

## The Project Eagle Story

the engineering of the  
new Lotus Evora

## Driving dynamics

for energy-efficient vehicles

## Q&A with Bob Lee

Chrysler's powertrain head

## Lotus Evora

design story



# Welcome

**Over 20,000 owners, fans and clients from all around the world descended on our Hethel headquarters last month to be part of the Lotus 60th Anniversary open day celebrations. It was a fantastic tribute to our heritage and proved a very memorable day.**

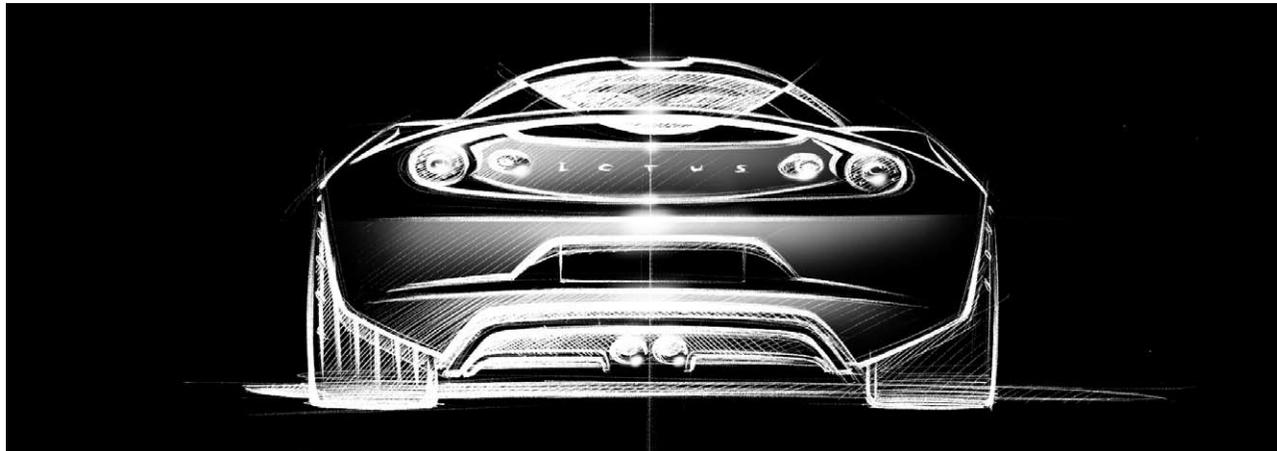
As part of this, we allowed partial access to our normally highly-confidential engineering facilities, giving people the rare opportunity to explore the inner sanctums of the design studios, engineering workshops and powertrain facilities and see some of the high-tech tools and equipment that we use behind closed doors. Admittedly, it was a bit of a headache in the days leading up to the event to ensure all the confidential client vehicles we couldn't show were well and truly locked away, but the unexpected access provided was incredibly well received by everyone.

The spirit of openness continued with the 'Project Eagle Story', a detailed tour of the development of the new Lotus Evora, which proved a real highlight of the day. It is normal in our industry that highly polished show cars at motorshows are the only part of the development and launch that the public get to see first-hand. However, so impressive is the technical excellence and rigour that underpins the Evora, that we displayed the 'real engineering' of the project ranging from design clays, seating bucks, mule cars, engineering prototypes and crash-tested cars. Working prototypes were whisked back from test activities all over Europe; one calibration car not returning until the night before, leaving no time for even a quick jet-wash, but it went on display nonetheless. All along the way the engineers happily chatted to the crowds that passed through.

In some ways, it was sad at the end of the day that the swipe-access doors closed and the site was once again secured. But at the same time, the enthusiasm of the thousands of visitors reinforced the importance of the work we all had to get back to on the numerous exciting cars and client projects that will ensure a bright future for Lotus for years to come.

Whether you made it to Hethel for the 60th or not, highlights from the day are just two of the topics featured in this issue, with Russell Carr explaining the Evora design story and Rob Savin reviewing the development story. I hope you enjoy it.

Peter Morgan  
Marketing Manager – Lotus Engineering



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## US: Toyota opens new R&D campus

Toyota (TMC) has announced that Toyota Technical Centre (TTC), a division of Toyota Motor Engineering & Manufacturing North America (TEMA), has opened a new campus in York Township, Michigan.

