proActive
The official industry newsletter of Lotus Engineering

Issue 29
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Welcome

We've been picking up a few awards over the past few months. The latest are from the *Autocar* Awards, *iMotor* and *The Engineer* Awards. These recognise the general successes of our high technology business and the expanding range of fabulous Lotus cars, as well as the specific achievements of our Hotfire research project. It is to the credit of the whole Lotus team that many aspects of our business are now being acknowledged.

More noteworthy still are our latest financial results announced recently showing a return to significant profitability.

Whilst there is great deal to be proud of and excited about at Lotus at the moment, we are acutely aware that the industry as a whole is facing a tremendous challenge in the current economic climate. Despite the difficult times, the industry still has to work towards its obligations to reduce the environmental impact of the cars it produces. As we drive technology forward with cleaner engines, electric and hybrid vehicles, sustainable fuels and lightweight solutions, clients are continuing to turn to Lotus Engineering.

Although we certainly cannot be complacent, we have a strong order book for our engineering services and technologies, and as large and diverse a range of clients as we have ever had. The forecast for the industry over the coming months is clearly not good, but we're confident of weathering the storm and indeed coming out the other side even stronger.

Enjoy the read.

Peter Morgan
Marketing Manager – Lotus Engineering

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“The new drop-top will be offered with two exclusive new colours - ‘interchange yellow’ and ‘horizon blue’. Roof colour options are black, ‘denim blue’ and ‘hot chocolate’”

US: Better Place to build electric car network in Hawaii

Better Place, the mobility operator, has signed a deal with the governor of Hawaii to build an electric-car network in the US state.

The move is only the second of its kind announced in the US.

“Attracting investments into the state is a major component of our Five-Point Action Plan to help stimulate the economy,” said governor Linda Lingle. “Today’s announcement is a significant move towards our state gaining independence from foreign oil. This public-private partnership is exactly the type of investment we have been working on as we continue to carry out our Hawaii Clean Energy Initiative (HCEI), moving toward the goal of 70% clean energy for the state. It highlights the importance we place on finding innovative ways to attract investments in energy technology,” she added.

Better Place plans to begin permitting for the network within the next year and begin introducing vehicles within 18 months, with mass-market availability of electric cars in 2012.

Hawaii joins Israel, Denmark, Australia and California as markets for Better Place’s electric car networks.

“Hawaii, with its ready access to renewable energy resources like solar, wind, wave and geothermal, is the ideal location to serve as a blueprint for the rest of the US in terms of reducing our dependence on foreign oil, growing our renewable energy portfolio and creating an infrastructure that will stabilise our economy,” said Shai Agassi, founder and CEO of Better Place.

Hawaiian Electric Companies and Better Place Hawaii have signed a Memorandum of Understanding (MOU) to collaborate on the infrastructure and energy needs to power a network of public charging spots and battery swapping stations with renewable energy.

Source: just–auto.com editorial team

UK: Mini debuts ‘Openometer’ with new convertible

BMW’s long-awaited second-generation Mini convertible has a unique new option feature - the ‘Openometer’.

This, the automaker said, records the time spent by the owner driving with the top down, “meaning passengers can measure their visual coolness inside, even if it’s cold outside.”

In other respects, the completely redesigned drop-top is the same sort of evolutionary product as the well-received hatchback versions launched here at the end of 2006 and carries over the same design of fully retracting canvas roof that can be part-opened in ‘sunroof’ mode.

The new version, again built at BMW’s dedicated Mini plant just outside Oxford in England, goes on sale in the UK on 28 March with global market launches to follow.

The revised convertible will be sold in Cooper and Cooper S versions with the same new 1.6-litre petrol and (eventually) diesel engines from the PSA/BMW joint venture in place of the old Chrysler Brazil-made 1.6-litre petrol four and 1.4-litre Toyota diesel used in the outgoing line, sales of which ended earlier this year.

UK Cooper prices will start at GBP15,995 ‘on the road’ (about US$24,000) and the Cooper S from GBP18,995 (US$28,500). The first-generation Mini convertible was a best seller in the UK in the small convertible segment between 2004 and 2008 and about 164,000 first-generation cars were delivered worldwide.

The new drop-top will be offered with two exclusive new colours - ‘interchange yellow’ and ‘horizon blue’. Roof colour options are black, ‘denim blue’ and ‘hot chocolate’.

One big change for the UK is standard air conditioning with a cooled, lockable glovebox. The automatic canvas roof can be fully retracted or closed using a roof-frame mounted toggle switch in just 15 seconds and works at speeds of up to 20mph - handy if it starts to rain just as the lights turn green.

As with the previous model, the full-width electric roof can be retracted about 40cm (about 16 inches) to create the effect of a sunroof and this function works at up to 75mph (120km/h). Unlike its predecessor’s fixed anti-roll bars the new model features a single-piece roll bar situated behind the rear seats, ensuring passenger safety in the event of a crash. The roll bar will extend in milliseconds at the point of impact to protect the car’s occupants should the car overturn. Rear passenger headrests are now height-adjustable, too.

The body structure, floorpan, A-pillars and side sills have all been strengthened to offer greater crash protection. BMW claims this also significantly reduces ‘scuttle shake’, whilst body stiffness is further improved over the first-generation convertible. Yet weight is down 10kg.

Luggage capacity has been increased to 125 litres from 120 with the roof open and from 165 to 170 litres with the roof up. With the rear seat folded down and roof closed, luggage space totals 660 litres, 55 litres more than the old model.

Bike rack preparation will also be standard. The mounting points are obscured from view and positioned behind the rear bumper so owners are able to easily attach multi-function carriers.

Like the equivalent hatchback and Clubman models, the Cooper convertible has as standard a 120hp 1.6-litre I4 petrol engine with fully variable valve management, using technology based on the BMW Group’s Valvetronic technology.

The Cooper S gets the 175hp unit with twin-scroll turbocharger and direct fuel injection. Six-speed manual transmission is standard with both whilst a six-speed automatic is optional.

Technologies based on BMW’s EfficientDynamics systems are now standard and include auto start stop, brake energy regeneration and shift point display.

Source: just–auto.com editorial team

Industry **News**

> "The system will be available on all manual versions of the 2.2-litre diesel TD4 model which accounts for about half of all Freelander sales here in the UK"

INDIA: GM plans powertrain 'hub'

In a vote of confidence in the country recovering from a terrorist attack in Mumbai, General Motors said India would become its powertrain development hub for the Asia-Pacific region.

This follows earlier General Motors India (GMI) US$500m investments in new car and powertrain manufacturing facilities, the *Press Trust of India* (PTI) said.

"With our engineering facility in Bangalore as the foundation of our business in India, we are making the country the development hub of powertrains for Asia-Pacific region," GMI president and managing director Karl Slym told *PTI*.

Considering the fact that the hub will cover countries like Australia, China and Korea, choosing India as the location is a significant decision, he added.

The company already employs 1,600 in its engineering and research and development centre at Bangalore.

"In the second half of next year we may hire... 500 people [of] which 300 will be for the engineering division and 200 for manufacturing at Talegaon," Slym said.

Though the initial focus would be on development, GMI would also look at making India a powertrain manufacturing hub in future.

"We will have capacity beyond domestic consumption so we will definitely look at exports. Since the engines developed in India will be of small displacements, we will look at markets in the Asia-Pacific region and Eastern Europe," Slym told *PTI*.

General Motors has eight R&D centres worldwide and 11 engineering centres.

Last October, GM opened its second plant in western India, almost tripling its local production capacity to 225,000 vehicles a year. The company invested US$300m in the new factory in Talegaon, about 100 miles (160km) from Mumbai (Bombay).

The company already had capacity for 85,000 cars a year in India. It builds locally developed and GM Daewoo designs for sale under the Chevrolet brand. It also said it would invest another US$200m in an adjacent facility producing 300,000 engines a year for both domestic and export markets.

Source: just–auto.com editorial team

UK: Land Rover launching Freelander stop-start

An in-house engineering team and two major component suppliers have together developed Land Rover's new fuel-saving stop-start technology which will be available on manual diesel Freelander models from next May.

A Land Rover spokesman said the control system was developed by the automaker's engineering centre at Gaydon, Warwickshire, while Bosch provided the engine management and Denso contributed an uprated starter motor.

The system will be available on all manual versions of the 2.2-litre diesel TD4 model which accounts for about half of all Freelander sales here in the UK.

It's the first result of the Tata Group-owned automaker's GBP800m investment over five years in new environmental technology.

