurations and see the impact they can have on vehicle performance. In this trace we can quickly see the impact this has had on loads, corner speed and temperatures (the red is the base line and the black is the damper change). I would wager the loss in temperature is due to the fact the apex corner speed has dropped by 2km/h.

CONCLUSION

In closing then, while we haven't achieved the grand unified theory of racecar damping, we have delved into how damping ratio can be a very effective tool. Not only does it non-dimensionalise the way we can look at damping, but we can use it to force the behaviour of the racecar to get it to do what we want it to. Is this a magic bullet? No. However, if properly utilised it is a powerful tool to investigate what is going on with the car. It will also give us some food for thought for the next instalment in this series on racecar damping.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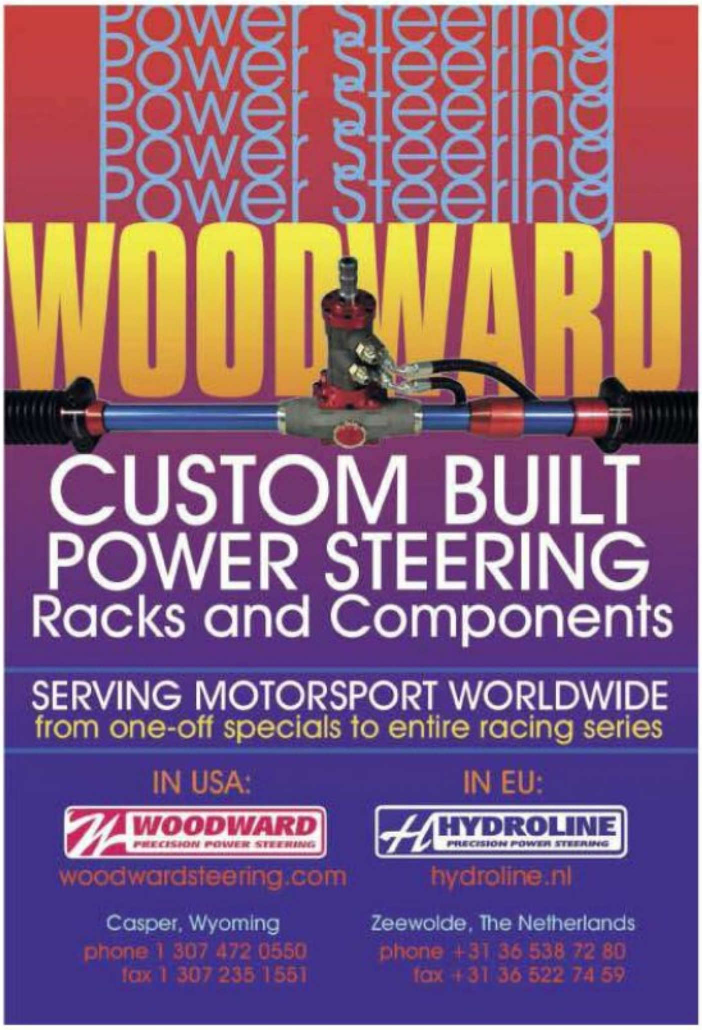
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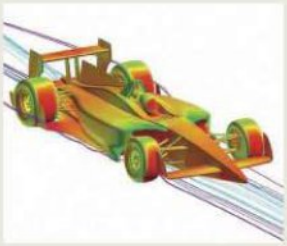
BRIEFLY...

OLD NAME RETURNS

FAI Automotive, the aftermarket supplier formed by the late Ian Walker, that ran a semi-works Lotus team in the early '60s, has moved into competition engine components with its new 'Extreme' range. The company is currently testing the potential for expansion but has already launched a range of multi-layer steel gaskets for the Lotus twin cam, Ford BDA/BDG, FVA/FVC and Formula Junior engines, plus crankshafts and con rods for the Subaru EJ20 and 25 and Mitsubishi Evo 4G63 and 4G64 engines.

LOLA INCREASES CFD CAPABILITY



Lola has started using a new High Performance Computer (HPC) built by OCF using Sun Microsystems' Sun Fire X2270 hardware. It is also using processing power from OCF's new cloud computing service RACE (Remote Access Compute Engine).

£100,000 FOR MOTORSPORT

The MIA has secured over £100,000 of Tradeshow Access Programme grant support from UK Trade Investment to help eligible UK small and medium-sized enterprises to exhibit overseas. Funding of £1000 is available for European shows and £1400 for US events (subject to UKTI terms and conditions). The following shows are eligible for TAP grants: Motorsport Expotech, PMW, IMIS, SEMA and PRI.

THE BUSINESS

Election engineering

CHRIS AYLETT

Vote for Motorsport Valley. Why?

As you read this, I suspect general election fever will be in full flow in the UK's Motorsport Valley. Why should readers without a business in the UK care? Simply because a great deal of the world's motorsport technological advances and equipment comes from Motorsport Valley. Business conditions for these businesses will affect world motorsport, from Formula 1 down to entry-level formulae.

To UK readers, just one bit of advice - please vote for someone! This is the most important election in the UK for decades and, as one friend put it, 'if you don't vote, don't bitch afterwards!' A pretty fair point, in my view.

Check the MIA website where we are showing a Manifesto for Motorsport. You need to contact the local politicians who are seeking your vote, put them on the spot with questions regarding your business and be sure they give you their plans for the future. The MIA Manifesto may help, but don't hold back. Those you elect will affect business more than ever before and can help your recovery prospects.

> "There are costs and risks involved, but what is business without these?"

Make no mistake, world governments have re-discovered the value of business. They need the wealth you create to pay taxes so they, in turn, can spend on public services. Your employees will spend their income and generate taxes, too. Your recovery and ability to pay taxes is vital to them. This is the time to hold them to account. They need your vote, so ask them what they will do to help your business. Whatever you do, don't waste your vote.

New business from NASCAR plans to introduce fuel injection in 2011, and the new IndyCar chassis with new engine suppliers (followed by Indy Lights), are great opportunities in the world's biggest market place for motorsport, the USA. Both developments will need new suppliers from around the world with necessary experience, which is just the kind of boost the industry needs. Taken together, these changes will have a significant long-term effect on the wider US motorsport industry, as their plans remove reliance on traditional carburettors and V8 engines, creating new opportunities in the process.