The new campus will handle TTC's product planning and engineering design operations, as well as serve as TMC's first collision-safety testing facility outside Japan.

At a ceremony to officially open the campus, attendees included Michigan governor Jennifer Granholm, TMC senior managing director Yasuhiko Ichihashi and TTC president Shigeki Terashi.

TTC, based in Ann Arbor, Michigan, and which has been Toyota's North American vehicle research and development base since 1977, has invested USD187m in the York Township campus. The campus, for which plans were announced in April 2005, will create 400 additional jobs at TTC by the end of 2010, 300 of which have already been filled.

The Ann Arbor campus will continue to carry out evaluation activities, powertrain design and development, and research into materials and cutting-edge technologies.

Toyota has established research and development bases in North America, Europe, Asia and Australia to carry out vehicle and parts design, planning and evaluation.

Source: just-auto.com editorial team

## Sweden: New Volvo chief pledges '09 turnaround

New Volvo boss Stephen Odell has pledged to turn around the struggling Swedish automaker as early as next year, just-auto has learned.

Odell made this aggressive message known to senior managers inside the company and, just a week after he officially took the reins at Volvo, the company has axed a further 4,000 jobs on top of the 2,000 announced in June.

"Stephen wants this turnaround very fast," said Volvo spokesman Olle Axelson.

Volvo has now pledged to cut a quarter of its 24,300 workforce in the space of four months in response to a pre-tax loss in the first half of the year of USD271m.

The job cuts are a mix of white and blue collar and consultant positions, with the bulk of them factory-floor jobs. Overall Volvo is losing 2,900 factory-floor workers, 1,800 office workers and 1,200 consultants, a deep change at Sweden's biggest exporter.

The cutbacks are a key plank in Odell's plan to get Volvo back in the black by reducing the production break-even point to between 350,000 and 370,000 units a year.

Volvo needs to re-size its operation around lower production and sales figures, because the tough US market, Volvo's single biggest, will drag sales down to around 400,000 units this year compared to 458,000 in 2007.

Volvo is also understood to have scrapped its long-term strategic goal of 600,000 cars a year, a target set around 2000/2001 when Ford's now-disbanded Premier Automotive Group was getting into its stride.

Volvo's main plant at Gothenburg, which builds the S80, V70, XC70 and XC90, is bearing the brunt of the cuts with 2,250 shop-floor jobs and 1,085 office jobs going.

Its second assembly plant at Gent in Belgium, which builds the C30/S40/V50, is suffering fewer cutbacks with 900 jobs going in total, despite the imminent launch of the XC60 soft-roader.

A body plant at Olofstrom will lose 350 factory and 110 office jobs while the engine plants at Skovde and Floby will share 60 lost positions.

Odell has moved fast to put his level headed new strategy in place.

Volvo was braced for a further round of job-cuts at last week's Paris show, the week that Odell officially took on the job of president and CEO.

Source: just-auto.com editorial team

## France: Renault, PSA, do electric vehicles joint venture with EDF

Renault and PSA Peugeot Citroën have both separately announced agreements with French group EDF to develop electric car projects. The French government owns 85% of the energy supplier.

The project will include development and marketing of electric vehicles and plug-in hybrids. In a statement PSA said the agreement covers several technological programmes, including:

- the definition of business models capable of driving the commercial development of electric vehicles;
- new energy storage technologies, such as lithium-ion batteries;
- vehicle recharging systems and protocols to enable vehicles and the network to communicate during recharging, as well as the standardisation of these systems and protocols.

Last June, PSA said it would work with Mitsubishi on electric powertrains.

The Renault agreement with EDF is focused on developing the infrastructure needed to recharge electric vehicles, supporting the automaker's plans to launch an electric vehicle in 2011. The two companies are planning to develop a commercial project that will be open to other companies.

EDF is already working with Toyota to develop a 'smart' charging terminal which currently is being tested here in the UK.

The news came as the French president, Nicolas Sarkozy, announced the French government would seek changes to EU state aid rules to allow it to fund research and development into low-carbon cars to the tune of EUR400m.