"We will reduce CO_2 output of our vehicles without comprising our values," said Murray Dietsch, director of Land Rover programmes. "We still have to have the best vehicles for the toughest conditions."

He described stop-start as the first step on Land Rover's green technology road map which will eventually lead to a diesel hybrid 'Landie' capable of 60mpg and with emissions below 120g/km.

"Downsizing is an important part of our future; we will have more compact, lighter vehicles with greater aerodynamic efficiency, low rolling resistance tyres and electric power steering among a long list of measures," said Dietsch.

Stop-start on its own reduces CO_2 emissions by 8%, taking the Freelander from 194g/km to 179g/km and reducing the owner's annual road tax (and tax on company cars) here in the UK.

Phil Wiffin, manager of stop-start systems at Land Rover, said that, on a typical 40-minute journey in London, a vehicle's engine is only needed for about 19 minutes.

"We're saying this is the world's first intelligent stop-start SUV. Fuel consumption in these conditions is improved by 12% which is a saving of GBP13 (about US$20) on a tank of diesel at today's prices on a typical London test route."

At the moment stop-start is only available with manual gearboxes but it will also be adapted for use with automatic transmissions and rolled out in other Land Rovers from around early 2011.

Features include sensors which will automatically restart the engine if the cabin starts to get too cold or too hot so that the air conditioning operates; this also works if the windows start to mist up. The engine also restarts automatically if the Freelander starts to roll more than 6-feet (2 metres).

There will be no price increase for stop-start-equpped Freelander models which will be badged 'TD4-e'.

Source: just–auto.com editorial team

"The in-cylinder geometry of the two engines was identical and features a close spaced direct injection system with a centrally-mounted injector architecture"

Lotus wins award for engine research that delivers 15% CO_2 reduction

Lotus Engineering, is celebrating its latest accolade after triumphing at '*The Engineer* Technology + Innovation Awards 2008' with another environmentally focused project. The winning project, Project HOTFIRE developed a gasoline direct injection (GDI) engine concept that reduces fuel consumption by 15% and was named the leading academic collaborative project in the automotive sector.

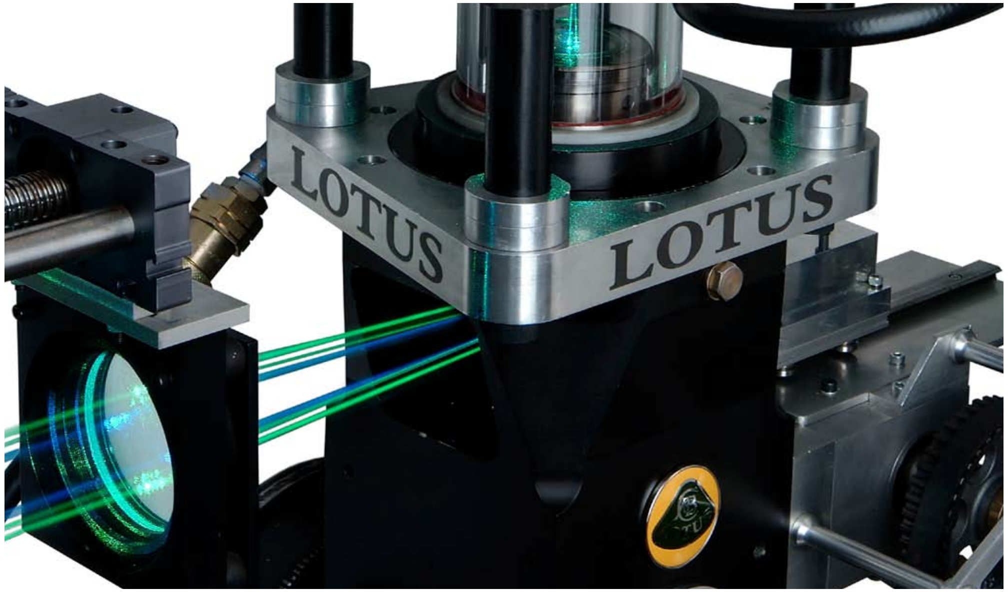
Project HOTFIRE was made up of a collaboration of engine specialists from Lotus Engineering, Continental Powertrain, University College London (UCL) and Loughborough University, with funding from EPSRC (Engineering and Physical Sciences Research Council). The project studied the potential efficiency gains of spraying fuel directly into the cylinders of a petrol-driven engine, rather than introducing a fuel/air mixture. Due to outstanding early results, the project progressed further with the delivery of a concept-car engine which has been the subject of interest from a number of large manufacturers. Mike Kimberley, chief executive officer of Group Lotus plc said: "I am absolutely delighted that our global high technology Lotus engineering division is continually being recognised for leading the industry across a number of advanced technologies which are contributing to the reduction of CO_2 emissions. Project HOTFIRE is an excellent example of an industry and academic partnership producing world-class research for the benefit of the environment and the car buyer."

Kimberley continued: "The most important part of the project is that the technologies developed are available and affordable and as we have already shown, can be easily implemented into next generation models to produce lower emissions."

Geraint Castleton-White, head of Powertrain at Lotus Engineering said: "The project studied the benefits of homogeneous, early, direct injection for a spark ignition engine, using inlet valve events to minimise throttling losses. Being able to introduce the fuel separately from the air gives you freedom with how you operate the engine, there is no fuel lost to the exhaust so hydrocarbon emissions are reduced, and you get more efficiency from the engine. It is our dedication to research such as this that keeps Lotus Engineering at the forefront of advanced combustion technologies, which ultimately will find their way into engines of the future."

Two single cylinder research engines were designed and constructed by Lotus Engineering, one of which was optically accessed. The in-cylinder geometry of the two engines was identical and features a close spaced direct injection system with a centrally-mounted injector architecture.

The optical version of the engine incorporated a full length fused silica quartz cylinder liner with a full view of the pent roof of the combustion chamber and a sapphire window in the piston crown. This allowed an advanced suite of laser diagnostics to measure air motion, injection characteristics, air/fuel mixing and combustion. This engine was based at Loughborough University for detailed studies of these in-cylinder phenomena.



The second engine was placed at UCL, and was updated to the same engine architecture as the optical engine, to measure emissions and fuel economy. The principle of the investigation was to use early inlet valve closing as a means of controlling the load on the engines, with a minimum amount of throttle, and so gain significant fuel savings. The emission measurements were essential, as any fuel savings could not be at the expense of the exhaust emissions from the engine.

The end application of this project is a direct injection spark ignition engine architecture that does not require stratified lean burn combustion to achieve significant, fuel economy savings of approximately 15%. This ensures that the system can be used over all speed/load ranges and eliminates the need for an expensive lean NOx trap which is usually required when lean combustion is employed.

Early results from this project were so successful that the same architecture was adopted for the Low CO_2 project, a collaboration between Lotus Engineering and Continental Powertrain with funding from the Energy Saving Trust (EST). This Low CO_2 project has successfully delivered a three-cylinder mild-hybrid engine incorporating the cylinder head design used by the research and this engine has been installed in Opel Astra demonstrator vehicles which demonstrate significant improvements in both performance and CO_2 emissions.

Source: Lotus Engineering

Lotus **News**

"The Lotus Evora will join the already successful stable of Elise, Exige, Europa and 2-Eleven high performance sportscars"

Lotus wins *Autocar's* 'Editor's Special Award for Excellence'

This prestigious award comes just a week after Lotus announced a GBP2 million profit for the last financial year, citing the growth of Lotus as a world leading high technology, ecological automotive engineering consultancy and the unveiling of the visually stunning Lotus Evora, the first new Lotus for 13 years, as amongst the key reasons for the accolade.

Mike Kimberley, chief executive officer was delighted to receive the award on behalf of Group Lotus plc: "It is an honour for me to be presented with this award, recognising the hard work of all our tremendously loyal and dedicated global staff over the last two years to execute the turnaround in the business fortunes of Lotus. Our 'can do' attitude has ensured the continued growth of Lotus into a much stronger and stable position consolidating our reputation as a global premium advanced automotive company".

Chas Hallett, *Autocar* editor, explained further why Lotus won the Editor's Special Award for Excellence: "The resilience of Lotus and its gathering engineering strength, culminating in the launch of the exciting new Evora, are the key reasons why it wins this year's Excellence award."