The MIA are organising a business development visit to NASCAR and IndyCar in May (timed to take in the Charlotte All Star Race and the Indy 500). Everyone is welcome to join us and this is a really good use of those limited travel budgets.

The bad news of US F1 and A1GP does no one in the industry any favours. We need to attract investors and sponsors and, to do so, we should expect financial due diligence to uncover how we perform. How the legislators could have carried out rigorous financial checks on US F1 and A1GP is beyond me. I just hope someone in responsibility thinks long and hard about such matters for the future as this 'brings motorsport into disrepute' - something for which many have been considered at fault in the past.

Sports' marketing budgets are substantial, and buyers select a sport to secure brand advantage. Ours must be whiter than white and right at the top of the league, and these stories make that hard to achieve.

The exchange rate of euro and sterling to the US dollar opens up substantial opportunities for European exporters. US companies can import products at a lower price than for many years, and financial commentators believe this will continue throughout 2010. This is good news for European exporters, but not so good for US manufacturers. The business world will rely, substantially, on export performance in 2010 and 2011 to build their way out of recession, so now is the time to focus on exports and chase new markets. There are costs and risks involved, but what is business without these?

We face a cautious, modest recovery, spread over the next two or three years. In 2010 motorsport is going to have a quiet, careful period, where caution is the by-word and real cash, in the bank, is king. This will change the face of the industry for years to come. Some companies will emerge stronger, with more market share than before. Make sure yours is one of those. Good, experienced management will be vital to that success.

Chris Aylett is CEO of the Motorsport Industry Association (www.the-mia.com). Please email chris.aylett@the-mia.com if you have any comments.

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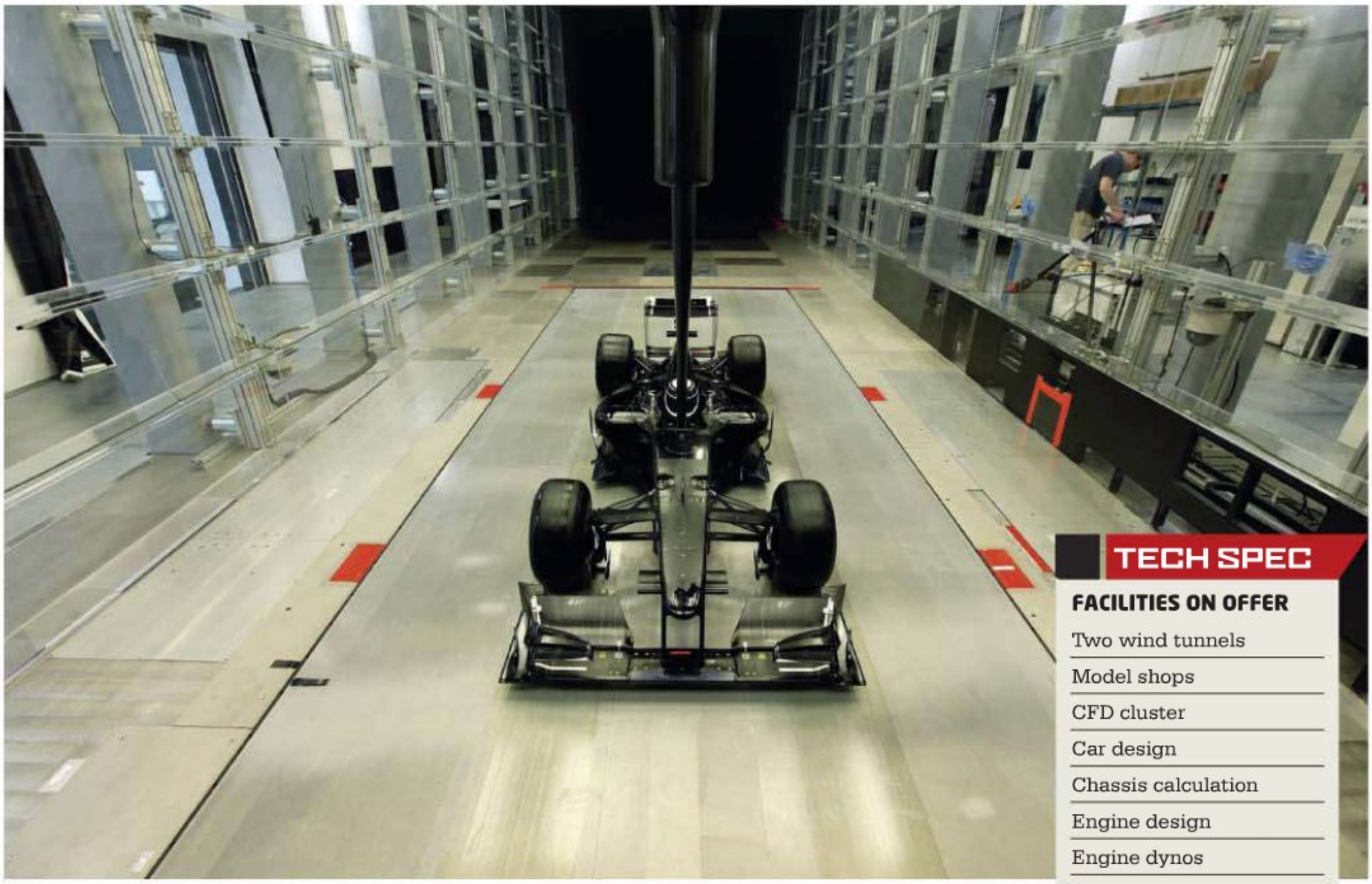

Two state-of-the-art wind tunnels are available, one of which accomodates a full-size car. Both use PIV technology

With more than 30 km² of floor space, two wind tunnels and a mind-boggling array of research and development equipment the Toyota Motorsport facility in Cologne-Marsdorf, Germany could be considered a motorsport engineer's dream. Only a dream because it was off limits to anyone outside of the Toyota works World Rally, Le Mans and Formula 1 programmes, but the facility is now available to customers.

'Over the winter we basically had to find a new business model for the facility,' explains business development manager Jens Marquardt. 'In recent years we have invested a great deal into good equipment, as well as into good people, so we obviously had to find a way to make the best use of that.