Source: just-auto.com editorial team



# Industry News

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The current turmoil and financial crisis adds risk to the 2008 forecast of up to 200,000 units, as it is unclear how consumers will respond in the fourth quarter

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## US: JD Power revises down market forecasts

JD Power is now forecasting that the total US light vehicle market will drop to 13.6m units in 2008, 16% under last year's 16.1m total. A further drop to 13.2m units is projected for 2009. The forecaster and market analyst also said that Europe's market is set to decline while growth in China and India is slowing.

As the US new vehicle retail market continues to deteriorate, new vehicle retail sales (excluding fleet sales) are projected to end 2008 at 10.8m units, which is 2m units below 2007 sales, according to JD Power.

JD Power says that approximately two-thirds of the decline in retail sales - which are reflective of actual consumer behaviour in the new-vehicle marketplace - can be attributed to consumers delaying vehicle purchases.

On average, consumers are keeping their vehicles four months longer in 2008 compared with 2007 - up from 67 months to 71 months. The remaining one-third of the volume decline comes from reduced leasing activity. Additionally, fleet sales are expected to decline to 2.8m units in 2008, which is well below the 3.3m unit level achieved in 2007.

“Buyers are both voluntarily and involuntarily exiting the US new vehicle market,” said Jeff Schuster, executive director of automotive forecasting for JD Power and Associates. “The additional decline in expected vehicle sales is a function of growing concerns around availability of credit and leasing, declines in vehicle equity and general economic stress.”

The current turmoil and financial crisis adds risk to the 2008 forecast of up to 200,000 units, as it is unclear how consumers will respond in the fourth quarter.

Market uncertainty has also led to a downward revision of the 2009 US light vehicle forecast. Total new light-vehicle sales are expected to drop to 13.2m units in 2009, with the retail sales market declining to 10.6m units.

“Falling trade-in equity, fewer leasing options, credit market restructuring and the increased migration to used vehicles are all putting added pressure on the US new vehicle sales market in 2009,” said Schuster. “Any truly pronounced recovery appears to be more than 18 months away.”

### China and India slow

Slowing within China's automotive market is projected to intensify during the fourth quarter of 2008, and will likely lead to a downward revision for 2009. Despite the slowing, light vehicle sales - including passenger vehicle and light commercial vehicle segments - in China are expected to reach 8.9m units in 2008, which marks an increase of 9.7% from 2007. However, the projected growth rate for the China automotive market in 2008 is less than one-half of the 24.1% growth achieved in 2007.

The light-vehicle sales forecast has also been reduced for the India market, down 6% from the original forecast of 1.9m units to 1.8m units for 2008. The 5.1% growth rate forecasted for 2008 is considerably less than the increases seen in 2007 (16%) and 2006 (21%).

### Europe to fall

Light vehicle sales in Europe are expected to fall to 21.3m units in 2008, marking a 3.1% decline from sales in 2007. Within Western Europe, sales are forecasted to decline to 15.6m - a decrease of 7.5% from 2007. While sales in Eastern Europe are expected to increase to 5.8m in 2008 - up 11.3% from 2007, growth within the region is slowing considerably.

“While the global automotive industry is clearly experiencing a slowdown in 2008, the global market in 2009 may experience an outright collapse,” said Schuster. “While mature markets are being impacted more severely than emerging markets, no country or region is completely immune to the turmoil.”

**Source:** just-auto.com editorial team





## Lotus developing hybrid drivetrain for motorsport

Lotus Engineering, the world renowned automotive consultancy division of Lotus is collaborating with Oaktec to develop the performance of a Honda Civic Hybrid for stage rallying and circuit racing.

Recognised as a global leader in hybrid and electric vehicle development, Lotus Engineering is supplying technical expertise to Oaktec in developing racing technology that exploits the performance potential of the petrol electric Honda hybrid system. The Honda Civic Hybrid will compete on the racetrack with ultra-low exhaust emissions and high fuel efficiency.

Lancashire-based Oaktec, a specialist in energy-efficient vehicle design, approached Lotus Engineering to investigate areas of battery and system control technology that enable maximum racing performance and efficiency from the hybrid drivetrain. The collaboration is in partnership with Energy-efficient Motorsport (EEMS), Motorsport Development and Honda UK. The project has won funding from the Northwest Regional Development Agency (NWDA).