Mike Kimberley returned to Lotus in 2005 as a non-executive director, before being appointed chief executive officer of Group Lotus plc in 2006. Over the last 12 months Lotus Engineering, the company's high-technology engineering consultancy business, grew its global third-party customer base and was awarded with new and valuable contracts worldwide – 340 projects with over 140 clients. Customer demand has lead to the creation of new departments within Engineering, especially focused on biofuels, electric and hybrid electric vehicles. The Lotus Evora, the first all new Lotus in 13 years, is a 2+2 mid-engine V6 sportscar and first deliveries to customers are expected to commence in Spring 2009. The Lotus Evora will join the already successful stable of Elise, Exige, Europa and 2-Eleven high performance sportscars.

Source: Lotus Engineering

iMotor readers choose the new Lotus as "Overall Most Rated Car 2008"

The new Lotus Evora has added yet another award to its growing trophy cabinet, this time for *iMotor* Magazine's "Overall Most Rated Car of 2008". In every issue of *iMotor* (which has an ABCe of 108,600), readers have been 'rating' and 'slating' the cars featured; and out of 40,000 votes counted, 95 per cent of voters rated the Lotus Evora, compared to just 5 per cent slating it making the new 2+2 the most highly rated car in 2008 by *iMOTOR* readers.

Mike Kimberley, CEO of Group Lotus plc, is delighted with the award, "This award from *iMotor* readers is particularly special as it demonstrates that we have produced a car that already has a fan base amongst the cognoscenti, despite the car being a few months away from the sale date in the spring."

iMOTOR editor Mat Watson said: "Unlike other car magazine awards, ours are decided by the readers. Also they include concepts, models that are not yet on sale and some which the press has yet to drive. And it's clear the *iMOTOR* readers rate the forthcoming Lotus Evora more than any other car we have featured in the mag. It's 'rated' score of 95 per cent is truly impressive and enough to see it beat brilliant machines such as the Lamborghini Gallardo LP560-4 and Nissan GT-R. There's clearly a lot of excitement for this new Lotus."

To see the awards click here

To see an interview with Roger Becker, Lotus Vehicle Engineering Director, as he drives a prototype of the Evora around the Lotus Test track at Hethel click here

Source: Lotus Engineering

> "The GT4 Supersport generates up to 80kg of positive downforce at 100mph, which is over 10% of the car's weight"

Racebred 2-Eleven unleashed

The Lotus Sport 2-Eleven GT4 Supersport race car asserts itself at the pinnacle of the 2-Eleven range, combining race-winning pedigree with unparalleled handling and balance.

Building on the success of the 2-Eleven road and track variants, Lotus Sport has developed this GT4 Supersport race car to compete in the European SRO GT4 Supersports category.

The Lotus Sport GT4 Supersport pushes the limits to the extreme: wearing a dramatic composite body, full rollcage and with increased power and a sequential gearbox it provides a race-winning package. The GT4 Supersport offers an advanced aerodynamic package, with aggressive styling alluding to its searing performance and phenomenal racing potential.

Mike Kimberley, chief executive officer of Group Lotus plc, said: "Lotus has an enviable motor racing heritage that includes some of the most successful racing cars in history. We are confident that the 2-Eleven will continue our winning tradition and become a classic of the future. The 2-Eleven GT4 Supersport offers one of the most cost-effective, competitive and easiest routes into this level of motorsport."

Lotus Sport has increased the power and torque available in the GT4 Supersport car to 270PS and 247Nm from the standard supercharged cars 255PS and 242Nm engine. The increases in power and torque have been gained through improved induction and exhaust systems, and with a high ratio supercharger drive system for increased levels of boost. To maximise the upgrades to the engine, the engine management system has been remapped and optimised.

Lotus Sport is offering a six-speed sequential gearbox with a centrally-mounted push/pull lever and gear selector display. The gearbox is integrated with the engine management system to allow flat shifts up through the box and an 'autoblip' rev matching system on downchange. This transmission offers lightning quick gear changes, shaving those all important tenths off each gear change. A plate-type limited slip differential, employed to improve traction out of corners, competes the setup.

Chris Arnold, head of Lotus Sport, said: "The GT4 Supersport has some exceptional new features and provides a compelling package that has race winning credentials. This is a hugely exciting new car for Lotus Sport; we have already had good success in mainland Europe with the test car and we are looking forward to our customers successes in the 2009 season."

There will be an initial run limited to ten cars priced at GBP78,255 MSRP with delivery dates in March ready for the '09 racing season. Some GT4 Supersport features can be retro-fitted to 2-Elevens that have already been purchased, offering increased versatility and allowing owners to upgrade their car as they hone their skills.

The 2-Eleven double wishbone suspension is uprated with stiffer race focused springs and dampers. The dampers are the race proven two-way adjustable Ohlins units, allowing the handling to be fine-tuned for optimum track setup.

The rear suspension has been upgraded with the addition of race spec rear toe links. Semi-slick AO48 Yokohama's are fitted as standard. Another new addition for 2009 is the Lotus manufactured FIA compliant carbon fibre race seats. The Lotus Sport seats are HANS approved and are complimented with a Schroth 6-point race harness. A 70 litre FIA approved bag tank is fitted as part of the GT4 Supersport spec along with a plumbed-in fire extinguisher system. A concession to easier ingress and egress comes in the form of a removable Lotus Sport steering wheel.

The GT4 Supersport has a rigid tonneau cover to improve aerodynamics. The aero package is improved with significant levels of downforce generated by a carbon fibre rear wing and rear diffuser, balanced by a deep front splitter. The GT4 Supersport generates up to 80kg of positive downforce at 100mph, which is over 10% of the car's weight.

The race car retains the excellent sports-tuned ABS, variable traction control and launch control systems available on the current 2-Eleven. These race-proven systems have been thoroughly tested and give exceptional feel and control in a wide variety of conditions.

Source: Lotus Engineering

> Clearly we are very closely watching the state of the global economy, and it is obvious that the world is changing very rapidly

Lotus – year end financial results to 31 March 2008

Improvements in efficiency, careful cost-cutting, together with steady sportscar sales and increased third-party engineering consultancy sales, have contributed to a GBP2 million profit for Lotus Group International Ltd, (LGIL). Investment into R&D and new products has risen by 95%.

Lotus Group International Ltd, which includes Group Lotus plc, the global sports car manufacturer and engineering consultancy, has filed and had published its financial results for the year ended 31 March 2008:

Year from / to	01 April 2007 to 31 March 2008	01 April 2006 to 31 March 2007
Turnover for the year	£108.796 million	£133.190 million
Profit for the year (excluding R&D)	£2.023 million	(£4.888 million) loss
Investment in Research and Development and new products	£11.934 million	£6.115 million

Commenting on the latest financial figures, Mike Kimberley, chief executive officer for Lotus Group International Ltd and Group Lotus plc said: "These results are a tremendous turnaround achievement for Lotus. I would like to thank all Lotus staff for their exceptional dedication and hard work to ensure the effective turn-around of the business. We are also tracking our strategic five-year plan which enables Lotus to deliver an exciting new range of vehicles, develop and sell new advanced technologies through our extensive global operations and engineering client base and ultimately put Lotus on a greener and firmer footing and a consistently profitable commercial basis for the future."

Key commentary for the above figures:

• LGIL increased its cash reserves from 2006-7 by over 1200% from GBP640,000 to GBP8,223,000, thanks to the shareholders' support of the new management.
• By achieving the GBP2.023 million profit, LGIL has exceeded the first year target of its strategic Five Year Plan.
• Investment in research and development and new products has risen by 95%. This investment includes advanced engineering research and development into future technologies and capitalised R&D into new product development including the new Lotus Evora and updates to the current Lotus lineup of the Elise, Exige, Europa and 2-Eleven.
• Over the last financial year, Lotus Cars introduced three new market derivatives to its small vehicle platform: the Elise SC, Exige S with 240hp Performance Pack, and the Exige Cup 260. These three versions of the award-winning Elise and Exige are selling well in the global market.
• The exceptional success of the 2-Eleven track car required production to be increased and transferred from Lotus Sport to the main Lotus assembly facility at Hethel.
• New markets were opened successfully during the year in South Korea, Thailand and Estonia.
• Lotus Engineering, the company's high-technology engineering consultancy business, grew its global third-party customer base and was awarded with new and valuable contracts worldwide – 340 projects with over 140 clients. Lotus Engineering Inc in the US made record profits and Lotus Engineering Malaysia returned to profitability. Further expansion overseas took place including the opening of a sales office in Japan and setting up a subsidiary in China.
• Customer demand has lead to the creation of new departments within Engineering, especially focused on biofuels, electric and hybrid electric vehicles. Over the next year, six different electric and hybrid demonstration cars, using different technology, will be delivered to different global customers.
• In January 2008 the first product from Lotus's relationship with Youngman in China, the Europestar, was launched in Beijing. Lotus's collaboration with Youngman and Proton continues with various other projects.
• A major strategic alliance was initiated and formally signed with King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia and is progressing very positively with Lotus and Proton joint teams.