'We have retained around 200 staff. And this is the opportunity for us to bring this into a new future and open it up to a wider customer range and make our services available to anybody.'

The Toyota Motorsport facility is unique in the world, utterly dedicated to automotive R&D, as Marquart is keen to point out. 'I think we are different compared with companies like Dome and Dallara. They are chassis manufacturers and developers so they cover the whole chassis side. What we have is the whole powertrain side as well. We can provide engine development, gearbox development, car development, everything. We are not limited to one part and that is what makes us different. As in the past, when we were participating in Formula 1 we did the whole car. Now that is something we have transferred to being available to customers.'

> **"engine development, gearbox development, car development, everything"**

As the facility was built for a single team, rather than the comings and goings of secretive customers, the question of confidentiality is something that the staff in Cologne will have to contend with. 'It is one of the keys for us now, that assurance of confidentiality to a customer,'

TECH SPEC

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The scale of the facility means client confidentiality shouldn't be a problem

THE FACTS

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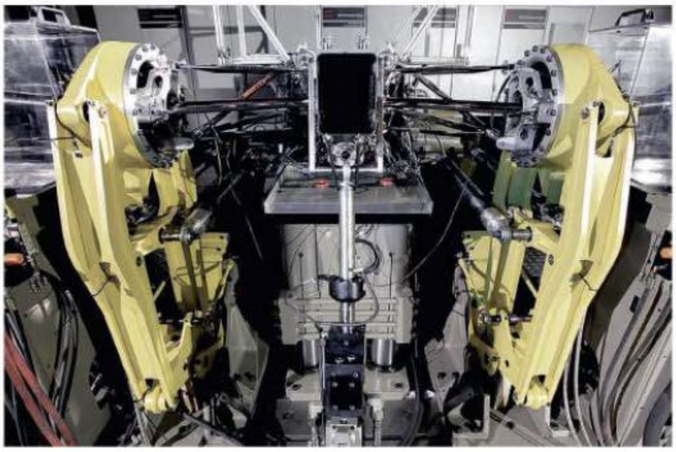

The transmission test rig can be used to apply suspension loads to a gearbox

Just one of the three autoclaves available for use, two of which are big enough to take full size car bodies

explains Marquardt. 'We are lucky that what we have hasn't been built on a small scale and that gives us the opportunity to divide sections into customer-dedicated areas and, through that, ensure people their confidentiality. From our F1 past it is something we know is very important.'

Toyota's two wind tunnels benefit from Particle Image Velocimetry (PIV), which involves the use of lasers that illustrate the movement of tracer particles in the air flow. This is digitally recorded to provide an accurate analysis of airflow at any given point. Visualisation of flow structures in x, y and z planes within the tunnel allow direct measurement of local flow velocity vectors, as well as accurately validating CFD predictions of velocity and vorticity fields.

Post-processing and comparison to CFD calculations is streamlined, while PIV begins at short notice with a quick start-up time and, thanks to seeding technology, no clean-up after use. This enables normal testing to resume immediately. As well as PIV, the tunnels also feature continuous motion and High Speed Data Acquisition (HDSA) systems to provide higher levels of data more efficiently than standard wind tunnels.

In continuous motion mode, a user-defined programme of ride height, yaw, roll, steer and individual pre-load changes provide continuous motion on a pre-defined trajectory, while the HSDA system is continuously acquiring data at high frequency.

'On the wind tunnel side, in the later stages of our programme we ran the two tunnels seven days a week on shift operation. So all of the model making and the design was focussed on that, which required a lot of people. Now that area has been shrunk down, but I think what we have available is still quite capable of handling a variety of programmes in parallel.

'The extent of services a customer might expect to get from us is a very broad range, especially in the wind tunnel area' concludes Marquardt.