Mike Kimberley, Chief Executive Officer of Group Lotus Plc said: “Lotus Engineering has an enviable track-record in the global automotive industry for the successful delivery of hybrid vehicle programmes, applying advanced technologies on the road and now on the racetrack. Our dedicated Hybrid and Electric Vehicle Technologies Group is working on a large number of third-party client projects and the collaboration with Oaktec is yet another demonstration of our advanced skills and expertise in the area of hybrid vehicle engineering.”

The environmentally-friendly Honda IMA hybrid technology used on the Honda Civic Hybrid is ideally suited to a motorsport application and has further potential to enhance power while retaining high fuel efficiency. The 1339cc Civic uses a Continuously Variable Transmission (CVT) to complement the hybrid-drive in race and rally conditions. This CVT enables the car to be driven at constant full power making performance very accessible, and in tandem with the hybrid system gives excellent performance and efficiency.

Paul Andrews, Senior Partner of Oaktec said: “We have been developing the Honda Hybrid system for motorsport since 2004 and achieved a great deal of success in rallies around the UK, including a championship win in 2006 with a Honda Insight in the F1000 Class A Championship. Maximising racetrack performance from a hybrid drivetrain is a complex technical exercise but one that Lotus Engineering has the experience and expertise to help us deliver. We look forward to seeing our success on the rally tracks replicated in the race circuits. We will be breaking new ground with the project when Gavan Kershaw of Lotus Engineering and Jamie Corstorphine of *Autocar* magazine will race our Honda Civic Hybrid for the first time in the Dunlop Max Sport Cup at Rockingham circuit on 28 September.”

Phil Barker, Chief Engineer of Hybrid and Electric Vehicle Technologies at Lotus Engineering said: “Hybrid and electric vehicles are already established on our roads but to make them successful on the racetrack, a number of technical changes have to be employed. Working with Oaktec, we will create a revised electrical specification for more power and a control system that will allow a more aggressive regenerative braking strategy. Lotus Engineering’s work on the Honda Civic Hybrid will prove that you can still get high performance while using green technologies.”

**Source:** Lotus Engineering

## Lotus Europa receives diamond treatment

This year Lotus celebrates its 60th birthday and to properly mark the occasion, the British sports car manufacturer has produced a real gem of a car - a fully customised, diamond-set Lotus Europa valued at GBP150,000 which was launched at Lotus' birthday celebrations in Hethel, Norfolk on 14 September 2008.

The diamond anniversary Lotus Europa has received the highest level of customisation from cosmetic enhancements to performance upgrades. Inside, the car boasts sumptuous textures created using the finest quality leather for a superior quilted trim, while the bespoke gear knob and controls feature sparkling diamonds set in cool matt black metal. The diamond scheme is completed with a specially designed rev counter and speed dials that feature diamonds highlighted by hidden LED accent lighting.

An exclusive paint finish has been applied to the sleek form of the Europa, giving the already sophisticated model a truly spectacular finish. A high gloss black base has been adorned with tiny glass flakes giving the appearance the car has been showered with diamonds. Tinted glass and black and silver wheels complete the monochrome scheme in polished, stylish fashion while a beautiful, diamond-set Lotus nose-badge proudly crowns the car.

Mike Kimberley, Group Lotus CEO had this to say about the bespoke Europa: "I'm always proud to launch a special edition Lotus and this commemorative, bespoke Lotus for our Diamond Anniversary is very special indeed. We are a global, high-technology engineering consultancy and sports car company and reaching this special milestone demonstrates our tenacity and creativity as much as our expertise and professionalism."

The diamond anniversary Europa is the culmination of skill and expertise from many of Lotus' production teams and suppliers. The project was championed by Winsor Bishop, East Anglia's premier diamond specialists, who are supplying Lotus with around GBP111,000 worth of diamonds for the stunning car. "We were delighted to work with Lotus on this exciting project and are thrilled with the sparkling results," remarked Sophie Croydon, Director of Winsor Bishop. "Diamond-setting a car was a first for Winsor Bishop, by specifying 164 beautiful Round-Brilliant Diamonds with a market value of GBP111,100, we have helped create a truly unique Lotus Europa."

This beautifully hand-crafted British sports car is not only stunning and luxurious, it drives like a dream too. Achieving 0-60mph in less than 5 seconds and a maximum speed of 146mph, this Lotus Europa is certainly a car of style and substance.