Looking to the future:

• The new financial year has seen the acquisition of a key strategic supplier, Holden Aluminium (Worcester) Limited, which has become Lotus Lightweight Structures Limited. This additional facility, which complements the facilities and IPR at the Hethel Headquarters, supplies the Lotus lightweight, high technology chassis for Elise, Exige, Europa and for the new Lotus Evora which was unveiled at the British Motorshow in July 2008.
• The Lotus Evora, the first all new Lotus in 13 years, is a 2+2 mid-engine V6 sportscar and first deliveries to customers are expected to commence in Spring 2009.
• New markets are being developed in China and the Gulf States for Lotus Cars.
• In the coming year, a sales and technology alliance venture will be set up in India to deal with the increasing level of work and enquiries from our automotive industry customers.

In summing up, Mike Kimberley said: "Clearly we are very closely watching the state of the global economy, and it is obvious that the world is changing very rapidly. Lotus, by being small and flexible, is set to deal with the new demands from our global consumer and business customers and over the last few months, the demand for our green and environmentally-sustainable technologies has increased, with many of the world's car companies working with us on alternative fuel vehicles, electric and hybrid vehicle solutions and lightweight structures.

"Lotus is now recognised as a world leader in research and development in these exciting areas of high technology, green and sustainable driving and we have a duty to share our advancements with the rest of the automotive industry for the sake of the future of personal transport and the car. We are proving that it is possible to have a guilt-free car in the future with desirable and enjoyable levels of performance, economy and sustainability and Lotus is one step closer to this utopian solution. Lotus has taken the necessary steps to reduce the impact of the global financial crisis and will continue to do so."

Source: Lotus Engineering

Off the line
Preparing for Evora production

“There are over 30 possible option combinations for the rear engine module alone and at least another 24 combinations for the car’s front-end”

A major milestone has recently been achieved in the development of the new Lotus Evora. The first of the VP (Validation Prototype) cars came off the production line to high acclaim from the manufacturing team. We take a look at what has gone into setting up the manufacturing facility for Evora.

The VP phase is about proving that the car’s design and tight engineering specification is robust for manufacture. It enables the engineering and manufacturing teams to confirm that the decisions for establishing the car’s ‘production intent’ parts, processes, equipment and tooling have been the right ones. VP is also a strategic phase in the passage of a new product from the designer’s screen to the factory floor which enables learning how best to build the car in the most efficient and effective manner and to identify early on further improvement opportunities.

There will be a total of 32 Evora’s built during this VP phase. Once these have completed their journey through our production lines, they will be used to validate the final development and type approval of the car. Some of these cars will be used for crash testing and the engineering teams will use some for further performance trials and tests. A small number of the cars will be used to assist in new development work for model year changes and option upgrades.

So what does it take in manufacturing to produce this super flagship for Lotus? And what is the sequence of build stages it goes through to become a product of the highest manufacturing quality when it arrives at the Lotus ‘buy-off’ station at the end of our production system?

Evora only really starts to take shape as it is processed through General Assembly. Superlatively-painted body panels leave the Paint Shop and are decanted and distributed to their respective ‘point-of-fit’ workstations within the production lines. The first part of the assembly production system for Evora (the Factory 5 chassis line) focuses its efforts to assemble Evora’s unique modular structure.

It is here that Evora presents Lotus with a new way of building cars. Whereas current Lotus cars have their rear sub-frame and front-end structures gradually built up in situ on the chassis (to form a single unit), the Evora is very different. The whole of the under-carriage chassis structure is made up in three modules – the front-end structure, the main ‘centre body’ section and the rear-end section – each one pre-assembled separately. As the main ‘centre body’ section progresses along the Factory 5 production line, the other two modules are constructed and built up as complete sub-assemblies. These are then moved into position at strategic locations and ‘married up‘ to form the overall support structure of the car. The roof is also assembled and bonded. This modular approach provides greater flexibility and efficiency within the production system. It makes access far easier to assemble (or replace) parts and will better facilitate engineering updates and new model year changes. Evora’s modular structure also offers several advantages in terms of improving ergonomics for the production team member.

However, that is not to say that assembling Evora isn’t complex. There are over 30 possible option combinations for the rear engine module alone and at least another 24 combinations for the car’s front-end. These represent a range of customer options including suspension type, left-hand or right-hand drive steering, painted or non-painted callipers, brake discs, and oil cooler options – and this is before we get to talk about the Evora’s high-quality interior. This means each module can be specified to totally meet the customer’s exact requirements.

Also within Factory 5, the car’s doors, windscreen, bulk-head, roof and body sides are assembled. For the earlier EP builds (Engineering Prototype) all of Evora’s body panels were produced and laminated in-house. For VP build, all panels have been imported from France. VP is, therefore, our first opportunity to validate ‘supplier’ produced body panels. The quality and finish of these panels has been impressive. The tools that currently produce these parts are made of steel and allow for any fine adjustment or changes to the panel

> Visual Process Control is an important feature of the Lotus production system

surfaces. Once they have been totally proven out, these steel tools will be chromed and become the 'bought off' body panel tooling for production ready parts.

On leaving Factory 5, the car is then transferred, somewhat counter-intuitively, to Factory 4 – the numbering of each of Lotus's factory reflects the way the site has developed over the decades, rather than its sequence in the process today. Here, the first few stages are laid out as a carousel line which is equipped to dispense various fluids such as oils, coolants and brake fluid into the car. Evora then progresses through the main trim assembly production line.

A large number of Evora trim components will actually be manufactured on site at Hethel, but away from the Evora assembly lines. The 'soft trim' development team is hard at work finalising the car's interior trim patterns and we have invested in state-of-the-art laser-cutting facilities, which exactly replicate our sophisticated CAD designs. All leather for the Evora seats will be cut and trimmed in this way. This technology allows for the most cost-effective arrangement of pattern shapes to cut whilst simultaneously, minimising 'off-cut' waste from each leather hide.

In the trim assembly line, like the chassis line, 'lean racking' has been introduced to house our line-side Kanban parts delivery system. This tubular system makes efficient use of line-side space and presents materials in an optimum and ergonomically-friendly state. Team leaders and members have also used its simple construction to create 'tailor-made' sub-assembly benches, parts trolleys and visual control stands. It is an extremely flexible system. It allows for an effective floor plan and efficient organisation of the workplace to support the people who assemble the car.

Lotus has also developed its own 'Visual Process Control' system for each of the Evora lines. These help to ensure that the car is built to the highest quality standards and will also be used to track the QCD (Quality, Costs and Delivery) performance for those lines. Visual Process Control is an important feature of the Lotus production system. It helps supervisors and team leaders to focus their efforts on producing Right First Time quality at every work stage.

It is in Factory 4, once the trim and special Recaro seats are assembled in the interior and the front and rear clam-shells are assembled on the exterior, that the car really does start to become instantly recognisable. As it works its way to the final stages of this line, fitment of optional forged or cast alluminium wheels concludes this phase of the production process before the car receives a standard Quality Inspection Process (QIP) verification. It is then routed to Factory 8 for its final testing stages such as on the rolling road before undergoing 'Final Finish' processes.

As a part of any Lotus new model introduction, Lotus Manufacturing will run a 'Station Readiness' programme. The aim is to ensure that each work stage is certified ready to build the new car. As the Evora approaches its SOP (Start of Production) date, the readiness programme will confirm whether we have succeeded in training all team members to a defined, proficient level. The programme will also establish whether our production processes

Off the line
Preparing for Evora production

> "It is our first new vehicle platform in 13 years and we are immensely proud of it"

are fully capable. To enable this, 'Station Readiness' criteria are defined specific to each category of our production resources i.e. people, equipment, documented standardised work methods and materials and parts availability. The production environment itself is also up for close scrutiny. Our progress in meeting the criteria is reviewed each day at a formal meeting. Having this 'production enabling' information allows us to compare the specific readiness status with where we have planned to be.