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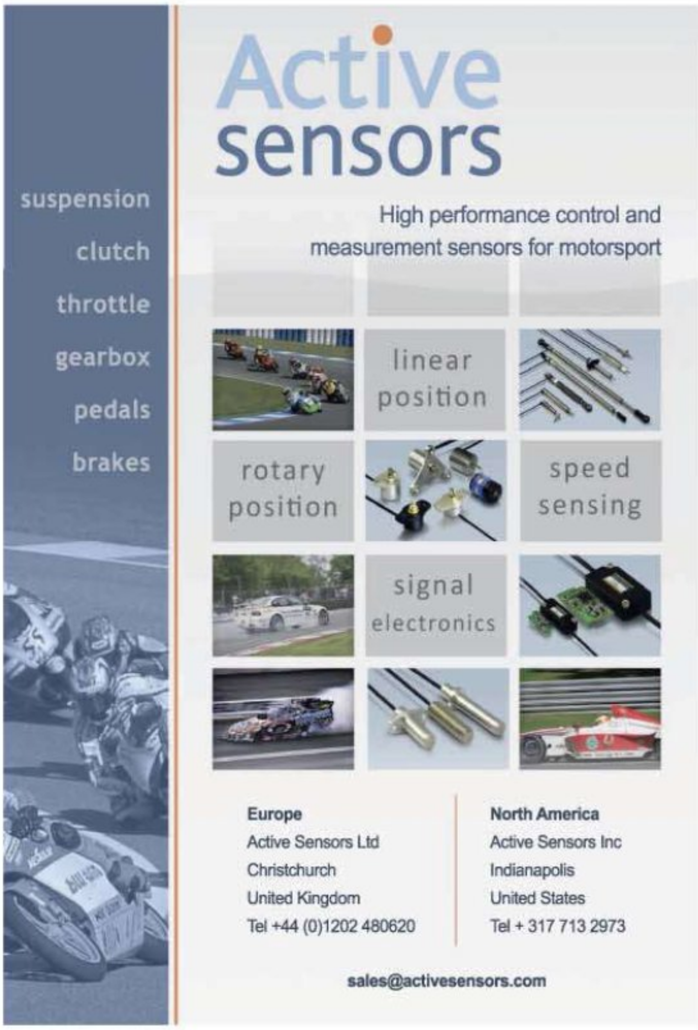
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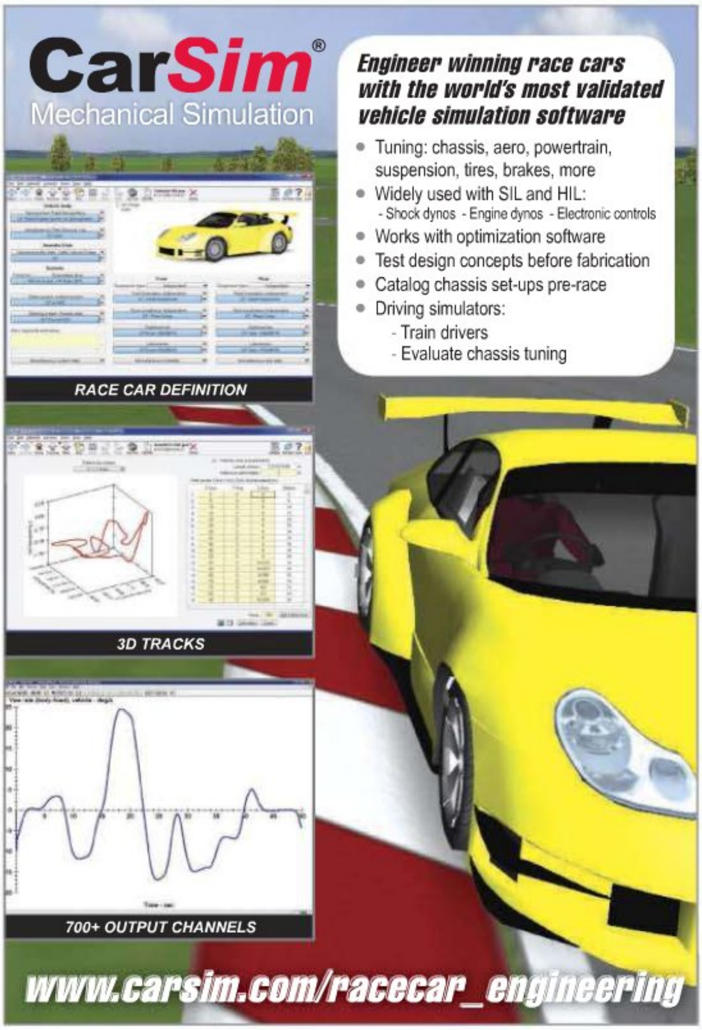
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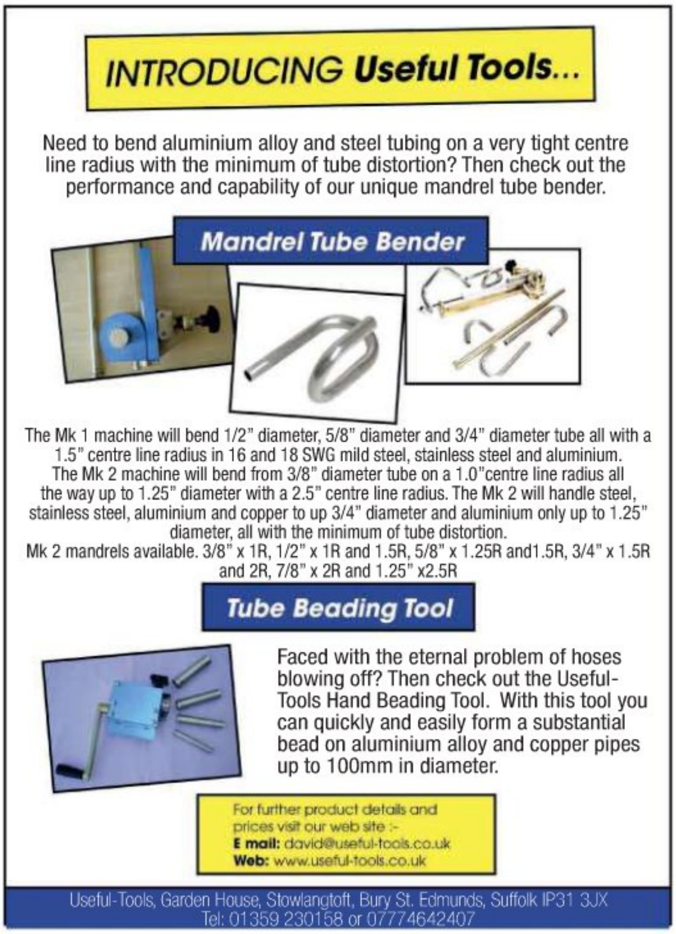
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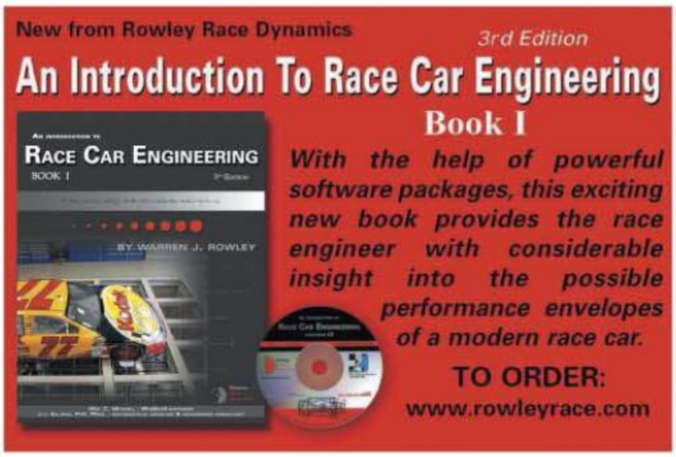
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F: +44 (0) 1303 252508t

VALVE SEATS
CHE PRECISION INC
T: USA (+1) 805 499 8885

G&S VALVES LTD
T: +44 (0) 1483 415444
Alder Works Cattershall Lane,
Godalming, Surrey GU7 1JS, England
www.gsvalves.co.uk
gsvalves@aol.com

VALVE SPRINGS
DIAMOND
T: USA (+1) 313 792 6620
EDELBROCK
T: USA (+1) 213 781 2222

G&S VALVES LTD
T: +44 (0) 1483 415444
Alder Works Cattershall Lane,
Godalming, Surrey GU7 1JS, England
www.gsvalves.co.uk
gsvalves@aol.com
HERBERT TERRY & SONS
T: +44 (0) 1527 64261