Source: Lotus Engineering



## Lotus Evora aluminium structure celebrated

The Lotus Evora, the all new sports car from one of the leading global car marques has won a prestigious award at the European Aluminium Awards 2008. The aluminium structure of the Lotus Evora, the world's only mid-engined 2+2 was triumphant, capturing the Overall Jury Prize, celebrating the technological advancements of the Lotus aluminium vehicle architecture.

In what is the first award to be bestowed on the visually-stunning Lotus Evora, even before production is underway, the award, only presented when special recognition is warranted, recognises the latest developments of this low-volume version of the Lotus vehicle architecture technology. The European Aluminium Award is the leading international prize of the aluminium industry and was presented to Lotus at the prestigious International World Trade Fair 'Aluminium 2008' at Messe Essen in Germany on Tuesday 23rd September.

Mike Kimberley, Chief Executive Officer of Group Lotus, said: "We are absolutely delighted that the Lotus Evora has won such a prestigious award so soon after its official unveiling at the British International Motor Show in July. The Lotus Evora architecture is an advanced, lightweight technology that provides a foundation for our long term model plan for future Lotus and client products."

Kimberley continues: "This structure is the latest development of our vehicle architecture technology which was celebrated as the leading entry in the Aluminium Awards in 2006. The Evora heralds an exciting new era for Lotus Cars and proves that you can have phenomenal performance, fuel efficiency, elegant design and practicality all in a mid-engined 2+2 sports car."

A statement from the jury said: "Lotus provides an automotive structure with a unique approach. It combined adhesive bonding techniques with mechanical joining, resulting in innovative and creative solutions. Lotus used its expertise in lightweight materials to complete this structure, achieving a low weight and a high structural stiffness and therefore ensuring a major impact on environmental and sustainable performance."

Richard Rackham, Vehicle Architect at Lotus Engineering, said: "The Lotus Evora demonstrates an accumulation of our core competencies in aluminium and composite body engineering, joining techniques and vehicle systems integration. Lotus pioneered the technology of bonded aluminium extrusions for use in road vehicles and has successfully developed high performance cars for other car companies around the world. One great advantage of our low-volume vehicle architecture technology is that it can be used by one car manufacturer looking to develop a range of niche products, or by a group of car manufacturers looking to share investment, but still retain a high degree of end product separation."

**Source:** Lotus Engineering



Lotus Engineering's Alice Bolger, Adriaan Gerber and Ingemar Johansson proudly accepting the Overall Jury Prize



## Petrolheads and politicians – the Exige 270E Tri-fuel hits The Netherlands

The weekend of 16-17 August 2008 saw the Lotus 270E Tri-Fuel in action at the Bavaria City Racing event at Rotterdam, The Netherlands. Bavaria City Racing hosts a wide variety of cars, from the latest Formula One machinery to off-road beasts like the Bowler Wildcat. Initially they were displayed in a large indoor arena, with the sound of race-spec engines filling the hall but when the showcase arrived on the Sunday, the streets of Rotterdam morphed into a race track and the cars wowed the crowds by demonstrating the latest motorsport technology.

The Exige 270E Tri-Fuel made the journey over to the Netherlands the week before for a number of press activities. Lotus Engineering Vehicle Dynamics Engineer Gavan Kershaw wowed journalists by demonstrating the additional power while running on biomethanol at Zaandvoort race track and the following day, the car made a journey to The Hague where the Dutch Prime Minister, Jan Peter Balkenende, and Transport Secretary, Camiel Eurlings (top picture) experienced driving the Exige and received a presentation on the benefits of a flex-fuel vehicle.

The weekend culminated in the car being demonstrated in front of over 90,000 people on the streets of Rotterdam! The Lotus Exige 270E Tri-Fuel received extremely positive coverage from the event and served to reinforce Lotus Engineering's 'Efficient Performance' technologies and reputation as the world's leading automotive engineering consultancy.

Source: Lotus Engineering



# The Project Eagle Story

## the engineering of the new Lotus Evora

“ To see it, it is difficult to believe its importance in laying the foundations for the driving dynamics and influencing the engineering design of the Evora ”

September 14 saw Group Lotus proudly open the gates to the Hethel facility in celebration of its 60th Birthday. Clive and Hazel Chapman officially opened the festival where over 20,000 Lotus enthusiasts and fans of the marque had shown up to take part in the revelry. Undeterred by queuing traffic, Lotus cars both past and present snaked their way to the factory, making for a truly unique kind of car park.