You might think that the Validation Prototype phase for a new vehicle was a big enough task on its own. However, before the VP phase is finished the manufacturing team faces the added task of building a pre-production EP phase (Engineering Prototype) for the American market. These so-called Federal EP cars will be built during the next few weeks. There are additional requirements for these cars so that they meet the different Federal legislation for emissions and crash testing.

Building EP cars and VP cars together will add complexity to the jobs of material control and internal logistics. The pressure is on to make sure that we have all the relevant parts to cater for the different global markets. Fortunately, by having a dedicated assembly line for Evora, we have been able to facilitate the best layout for parts line-side and to uphold the mantra for ensuring 'right part, right place, right time' delivery.

At 27 months, the Evora programme is incredibly aggressive for an all new vehicle of such quality. Being fast-to-market does have its challenges and frustrations particularly when running a tight programme with very short supplier lead times. Nevertheless, all at Lotus are extremely enthusiastic about Evora. It is our first new vehicle platform in 13 years and we are immensely proud of it. Its creation is a credit to our designers, engineers and the whole manufacturing team.

Source: John Vigar and Paul Culley - Lotus Manufacturing

Designing suspension for hub motors
– the dynamic challenges for future EVs

> One of the greatest opportunities for electric vehicles comes from new motor technologies that can be mounted at the wheels

Projects and technologies involving electric vehicles have been an expanding part of Lotus Engineering's client work over the last few years. Increasingly seen as important for greener future vehicles, efficient propulsion is not the only consideration in engineering successful electric vehicles. Consumer expectations for the dynamic performance of the vehicle will need to be met and Lotus Engineering's driving dynamics engineers are already very experienced in applying their expertise to cars with electric motors.

One of the greatest opportunities for electric vehicles comes from new motor technologies that can be mounted at the wheels. These can offer significant benefits in vehicle packaging.

However, placing hub motors on a suspension system will have obvious constraints on the design and packaging of the suspension system and it may therefore be difficult to maintain the same geometry positions as a conventional set-up. What is less obvious, however, is that the same geometry positions are not desirable. An important example of this is the anti-lift characteristic for a front wheel drive vehicle which defines how the front suspension of a vehicle will oppose the natural front 'lift' during acceleration. For a rear wheel drive vehicle, anti-squat is a similar characteristic and defines how the rear suspension of a vehicle will oppose the natural squat during acceleration.

Anti-lift (or squat) is quoted as a coefficient. If the value is zero, the front lift (or rear squat) will only be reacted by the suspension springs. Conversely if the value is 1, there will be no lift (or squat) at all and the suspension geometry will create forces that fully compensate for the rearward weight transfer during acceleration.

A conventional vehicle

For a convectional front wheel drive system, with the drive torque supplied via a drive shaft at the hub centre, the anti-lift characteristics are determined by the motion of the hub centres. Diagram 2 shows how front anti-lift is calculated. Rear anti-squat is calculated in a similar manner (i.e. rear hub motion projected to the front axle).

To achieve anti-lift, the hub must move forward as the suspension compresses. This conflicts with the requirement for good ride, which ideally has a slightly rearward motion of the hub with suspension compression. As always in developing driving dynamics of the vehicle, a compromise must be found that is most appropriate to the type of vehicle.

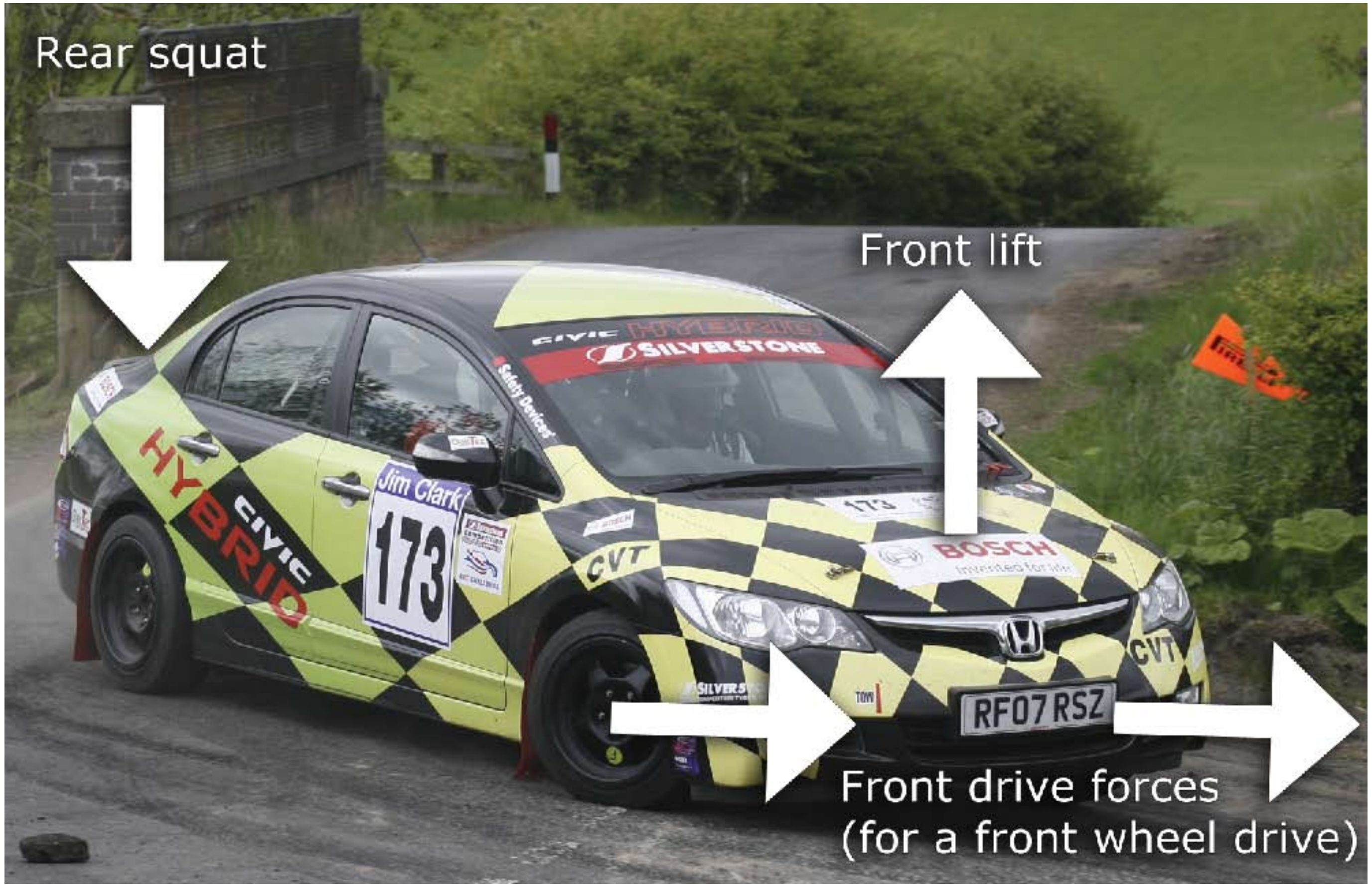


Diagram 1. Lift and squat during acceleration

> An important example of this is the anti-lift characteristic for a front wheel drive vehicle which defines how the front suspension of a vehicle will oppose the natural front 'lift' during acceleration

Designing suspension for hub motors
– the dynamic challenges for future EVs

> "However, for a hub motor set-up, anti-dive and anti-lift are both determined by the motion of the Hub Ground Point"

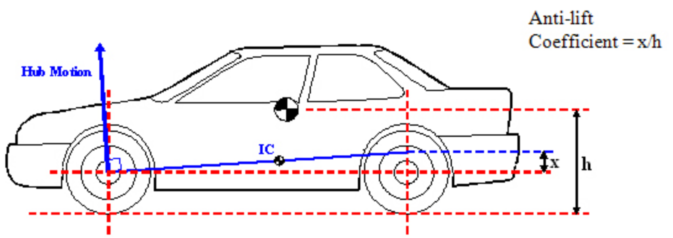


Diagram 2. Anti-lift calculation for conventional drive shaft set-up

Applying hub motors

When hub motors are fitted, the torque reaction from the motor is reacted in the suspension upright and hence into the body via the suspension links. It can be shown that this effectively modifies diagram 2 into diagram 3 where the motion of the upright projected to the ground is used (in place of the motion of the hub centre). This is often referred to as the motion of the tyre contact patch (TCP), although this can cause confusion, since the tyre contact patch connects to the hub via the wheel bearing and is therefore always below the hub centre (ignoring camber angles and tyre compliance). To state it another way, the point of interest for anti-lift is the point on the tyre, at the contact patch centre, which moves when the wheel is locked to the upright. We shall refer to this point as the hub ground point (HGP). This is shown in diagram 3

For interest, it can be seen in both diagram 2 and 3 that the upright rotates around an instantaneous centre (when viewed from the side of the vehicle), labelled IC. The front suspension systems in both diagrams are intended to be identical.