KENT CAMS
T: +44 (0) 1303 248666
Units 1-7 Shorncliffe Industrial
Estate, Folkestone,
Kent, CT20 3UJ, England
www.kentcams.com
info@kentcams.com
F: +44 (0) 1303 252508

KURT KAUFFMANN
T: Germany (+49) 711 518300
PERFORMANCE SPRINGS
T: +44 (0) 1253 716900

PIPER CAMS
T: +44 (0) 1303 245 300
Unit 5 & 6, Bowles Well Gardens, Folkestone, Kent, CT19 6PQ
www.pipercams.co.uk

VALVE SPRING RETAINERS

KENT CAMS
T: +44 (0) 1303 248666
Units 1-7 Shorncliffe Industrial Estate, Folkestone, Kent, CT20 3UJ, England
www.kentcams.com
info@kentcams.com
F: +44 (0) 1303 252508

PIPER CAMS
T: +44 (0) 1303 245 300
Unit 5 & 6, Bowles Well Gardens, Folkestone, Kent, CT19 6PQ
www.pipercams.co.uk

QUALITY ENGINEERED PRODUCTS
UK Distributors for Catcams
Unit 10, Old Kiln Works, Ditchling Common Ind Est, Hassocks, West Sussex, BN6 8SG
T: 01444 243720
F: 01444 247906
webenquiry@catcams.co.uk

WATER COOLERS

AH FABRICATIONS
T: +44 (0) 1432 354704
Unit 6H Thorn Business Park, Rotherwas, Hereford, HR2 6JT, England
www.ahfabrications.co.uk
alexahfabs@fairadsl.co.uk.
F: +44 (0) 1432 359762

WATER INJECTION

AH FABRICATIONS
T: +44 (0) 1432 354704
Unit 6H Thorn Business Park, Rotherwas, Hereford, HR2 6JT, England
www.ahfabrications.co.uk
alexahfabs@fairadsl.co.uk.
F: +44 (0) 1432 359762

ERL
T: +44 (0) 1273 581 007

WATER PUMPS

DAVIES, CRAIG
T: Australia (+61) 39 499 7433
PERFORMANCE SPRINGS
T: +44 (0) 1253 716900

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TREVOR MORRIS ENG
T: +44 (0) 1547 530289

COMPUTER SUPPLIES

COMPETITION DATA SYS
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FUELTRONICS
T: Australia (+61) 88363 2199
PERFORMANCE TRENDS
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DATA ACQUISITION

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B&G RACING
T: USA (+1) 602 274 2537
COMPUTECH SYSTEMS
T: USA (+1) 800 870 8383
CORSA INSTRUMENTS
T: USA (+1) 313 761 1545

COMPETITION SYSTEMS
T: +44 (0) 8707 444 666
Hyguniper, Long Lane, Shore, Newbury, Berkshire, RG14 2TA
www.competitionsystems.co.uk

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DATRON TECHNOLOGY
T: +44 (0) 1908 261 655
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GENERAL ENGINE MANAGEMENT SYSTEM LTD (GEMS)
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T: +44 (0) 1784 470527
info@gems.co.uk
www.gems.co.uk

INTERCOMP
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ISAAC INSTRUMENTS INC
T: Canada +1(450) 658 7520
LONGACRE
T: USA (+1) 425 485 0620
MOTOR SPORT ELEC
T: Australia (+61) 7 3290 1309
PI RESEARCH
T: +44 (0) 1954 253600
QUANTUM SUSPENSION
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RACE DATA ENGINEERING
T: USA (+1) 714 449 1445

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10 Wedgwood Road, Bicester, Oxon OX26 4UL
www.stackltd.com
sales@stackltd.com

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MOTEC
T: AUSTRALIA (+61) 3 9761 5050
MOTEC
T: JAPAN (+81) 489 46 1734
MOTEC SYSTEMS
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PRECISION RACE SERVICES
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SUPERCHIPS
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TREVOR MORRIS ENG
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WALBRO ENGINE MANAGEMENT
T: USA (+1) 989 872 7091

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KULITE SENSORS
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MAGCANICA INC
T: USA (+1) 858 454 8950

PENNY & GILES
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15 AIRFIELD ROAD, CHRISTCHURCH, BH23 3TG, UK
F: +44 (0) 1202 409 475
www.pennyandgiles.com
sales@pennyandgiles.com

Variohm-EuroSensor Limited
T: 01327 351004
Williams Barns, Tiffield Road Towcester, Northants, NN12 6HP
F: 01327 353564
sales@variohm.com
www.variohm.com

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REGENT
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T: Sweden +46 8532 55890

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Dino Paoli S.R.L
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Via Guido Dorso, 542100, Reggio Emilia, Italy
F: +39 (0) 522 304 864
www.paolipitstop.com
info@dinopaoli.com

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T&S
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FUJITSU
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KISTLER
T: Switzerland (41) 52 224 1111
NOVA
T: USA (+1) 615 832 6355

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MAGNAFLUX
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www.carsim.com/racecar_engineering

D.A.T.A.S
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F: +44 (0) 24 7663 9559
www.apracing.com
sales@apracing.com

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CHAMPION
T: +44 (0) 1953 888664

PYROMETERS

AP RACING
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Wheler Road, Seven Stars Industrial Estate, CV3 4LB, England
F: +44 (0) 24 7663 9559
www.apracing.com
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STACK
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www.stackltd.com
sales@stackltd.com
F: +44 (0) 1869 245500

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MRTC
T: +44 (0) 1509 812 610
STRODE SOUND
T: +44 (0) 1761 419 248

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3D SYSTEMS UK
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CRP TECHNOLOGY
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Via Cesare Della Chiesa, 21, 41100 Modena, Italy
www.crptechnology.com

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BMRS
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Unit 5 Chancerygate Business Centre, St Mary's Road, Slough, SL3 7FL
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USA - 4005 Dearborn Place, NW, Concord, NC 28027
www.bmrs.net
GARTRAC
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T: +44 (0) 1332 850515
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T: +44 (0) 1480 464052
www.rollcentre.com

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T: +44 (0) 1432 354704
Unit 6H Thorn Business Park, Rotherwas, Hereford, HR2 6JT, England
www.ahfabrications.co.uk
alexahfabs@fairadsl.co.uk.
F: +44 (0) 1432 359762