The Lotus Car clubs were out in force, and alongside our own Lotus Club International they displayed members' cars for a best of show car competition judged by ex-F1 driver Martin Donnelly. In addition, Classic Team Lotus presented some of its F1 machinery that once more attracted the crowds. And, for lucky thrill seekers, Lotus Sport was offering high-speed demonstration laps out on the test track where the grins came thick and fast leaving everyone short of breath and high on adrenalin.

However, one of the real must-sees of the event was the Project Eagle development story, a tour revealing many previously unseen aspects of the new Lotus Evora. Visitors had the opportunity to speak first-hand to the designers and engineers who have been directly involved in bringing this car to fruition. It provided an unprecedented insight into modern vehicle development.

The story, like the project, started with Lotus Design which demonstrated the creative process for Project Eagle through concept development, initial sketch work, 1/3 scale models, engineering collaboration and final design through to full size models which were displayed in the confidential design studio. All along the tour the engineers involved day-to-day in the project enthusiastically explained what was on show and their role in the project.

The body engineering team displayed prototype panels, the tools used to make them and a complete body and chassis buck which was used for panel fit analysis on the engineering prototypes. The body structure of the Evora will exhibit world-class panel fit standards and surface quality, and the lightweight composite panels are also designed to both increase chassis stiffness and energy absorption in the event of pedestrian and vehicle impacts.

Under the skin of the Evora sits the aluminium structure which utilises a low-volume version of Lotus' versatile vehicle architecture technology constructed from rivet-bonded extruded and folded aluminium parts. The structure for this new car, like the current small car platform products, is made by Lotus Lightweight Structures

based in Worcester. The full structure was displayed by the chassis team while LLS displayed the front crash structure and also showed the evolution of raw aluminium into extrusions, machined parts, anodised treatments and assembly into the bonded chassis unique to Lotus's products.

Early on in the programme, when the all new vehicle structure and design were still only computer-aided-designs in the virtual world, the development teams were already hard at work. Mule cars were built to develop aspects such as the driveline and chassis, to quickly understand and validate the dynamics behaviour of the vehicle and to start the development of complex chassis systems. One mule vehicle, on the surface a modified Esprit, was on display having been the test bed for much of the initial vehicle dynamics work and being used for the ABS and traction control system development in Sweden (as featured in proActive 25). To see it, it is difficult to believe its importance in laying the foundations for the driving dynamics and influencing the engineering design of the Evora.

However, it is when engineering prototypes arrive that the tangible results of all the early design and analysis really become evident. Many of the project's engineering prototypes were on show, all rushed back from far-flung reaches of Europe where they had been involved in various types of testing. These cars are instantly recognisable as the Evora and so, heavily disguised, were the target of many spy-photographers' cameras ahead of the unveiling at the British International Motorshow in July. The prototype that had been used for the Pave testing, went through extreme durability testing over very uneven cobbled surfaces, still sported its disguise, showing the care and effort that the teams had to go through to protect the shape and design of the vehicle during early testing. It has to be said that this was not only to the annoyance of the media but also some of the engineers wanting to push the car faster than the camouflage would allow.

An excellent aspect of the Eagle story was that it gave an opportunity to explain some of the often overlooked but incredibly important aspects of the programme. The Lotus Quality and Supply Chain departments displayed their invaluable work in ensuring the exacting quality targets of the car will be met through in depth displays of the project through timelines and presentation boards. Similarly the Lotus type approval department gave an extensive display to highlight the complexity and detail of modern vehicle legislation. Presentation boards listed the extensive aspects required to meet