A typical value for anti-lift is dependent on many variables, including wheelbase, spring rates, damper rates and engine motor power. High levels of anti-lift will reduce lift but have a detrimental effect on (transient) tyre grip during acceleration due to the rapid unloading of the tyre vertical force. To improve front wheel drive grip, pro-lift is sometimes used.

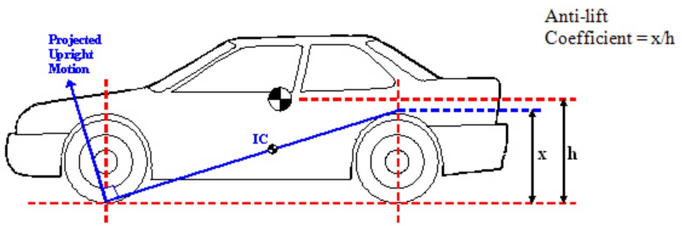


Diagram 3. Anti-lift calculation for Hub motor set-up

To obtain the same level of anti-lift (and the same applies to anti-squat at the rear), and hence maintain similar dynamics characteristics, the geometry required for hub motors must be different from that used in a conventional drive shaft set up. Also, since hub motion (for hub motors set-up) has no influence on either anti-dive or anti-lift, the hub motion can be designed to move slightly rearward with suspension compression for optimum ride without the need for compromise.

Under braking

The motion of the hub ground point determines another suspension characteristic at the front called front anti-dive. This defines how the front suspension of a vehicle will oppose the natural front 'dive' during braking. There is a similar characteristic at the rear and defines how the rear suspension of a vehicle will oppose the natural lift during braking. This is called (rear) anti-lift (under braking).

For a conventional vehicles, the front anti-dive can be tuned independently of the front anti-lift since anti-lift is determined by the motion of the hub and anti-dive is determined by the motion of the hub ground point. (The motion of the hub ground point is determined by the hub motion plus a contribution from the caster change).

However, for a hub motor set-up, anti-dive and anti-lift are both determined by the motion of the hub ground point, and cannot be tuned independently and therefore a suitable compromise must be found. The same is true at the rear, where both rear anti-squat (accelerating) and rear anti-lift (braking) are both determined by the motion of the rear hub ground point. Again a suitable compromise must be found.

The compromise required between anti-dive and anti-lift for hub motor vehicles is again dependent upon the type of vehicle, centre of gravity height, spring rates etc. For good brake control, some vehicle pitching is required, so 100 % anti-dive would not be advantageous. If a vehicle has a high centre of gravity, short wheel-base and soft springs (an off road vehicle for example) then a high value of anti-dive is required (up to 70 %). Conversely, long wheel-base vehicle with stiff springs (sports cars) often do not require any anti-dive (0%). For interest, it is often quoted that anti-dive has a detrimental effect on ride. This is not true. If the wheel is free to spin, the ride is not affected by the motion of the hub ground point. It is only affected by hub motion which ideally should be slightly rearward with suspension compression.

Structural considerations

The application of electric hub motors at the wheels not only has implications for suspension geometry and dynamics performance. With the drive torque now being reacted through the suspension links, the parts must be structurally capable of withstanding the torque. For a conventional vehicle, the front suspension is designed to withstand braking torques, and these will be greater than the drive torque of hub motors when installed. However if hub motors are fitted to the rear, braking torques are much lower and the suspension links of conventional vehicles may be unable to withstand the forces, necessitating a strengthened suspension design.

Bushing considerations

There are also bushing considerations when hub motors are used. Once again with the drive torque now being reacted through the suspension links, all the bushes will have compliance effects. Toe changes under drive torques must be considered if torque steer is to be avoided. During constant cruising speeds, the bushes will see permanent forces to react the drive torques. This will pre-load all the bushes which can have a detrimental effect on noise isolation unless it is carefully considered.

New opportunities

Although the application of hub motors does pose a number of challenges, these can be overcome with careful engineering. Beyond the environmental and packaging benefits, it should be remembered they offer other advantages which Lotus is researching. Having hub motors (front or rear) removes the need for a differential and opens up the possibility to drive the left and right hand motors with different torques. This gives two obvious possibilities:

- Greater turn-in response – by monitoring the steering input and increasing the torque to the outer wheels (of the turn), whilst decreasing the torque to the inner wheels.
- Stability control, by monitoring the yaw response and changing the motor torques to stabilise the yaw motion.

This is a subject called torque vectoring but that is a discussion for another time…

Source:
Malcolm Burgess – Chief Engineer, Vehicle CAE, Lotus Engineering

INTERVIEW: Ian Foley
MD at Williams Hybrid Power

"We approached Williams and Williams agreed that we had a promising technology and we took it from there"

With origins in developing advanced flywheel energy storage for vehicle applications, Williams Hybrid Power (WHP) was formed in 2008 when Williams F1 took a stake. WHP is developing a version of its flywheel system for use in Williams F1's Kinetic Energy Recovery System (KERS) to be introduced in its Formula One cars in 2009. Ian Foley is WHP's Managing Director. just-auto editor Dave Leggett interviewed him for proActive.

DL: Can you explain the background to the company?

IF: Yes, it was formed to develop flywheel energy storage systems and the initial focus was on the Williams system for the Formula One car next year, but the aim of the company is to take the technology that has been developed for that and apply it in other areas – both automotive and non-automotive.

DL: How did the Formula One connection come about?

IF: About two years ago the FIA announced that hybrid-type systems would be allowed from 2009 and those systems were going to be limited by the regulations to about 60kW maximum power or 400kJ per lap, which effectively means 60kW for about 6 seconds. That's just about enough to allow an overtaking manoeuvre that otherwise wouldn't have happened. So, the FIA specified the overall performance parameters but the technology was otherwise open so it's up to teams to search around for the best technology.

We approached Williams and Williams agreed that we had a promising technology and we took it from there.

DL: Are all the Formula One teams investigating similar technologies?

IF: They are all introducing hybrid systems of some sort. Exactly what they are doing and what technologies they have chosen, we don't yet know. I think we will see lots of battery systems out there – probably with lithium-ion batteries, maybe some super-capacitor systems and maybe a mechanical flywheel system and obviously Williams will have the WHP electrically powered flywheel system.

DL: And the development of your system for Williams is all going according to plan?

IF: Yes, we have started car testing. It's a very short timescale, even by Formula One standards, to reliably develop a whole new technology for a car, and we are in the middle of a very intensive development programme.

The 2008 Williams F1 car

DL: And the drivers are testing it out?

IF: Yes, we're in the early stages of that and it's all new to the drivers. The actuation of the system or the calling up of the 60kW for an overtaking manoeuvre is going to be under the control of the driver – he'll push a button for that to happen. But the recharging of the system will happen automatically.

DL: Do you think it will make a big difference to performance and make the sport more exciting?

IF: Yes. The idea was that in overall lap-time terms there wouldn't be a huge difference – maybe of the order of 0.2 seconds a lap - but hopefully the big difference will come from the system giving enough power to execute an overtaking manoeuvre that maybe wouldn't have happened before. So it should generate more overtaking which will hopefully make the racing more exciting.

DL: What's the set-up, in terms of resource, at WHP? How many people are there and what are they doing?

IF: There are five people here. There's a software engineer, a couple of mechanical engineers, myself and the original inventor of the system, Colin Tarrant. Right now we are fully focused on developing a Formula One system for next year. But we are also in discussions with a large number of companies about spin-offs.

DL: Could you sell your system to other Formula One teams?

IF: Who knows what may happen in the future, but our efforts at the moment are solely for the Williams team next year.

DL: What about the potential crossover for your technology to mass-market automotive applications – how realistic is that?

IF: It's a very realistic possibility. At the moment, the main focus on hybrids for the automotive industry is on battery systems but they are very expensive to manufacture. Also, the fundamental problem with all battery technologies at the moment is that if you continually deep cycle the batteries, the life is very short.