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STOP WATCHES

CASIO
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MST SPORTS TIMING
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www.stackltd.com
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F: +44 (0) 1869 245500

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F: +44 (0) 1869 245500

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CASTROL
T: Malaysia (603) 245 2642
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T: France +33 (0) 14744 4546

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Hillside Oil Works
Brighouse
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HD6 3DP
Fax: +44 (0) 1484 721263
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Web: www.millersoils-online.co.uk

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T: +44 (0)207 581 1933
T: Spain (+34) 91 456 53 00
SLICK 50
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T: USA (+1) 713 932 9954
STP
T: UK +44 (0) 1488 682655
T: USA (+1) 305 771 1010
TECH-LINE
T: USA (+1) 919 480 0905

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FUEL CELLS

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Unit 6H Thorn Business Park, Rotherwas, Hereford, HR2 6JT, England
www.ahfabrications.co.uk
alexahfabs@fairadsl.co.uk.
F: +44 (0) 1432 359762

ATL RACING FUEL CELLS
T: +44 (0) 1908 351700
1 Patriot Drive, Rooksley, Milton Keynes, Buckinghamshire MK13 8PU, England
www.atlltd.com
atl@atlltd.com

ATL RACING FUEL CELLS USA
Spear Road Industrial Park, Ramsey, New Jersey, USA
T: USA(+1) 204 825 1400
F: USA(+1) 201 825 1962

EARS MOTORSPORTS
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FUEL SAFE SYSTEMS
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T: USA (+1) 541 923 6005
for international calls
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T: Germany (+49) 2271 44905
OMP
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Switzerland: T: 41 61 9717 600
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692-693 Stirling Road, Slough, Berkshire, SL1 4ST, England
www.fhsracing.co.uk
info@fhsracing.co.uk
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SPV RACING
T: Australia (+61) 2 791 9899

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www.bmrs.net

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GOODRIDGE INDY
T: USA (+1) 317 244 1000
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HENRY'S ENG
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KRONTEC MASCHINENBAU Gmbh
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Pommernstraße 33, 93073, Neutraubling, Germany
www.krontec.de

RACETECH
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www.thinkauto.com
matt@thinkauto.com

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T: Martin Jones +44 (0) 1684 278218 mjones@moog.com
www.moog.co.uk/industrial/motorsport
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43040 - Varano Melegari
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ELAN
T: USA+1 (0)706 658 2518
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T: +44 (0) 1883 744443
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T: +44 (0) 1933 440774

Lola Cars International Ltd
Glebe Road, St Peters Road
Huntingdon,
Cambridgeshire PE29 7DS
United Kingdom
T: +44 (0) 1480 451301
F: +44 (0) 1480 482970
lola@lolacars.com
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PILBEAM
T: +44 (0)1778 424838

RML GROUP
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Park Farm Industrial Estate,
Wellingborough, Northamptonshire NN8 6TY, England
www.rmlmallock.co.uk info@rmlmallock.co.uk
F: + 44 (0)1933 676519

SHELBY AUTOMOBILES, INC
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ALLEN ORCHARD

THE INTERVIEW

LAT

What other motorsport projects has Sumo (JRM) been involved with?

The history behind JRM goes back nearly two decades. Towards the end of 2008 James Rumsey, executive director of JRM Group, purchased Chesterfield-based ADR Motorsport, the acquisition including the company's assets, good will and, most importantly, its highly skilled technical staff.

During the '90s ADR built and prepared a variety of race and rally cars for various championships, as well as providing on-event support. These included front-running one-make saloons such as Peugeots and Vauxhalls – up to British Touring Car Championship level – plus single seaters from Formula Ford to Formula Renault and Formula 3.

In the 2000s, as the customer base changed, the company's commercial focus and engineering emphasis moved towards rallying, primarily in the construction, preparation and development of Group N Mitsubishis. In 2004, the company's reputation in the sport, and its association with the Japanese brand, in both domestic and overseas markets, saw ADR contracted by Mitsubishi Motors UK to run its works rally team.

Allen Orchard, team manager, Sumo Power GT1 team

Started out racing Superbikes in his native Australia, switching to four-wheeled competition when he moved to England to race in Formula Vauxhall Junior and Formula Renault in the early '90s. He later started to run his own teams and now boasts over 20 years experience in the motorsport industry. This year he heads up Sumo Power GT's NISMO-supported assault on the FIA GT1 World Championship with the Nissan GTR. Sumo Power GT is a part of the JRM Group.

The project culminated with back-to-back victories in the British Rally Championship with the team securing the manufacturers' and drivers' titles in both 2007 and 2008. JRM has been running a continual development programme for its national and international-spec Mitsubishi Lancer Evolutions, culminating recently with an outright win on the Finnish Rally in February 2010.

In addition to all levels of circuit racing and rallying, the Group has experience of national level drag racing, European Drift and Time Attack.

How did the FIA GT deal with NISMO come about?

JRM wanted to expand its racing activities and also help promote the Sumo Power brand on an international level. When the opportunity arose to negotiate with NISMO to purchase the two cars, JRM showed the required level of professionalism and commitment over and above all the other parties to secure the deal.

How close will you work with NISMO throughout the season?

Very. We have NISMO technicians here at Rye [East Sussex, England] to assist with certain points and collect data.

What's it like to work closely with a major manufacturer?

Great! The NISMO personnel are as passionate as we are and having a window into the R&D office through regular meetings is very beneficial to everyone.

How much input did Sumo have in the development of the car?

Very little prior to the cars coming to us, but since their arrival we have instigated several engineering activities with our technical partners, like Exe-TC suspension, plus we are utilising our own in-house, state-of-the-art design, manufacture and inspection facility.

RACE MOVES

Force India's director of business affairs, **Ian Phillips**, has left the team. Phillips was with the outfit in its different guises for 19 years and, before joining the then Jordan team, filled a variety of roles in motorsport, including editor of *Autosport* magazine, manager of Donington Park circuit and team manager of the March / Leyton House F1 team.

David 'Dyno' Johnson has retired from Australian V8 Supercars team Dick Johnson Racing – his brother's team, which is now known as Jim Beam Racing – after 30 years. He says he now plans to spend time with his family.

James Key

James Key is the new head of Sauber's technical team, replacing Willy Rampf, who is set to step down as technical director in April. Key arrives at BMW-Sauber from Force India, where Mark Smith will replace him as technical director.