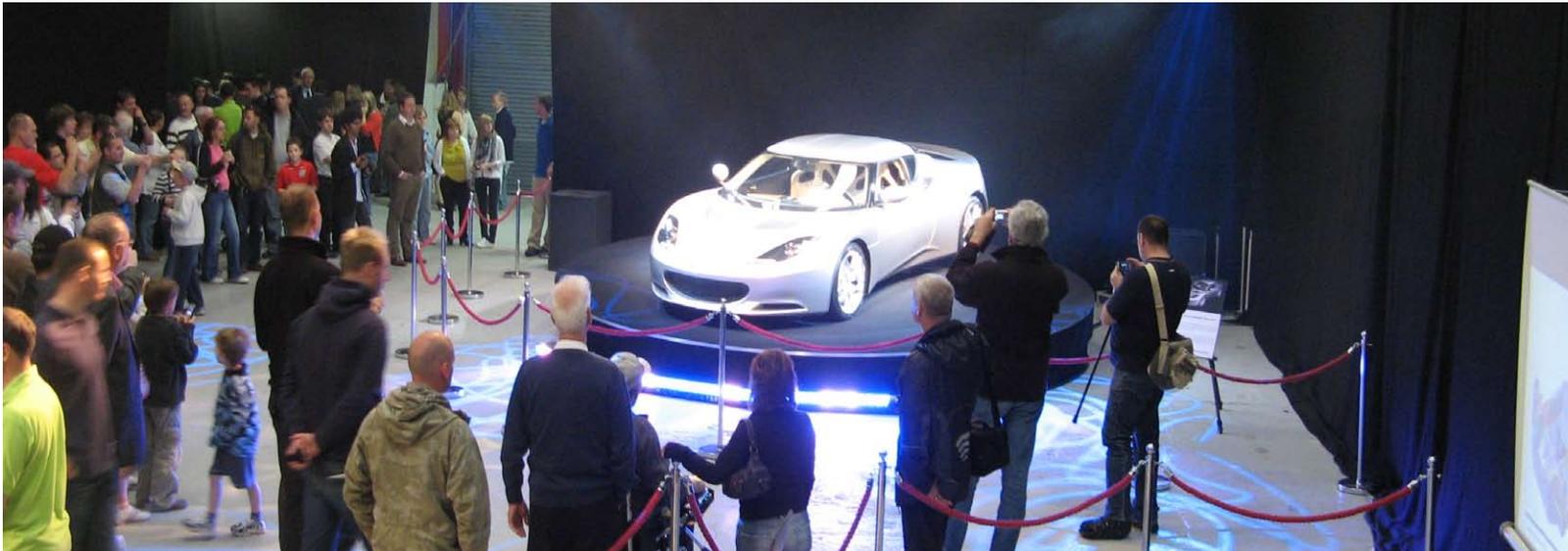
# The Project Eagle Story

the engineering of the new Lotus Evora

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The complex array of engineering, typically unseen by the outside world, fascinated all who took the tour

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world homologation regulation and a head impact rig and H-point dummy, which defines the correct occupant position for testing, were displayed in a vehicle buck and the G1 durability test car.

However, the more obvious results that the type approval and test and development groups have been hard at work was the crash test cars. Two vehicles that had undergone rigorous tests ably demonstrated the incredible strength of the occupant structure, while the videos of the dramatic tests when compared with the computer-aided-engineering animations showed that the results were only what we expected.

The Electrical team brought out yet another test car, the test bed of the electrical harness and systems, and complimented it with a case study of the bi-Xenon headlights, showing the level of detailed engineering that goes into all aspects of the vehicle.

Completing the engineering display was the Powertrain team. It had a test car, just back from high-speed testing in southern Europe the night before, displaying the instrumentation used to gather data during their work, as well as a complete V6 engine on display and another running on a dynamometer in the test cells.

The complex array of engineering, typically unseen by the outside world, fascinated all who took the tour, but ultimately it was only the intriguing prelude to the car itself. In the fitting conclusion, the Lotus Evora shone on the final podium showing that the engineering excellence of the Project Eagle story that preceded it underpins a stunning new car.

**Source:** Rob Savin, Product Strategy, Lotus Engineering

# Driving dynamics for energy-efficient vehicles

## A review of the IMechE seminar organised in conjunction with Lotus Engineering

“We are entering a new era of eco-austerity.” That was the assessment of Dr Peter Wells of the Centre for Automotive Industry Research in his keynote address at the third IMechE seminar organised, in association with Lotus Engineering. This year’s subject was ‘Driving dynamics for energy-efficient vehicles’, which brought together speakers and delegates from as far and wide as Japan, the US and Germany.

Wells described how we are at a shift point. Up until now, we have been able to afford to deal with environmental issues; however, the economic situation is worsening but the environmental issues do not go away. In discussing future regulations and economics, he suggested that China will not be affected by impending global recession, perhaps experiencing a reduction in growth rate from 7% to 5%, but that we are now at the end of the “American Century”.