INTERVIEW: Ian Foley
MD at Williams Hybrid Power

> "There is a lot of industry interest and we do anticipate that development programmes will be starting soon on road car applications"

The key unique feature of our technology is that you can continually deep cycle - discharge and recharge the flywheel – all day long and it will have a ten-year life.

Additionally, the manufacturing techniques needed to scale-up for mass production are all existing techniques. It's effectively a large electric motor and therefore can be manufactured cost-effectively in volume.

We can possibly occupy a niche in the hybrid sector where you want to charge and discharge the energy storage regularly at a deep level, and therefore it can be smaller overall than a corresponding battery system.

Technically, I think we can solve a number of the problems which are preventing or slowing down the adoption of battery hybrids, but obviously we need to convince the car industry of the benefits – and putting our system on a Formula One car is a great way to demonstrate it.

DL: And if the technology migrates to mass-market road cars, where's the benefit to the driver – is it in greater fuel efficiency or is it enhanced power on tap and the ability to overtake quicker?

IF: It can effectively be both. One benefit from having a device that can give a short-term burst is that you can downsize the engine and therefore get greater fuel efficiency from the engine while maintaining transient performance. So, for example a 2.5-litre car only needs a fraction of that power to cruise along at 70mph but when the driver wants to put his foot down to overtake, he wants the power for a relatively short amount of time.

This is one area where this technology is particularly suited. So we could see hybrid high-performance cars with much smaller engines but with a flywheel system able to deliver sufficient transient power with much greater fuel efficiency.

DL: How would this technology migrate to road cars? Would you work with engineers in the car companies, Tier 1 suppliers, other companies? How would it happen?

The flywheel

Flywheels have been used to store and stabilise energy for hundreds of years. Early examples include the potter's wheel and spinning wheels. More recently advances in bearing technology, power electronics and vacuum enclosures have substantially improved their performance characteristics. The first modern flywheel systems were large stationary installations used to provide uninterruptible power supply and the production of very large pulses of electricity for scientific or industrial use.

Only in the last two decades has flywheel technology been seriously considered for use in mobile applications. It was held back by prohibitive weight and unwanted precession forces. Both of these characteristics are determined by the specific tensile strength (the ratio of the hoop stress to material density) of the flywheel.

WHP has developed a patented technology aimed at providing a cost effective, environmentally friendly, solution for mobile energy recovery and storage.

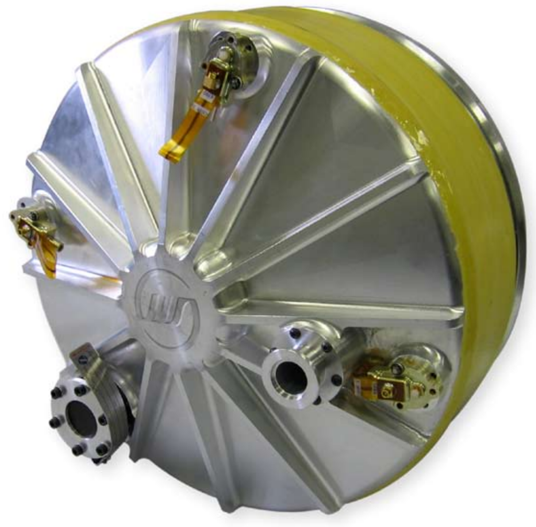
The flywheel is electrically driven, and can be considered as an electro mechanical battery, which can replace a conventional battery or Ultra capacitor pack in a hybrid system. The flywheel includes the patented 'Magnetically Loaded Composite'.

In essence this feature means that WHP can produce a wholly composite flywheel, which integrates the magnets of the electric motor into the composite. The key benefit this brings is that the flywheel system can be made significantly smaller and lighter than conventional flywheels, and also runs at very high efficiencies of between 97-99%.

The flywheel system is manufactured using conventional, scalable, manufacturing technologies and therefore provides the opportunity for cost effective volume production.

IF: It is very early days but we are at the stage of discussing with car companies and also Tier 1s the viability issues. There are obviously a number of steps to go through to get to there from being a prototype manufacturer with some machines on a Formula One car through to tens or hundreds of thousands a year on a road car.

There would need to be a development programme to modify the design in order to make it suitable for mass production, validate that in the field and then eventually get it into production.



At the moment there are a huge array of technologies and a lot of people in the frame trying to occupy the same space in the market that we are. We will be looking to work with car companies and Tier 1 suppliers to get to the prototype validation phase in a road car application and then be working with an existing mass-market manufacturer – possibly someone already making electric motors – to work on getting the product manufactured cost-effectively in volume.

DL: How long do you think it might be before a customer could go into a showroom and buy a car fitted with your flywheel hybrid system?

IF: There is a lot of industry interest and we do anticipate that development programmes will be starting soon on road car applications. It depends a lot on the political drivers for low carbon vehicles and also the pull from customers on the demand side. From where we are currently, it could be possible in a five-year timeframe.

Obviously, the current economic circumstances make it a lot more difficult, but companies have to think of the future and the climate change problem isn't going to go away. Ultimately, it depends on the

> Our focus has been to be able to demonstrate our system and technology on a Formula One car

motivations of the manufacturers and how much money they have got to spend.

DL: And there is solid interest?

IF: Yes. I think there is always what might be termed healthy scepticism when someone comes in with a new technology. There are a lot of technology companies generally that make claims that they cannot substantiate. Our focus has been to be able to demonstrate our system and technology on a Formula One car.

DL: Do you think WHP could be spun-off eventually?

IF: Maybe, who knows? The point of WHP being a separate company and not simply a part of Williams (a minority stakeholder) is to develop the flywheel business as a business. A lot of my focus going forward will be evaluating new business opportunities and which ones – both inside and outside the automotive sector – we should be focusing on.

We are looking at various niche markets and talking to people to develop products for those markets. I anticipate that within the next few months we will sign up a few of those and have a few projects running concurrently.

DL: What niche applications does the flywheel technology suit?

IF: Our competitive strength is the ability to deep cycle continually with no loss of performance. For instance, in the case of large, heavy vehicles continually stopping and starting, we are likely to be able to make significant fuel savings and lower emissions. It's really anywhere here you have lots of energy being continually cycled up and down.

DL: What do you see as the main business challenge going forward?

IF: The main challenge is to take the business from being a five-man business focusing mainly on a single product for Williams and manage growth to new projects and new customers, while also not losing focus on existing customers. I think expansion will present its own challenges.

DL: What drives you, personally?

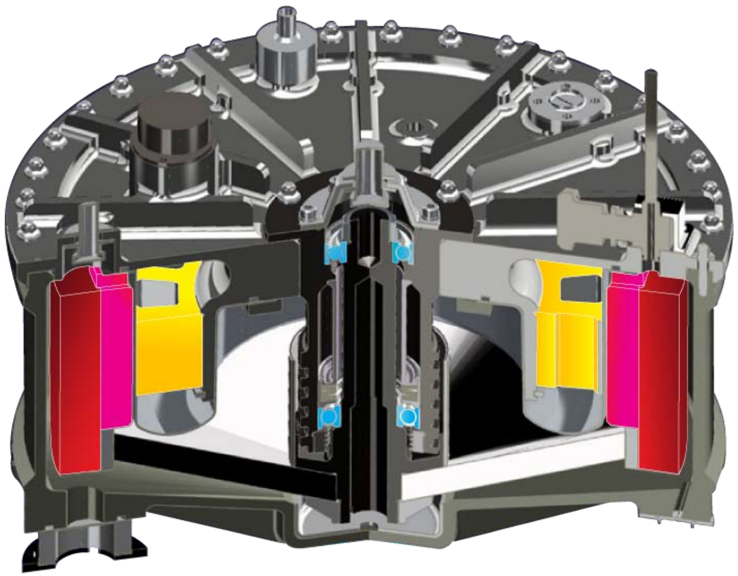
IF: I have always been fascinated by new technology. I was responsible for the development of the active suspension system at Lotus that we raced in 1992 and 1993 – interestingly, we were soundly beaten by Williams' active suspension system back then!

There is, of course, an immense challenge in taking a new technology and making a business out of it, but I have always been fascinated by new technology and that is something that very much inspires me at WHP.

Ian Foley

Ian Foley has a BSc degree in Electronic Engineering, and an MSc in Control Systems. Ian has a proven track record in the successful development of new technologies. After being responsible for the development of the Lotus Active Suspension system raced by Team Lotus in Formula 1 in 1993, Ian set up his own consultancy and has successfully developed control systems in the power and racing industries. Having identified the substantial potential for the application of the MLC flywheel technology to the automotive sector, Ian set up Automotive Hybrid Power in 2006, which became Williams Hybrid Power Ltd in March 2008.