Dato' Kamarudin Meranun and **SM Nasarudin** have joined the senior management team at Lotus Racing. Both are shareholders in the Norfolk-based team and they will act as deputy team principals, alongside team boss **Tony Fernandes**.

JC 'Jake' Elder, a long-time crew chief in the NASCAR Cup Series, has died at the age of 73. Known as 'Suitcase Jake' because he never settled down with one team for very long, Elder began his NASCAR career in 1960 as a fabricator for Petty Enterprises, and went on to crew chief championship-winning seasons with David Pearson in 1968 and '69.

Six NASCAR crew members have fallen foul of the governing body's stringent substance abuse policy: **William Hileman**, **William Wheeler**, **Matthew Huffstetler**, **William Keith** and **Kenneth Luna** have all been suspended indefinitely.

Doug George

Doug George has been appoimnted the new crew chief for Kevin Harvick Inc's no 33 Chevrolet in the NASCAR Camping World Truck Series. George moved to KHI in the off-season and began the season as crew chief for the outfit's no 2 car.

RACE MOVES

Steve Plattenberger is to act as interim crew chief on the R3 Motorsports no 23 Chevrolet in the NASCAR Nationwide Series, replacing **John Quinn** in the role. Plattenberger, who has been the team's shop foreman since last season, has prior crew chief experience and brings more than two decades of knowledge to the team.

Rick Humphrey is the new managing director of business operations for US track operator International Speedway Corporation. Humphrey has been involved in motorsport for 16 years and was previously president of the Talladega Superspeedway.


Anthony Hamilton LAT

Anthony Hamilton, the father of 2008 Formula 1 World Champion **Lewis Hamilton**, will no longer manage his son, concentrating instead on his new business GP Prep, a company which aims to give up-and-coming drivers test mileage in modern F1 cars, and with managing other sportsmen. The split is believed to be amicable.


Flavio Briatore LAT

Flavio Briatore has told the Italian press he is 100 per cent sure he will never work in Formula 1 again, despite winning a court action to overrule his FIA ban on working in motorsport. Briatore also said he had no regrets about his time in F1, which came to an abrupt end when his part in the Singapore scandal – when **Nelson Piquet jr** admitted to crashing on purpose to cause a safety car period – came to light.

The FIA has appointed nine new judges to its International Court of Appeal, all proposed by the Formula 1 teams. These are: **Sir Laurence Street**, **L Yves Fortier**, **Stefano Dambruoso**, **Prof Dr Ulrich G Haas**, **Prof Dr Gabrielle Kaufmann-Kohler**, **Dr Antonio Rigozzi**, **Sir Philip Otton**, **VV Veeder** and **James H Walsh**.

Roush Fenway Racing has moved crew chief **Drew Blickensderfer** from **Matt Kenseth's** Sprint Cup programme to crew chief on **Carl Edwards'** Nationwide car. **Mike Kelley**, who had previously served in this position, has now taken over the role of competition director for the Nationwide programme, while **Mike Beam** is heading up the speedway part of the R&D department for all of RFR.

Todd Parrott has taken Blickensderfer's position as crew chief for Kenseth *(see above)*. Parrott is a former Sprint Cup championship-winning crew chief with **Dale Jarrett** and came to RFR from Yates Racing.


Ricky Viers LAT

Ricky Viers is now crew chief for **Greg Biffle's** part time Nationwide car at Kentucky-based Baker Curb Racing. Viers previously worked at Red Bull Racing, while he also spent many years at Richard Childress Racing.

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ALLEN ORCHARD THE INTERVIEW

CONTINUED

This will help differentiate us from most of the GT1 grid.

Q What were (are) the main challenges of developing the GTR for racing?
It's no surprise to those who take a look at the GTR positioned next [compared] to a traditional Sportscar. We have a very high c of g and need to punch a big hole through the air. We can help by lowering as many items as possible in the cars, but it is still an inherent attribute of the car.

Q How do you rate the GTR's chances this year?
Very good. Our driver combination of Peter Dumbreck and Michael Krumm in the number one car is already working very well, and the level of expertise within the team is second to none. Lastly, and most importantly, the car has been built and developed superbly by NISMO, so we have all the elements required to achieve podium finishes.

Q What do you think of the new FIA GT1 World Championship as a concept?
We believe it will be a very exciting format and believe it will stimulate as much attention as GT racing did in its heyday in the '90s.

Q What are the motorsport plans for JRM and the Sumo Power GT team in the future?
Firstly, the GT1 involvement for us is long term. Likewise, our involvement in rallying is long term. But we are always looking for interesting projects and technical partners to work with. Our excellent financial stability means we can be fairly selective with projects and partners, but also offer reassurance that we are not just financially motivated. We are here for the long term and intend to develop our reputation for technical excellence and innovation.

AWARDS

The Brienne Davis Scholarship goes to...

The Universal Technical Institute Foundation has awarded Bobbie Newgard the US$25,000 (£16,500) Brienne Davis Memorial Scholarship - an award made possible thanks to a generous donation by NASCAR team owner Roger Penske.

The award is part of the Brienne Davis Memorial Scholarship Fund, which is a scholarship programme designed to help women gain the relevant education they need to pursue careers in the automotive industry.

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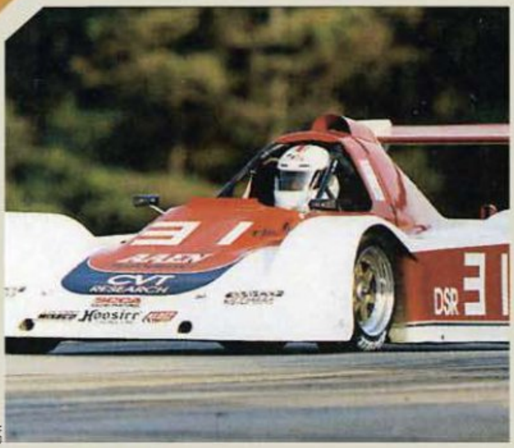