Source: just-auto editorial



- **Carbon fibre**
- **Stator**
- **Ceramic bearings**
- **Magnetic Loaded Composite**

> There is, of course, an immense challenge in taking a new technology and making a business out of it, but I have always been fascinated by new technology and that is something that very much inspires me at WHP

Under the skin
of the new Lotus Evora

> "Here at Lotus we've always been keen that our lightweight structures achieve more than mere lightness."

Performance – or, if you'd prefer, efficiency – through light weight has been the cornerstone of the Lotus engineering ethos since the dawn of the company. As a producer of world-leading sports cars, the correlation between low mass and improved vehicle dynamics infuses every decision we make, every technology we develop.

These days, of course, the whole automotive world is awake to the benefits of lightweight body systems and structures, although the key drivers now are reduced CO_2 emissions and fuel consumption rather than razor-sharp handling and good ride quality; the exciting thing about lightweight vehicles is that they allow you to achieve all these goals in a single package.

Here at Lotus we've always been keen that our lightweight structures achieve more than mere lightness. Versatility, functionality and cost-effectiveness are essential complementary elements to the reduction of mass, as we have proven over the years and will continue to demonstrate with the introduction of new technologies.

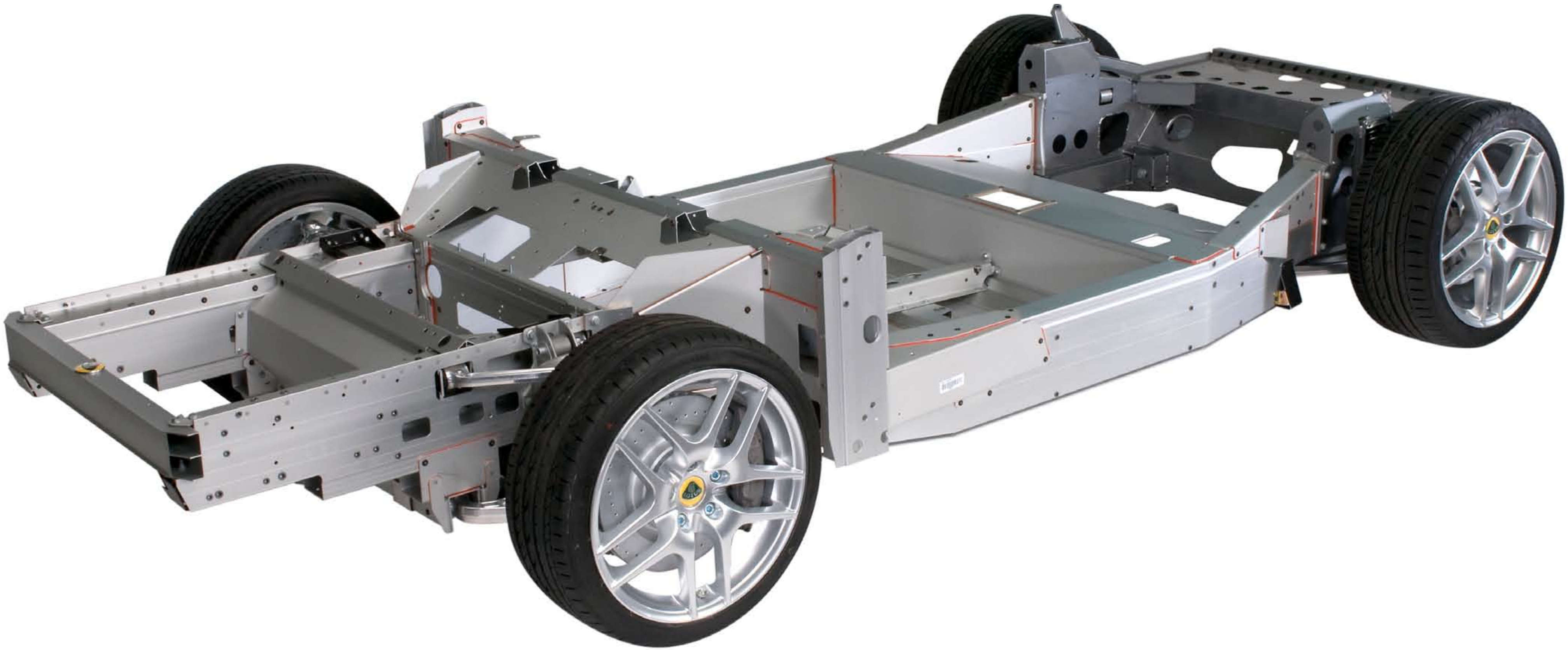
The ideal example of our approach to lightweight structures is the platform of the recently announced Lotus Evora, a 2+2 mid-engined sports car. It is the first production realisation of what we call Versatile Vehicle Architecture, or VVA, a modular technology approach that gives us the flexibility to adapt the platform to create vehicles both larger and smaller than the Evora, and even to change the orientation of the engine, simply and at relatively modest cost.

In common with our popular Elise platform models, the Evora's low-volume VVA central platform is constructed from epoxy-bonded extruded aluminium components; although welding techniques are now much improved, the process remains inherently damaging to materials and requires localised material gauge thickness. Bonding doesn't compromise the strength of the parent material and allows thinner and more consistent gauge materials, saving weight yet with no degradation of the platform's dynamic performance. It is essential, however, not only to have an adhesive formulation that is strong and durable for the lifetime of the vehicle, but also to correctly treat both surfaces of the joint being bonded; experience with the Elise has given us a wealth of knowledge on joint conditions, particularly in respect of coatings, corrosion and wear.

In some areas of the bonded structure, you will notice the use of riveting systems, but unlike some other aluminium structures currently in production, these have no structural purpose in normal service, but are employed simply to hold the structure in shape

Under the skin
of the new Lotus Evora

> The front, middle and rear sections are all bolt-on, replaceable elements with consequent advantages in terms of assembly and repair



whilst the epoxy cures, then resist peeling in the event of a major deformation. Because the adhesive is the dominant joining method, Lotus typically uses far fewer rivets per metre with resultant savings in weight and complexity.

But it is the modularity of the VVA platform that represents the greatest advance in this technology. The front, middle and rear sections are all bolt-on, replaceable elements with consequent advantages in terms of assembly and repair; the adaptability also greatly reduces the risks inherent in experimenting with new designs.

For the Evora the rear module, which accommodates the engine and rear suspension and also forms part of the crash structure, is of steel construction. We favour steel in areas where there are a concentration of load inputs and many complex components; we may be best known for our work with aluminium, but we also ensure that the materials we use are best suited to their process and application. The Evora's bolt-on front module employs an aluminium crash structure; it is the right material and process choice for that part of the car.

Such is the flexibility of the VVA system that the platform can withstand a variation in track width and wheelbase without the need for substantial re-engineering. In a typical whole vehicle programme this adaptability could, for example, reduce development time by six months.

Pleased though we are here at Lotus with the progress being made with VVA, it is just a part of our investigation into weight-saving technologies and techniques. Lightweight composites remain the focus of much attention, but the challenge is to improve their cost-effectiveness and volume potential. To achieve this we are exploring function integration, grouping several local components together into a single piece. This requires a non-conventional design approach; we already have practical experience of this mindset, for example the recyclable RTM composite front structure of the Elise is designed to perform five different functions: energy absorption, radiator mounting, body mounting, cooling air ducting and tow eye mounting.

We are also examining new materials, some of them extremely 'left-field' – our experimental Eco-Elise concept is bodied in a hybrid composite of polyester resin and hemp (the natural, sustainable material also features in the construction of the seats, while the upholstery is of eco-wool and the carpets made of sisal) and achieves an A-class surface finish. The hemp composite body and seats contribute towards a 32kg weight saving compared with the standard Elise.

No less exciting is our investigation into thermoplastics for use in ultra-compact energy absorbing safety structures. Such injection-moulded thermoplastics have a future in vehicle body construction and we are researching the new technologies by which to produce them.

That we are looking into many different methods of saving weight is no accident. The lightweight structure of the future will feature a range of materials and technologies, each carefully picked for their suitability for process and application. The integration of materials and functions will be key to reducing mass, while the modular versatility of the Lotus VVA system will substantially reduce the cost of producing high-quality, low-volume, brand-building vehicles.

Source: Brett Fraser

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