LAT

Olav Aaen's CVT-equipped D-Sport Racer from the 1990s

SAFETY SOLUTIONS

I read your story on head protection in open-cockpit racecars with interest. I had the opportunity to address the subject when I designed my open cockpit D-Sports racer in 1990 and a couple of situations caught my attention. First, a friend of mine was killed when he hit an Armco barrier head on. The bottom barrier gave away and the car wedged under the top rail, which came back and smashed his head. The other situation, which occurs frequently in NHRA drag racing, is cars landing upside down on top of the guard rails. Without the double roll bars mandated by the NHRA, decapitation would almost certainly be the result. I have yet to see a Formula 1 car land at 90 degrees on top of another Formula 1 car, but I believe the bargeboard could then inflict serious injury, as nearly happened in turn five at Road America during an IndyCar race when one car landed on top of another. As a result of these experiences, I designed my open cockpit D-Sports racer with a double rollbar set up, but in this case the second bar was extended forward at an angle in order to slow down any intrusion under guard rails. This design, which was featured in *Racecar Engineering* V5N2 p66, not only offered more protection, but also increased the torsion strength of the chassis substantially by reinforcing the cockpit area. There were no negatives, except perhaps a 4lb weight penalty, which I gladly exchanged for the increased safety offered and a better handling chassis.

Olav Aaen
by email

STRAIGHT TALK

PLM is the way, unfortunately

CHARLES ARMSTRONG-WILSON

They said it was the way of tomorrow and would make our world unrecognisable, but is it really an improvement?

We've seen the future and it is PLM, or so said the engineering software companies a few years ago. Product Lifecycle Management, they assured us, would take care of everything - track design changes, order raw materials, control stock levels, make the tea and give you a soothing massage. Well, everything but. Fast forward to the present day and we must surely by now be secure in that computer-aided design utopia, living a simpler, more fulfilling existence, thanks to the new generation of powerful software packages.

Well, it is here, just as they promised, and every CAD software house now has its version of PLM on the market. Even the blue chip product CATIA has been subsumed into the new PLM package suite of software products, V6, from Dassault Systèmes. This is the future and it's here, now.

Chatting to a CAD professional recently, I queried him about this new life he must be enjoying thanks to PLM, but no sooner were the words out of my mouth than he was spraying his beverage across the room in shock. 'You are joking,' he insisted. Slightly taken aback, I pushed him on the subject and, once he calmed down, he explained: 'It's all very well, provided you don't need to get any work done.' His point was that, while it will do everything it claims, the task comes with an unwelcome administrative burden.

I listened sympathetically, but couldn't help being sceptical. I've known him for years and knew his particular circumstances. He's a freelance one-man band and people like him are all too inclined to get set in their ways. Change is a chore and adopting new ways of working takes an investment of time that only returns a benefit in the long term. In the meantime, he would surely prefer to focus his efforts on the work that pays the bills today.

> **"It's all very well, provided you don't need to get any work done"**

Just then, another friend from a much bigger motorsport company breezed past and I recruited him for an opinion. His employer is part of a much larger concern and surely he would have embraced the benefits of PLM? 'Er, no, we don't have time.' My faith was taking a severe beating now, so I challenged him. What about the bigger company, don't they insist on your compliance? 'We're a pretty small part so they tend not to bother us and we can lock the doors,' came his response. Again, his point was that PLM was far too admin-heavy for the pace of work in motorsport. Things move too fast and if you want to keep up, you can't afford to be dragging that burden behind you.

So, PLM is the future, but not for motorsport, and is unlikely to be until the suppliers can simplify its implementation sufficiently to make it a practical proposition. Now I can't help wondering what effect it's having on the world of engineering outside motorsport.

Charles Armstrong-Wilson is a former editor of Racecar Engineering. *See p34 for his thoughts about the last 20 years of the magazine*

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LATE APEX

Fighting the odds

There has been much negative comment in the media, on websites and from individuals in the motorsport industry in the wake of US F1's failed attempt to make the 2010 World Championship grid. Let me say at the outset that I don't subscribe to these views. I accept, however, that there may have been some 'bending of the facts' – undoubtedly born of desperation – when it came to public and internal pronouncements from the team as the project began to unravel earlier this year.

The fact is, when we visited US F1 at its North Carolina base in mid-December last year, we found a busy facility that was clearly intent on delivering two cars to the grid for the opening race of 2010. That view seems to be supported by the fact FIA consultant, and former Jaguar F1 team principal, Tony Purnell, visited at about the same time and apparently pronounced himself satisfied with progress.

> "the likelihood is that it involves money or, more correctly, a lack of it"

What happened between those events and the recent admission by Ken Anderson that the team was seeking permission from the FIA to defer its entry until 2011, one can only surmise but, as with most things involving motorsport at the top level, the likelihood is that it involves money or, more correctly, a lack of it.

I was in the privileged position of seeing this at first hand when I became involved with the Minardi F1 Team in early 2001, at the point when Australian aviation entrepreneur, Paul Stoddart, stepped in and saved the struggling Faenza squad from impending closure. There isn't room to go into all the detail here but, on arrival at the factory, with just six weeks and three days to go until the start of the season, Stoddart found but a single, unfinished tub. There were no engine or driver contracts in place, and the workforce was clearly demoralised, although clinging to the slim hope there might be a last-minute reprieve. As history was to show, he and Gian Carlo Minardi succeeded in turning the situation around and the team made the grid in Australia, albeit with the second chassis assembled for the first time in the Albert Park garage.

Stoddart dug deep into his own pocket to make this happen, and to keep the team going during that first season. He also had to cope with at least one defaulting sponsor – a situation that was to crop up several times in the four years of his ownership.

The point is that it's easy for casual observers to criticise – and even condemn – the US F1 project, and the men who conceived it. The fact is, even 10 years ago, to take over a struggling F1 team and sort it to the point where it could field two cars for the season required something approaching a superhuman effort that none of those involved will ever forget. In the case of US F1, they were trying to do something even more ambitious – to set up a team from scratch, and in a part of the world without any Formula 1 heritage or connections.

Ken Anderson and Peter Windsor may be accused of many things, among them being naïve and unrealistic, and sadly, both employees and suppliers will have been adversely affected by what has transpired. Formula 1, however, is an exceptionally risky business, and those with a desire to become involved should understand that. The problem is, the siren call of the sport is such that it makes otherwise sane individuals imagine they can beat the odds.

EDITOR
Graham Jones


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