He put forward the idea that there would be no universal green technology solution. Instead there will be multiple solutions for multiple places and needs and we may experience a bifurcated market where there is a growing elite segment, with a desire for performance and exclusivity, and importantly a value segment where purchase and running costs and environmental impact will be key.

However, he suggested these times of eco-austerity are good news for engineers whose services and skills will be very much in demand. Driving dynamics are vital in conveying product and brand differentiation while needing to accommodate new technologies for cleaner vehicles by weight reduction and redistribution, regenerative braking and electric drivetrains.

With the scene set, Pim van der Jagt of Ford began the proceedings with his paper ‘Refuelling by brake pedal’. He discussed Ford’s early hybrid projects such as the Escape and the technologies that were employed. These pioneering programmes integrated many novel technologies but the current challenge Ford faces is to understand how more viable solutions can be adapted for the higher volumes and wider vehicle range that now need to be satisfied. He went on to explain the latest Ford research into a more pragmatic approach to braking systems for hybrids through its parallel regenerative braking solutions. He demonstrated that maximising regenerative braking forces and using the friction brake only when additional stopping force is required may require a complex and expensive electronic braking



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The Civic racecar is driven to race events and frequently returns a fuel consumption of 80mpg

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system. Modifications to existing, affordable technology can produce an acceptable system. Importantly, although pedal feel is affected, only a minority of expert drivers actually notice the difference.

Continuing the discussion into regenerative braking, Matthew Hancock and Dariusz Cieslar of Jaguar/Land Rover described the effect of rear wheel regenerative braking on four-wheel drive vehicles. Their research had shown even moderate regenerative braking had severe impacts on the stability of the vehicle and that its ESP system could not compensate. Switching off regeneration when wheel slip was detected severely limited the amount of energy that could be recovered. Instead, however, locking the centre coupling of the drivetrain as a stability control actuator was found to maintain stability without reducing energy recovery.

‘An Insight to the Future’ from Paul Andrews took a look at the history rationale and motivation of Oaktec’s endeavour in hybrid motorsport developments. From the initial forays into Formula 1000 rallying with a Honda Insight hybrid car, Andrew’s took us on the journey from those surprising early successes to the latest activity with a Civic hybrid. Paul extolled the virtue of the CVT for the motorsport application and the modification to the hybrid system to provide maximum assist and maximum regenerative braking make the car race-tuned without detriment to its green credentials – the Civic racecar is driven to race events and frequently returns a fuel consumption of 80mpg.

As an aside, on the very day of the seminar, Lotus and Oaktec announced plans to work together to develop the electrical and control systems for further performance on the hybrid racecar.

The Tesla Roadster is perhaps the first production example of an exciting performance electric car. After discussing the relative merits of a variety of green powertrain technologies from an efficiency standpoint, Brian Randall, Tesla Motor’s Test and Development Manager described the system make-up of the Roadster and explained that battery technology is key. Tesla’s know-how in batteries has produced a battery pack that provides 4 second 0-60mph performance, a range of 230miles and a life of 100,000 miles. Interestingly, Tesla has limited its use of regenerative braking, a theme of the morning session, only to the point where it simulates the engine braking of conventional sports cars. It is important for the market segment, Randall said, that the Roadster exhibits no unfamiliar characteristics to sports car enthusiasts.

Moving on to another form of future propulsion, Intelligent Energy has developed a range of proton exchange membrane fuels cells from 10W

# Driving dynamics for energy-efficient vehicles

“ This is good news for the engineers as the analysis and development of these ideas offers huge scope for keeping us all busy ”

to 75kW. Looking firstly at its demonstrator zero emission delivery van, Ashley Kells described the novel hydrogen storage system that was developed to allow quick refuelling. Interchangeable racks store hydrogen at 70MPa and can be removed and replaced once empty. High pressure gaseous storage, Kells said, overcomes that drawback of cryogenically storing liquid hydrogen and the associated losses of fuel over time. Overall Intelligent Energy's 10kW fuel cell hybrid achieves a range in excess of 300km. The latest stage of its work into fuel cell vehicle is the recently announced collaboration with Lotus on the fuel cell taxi programme.

Matthew Taylor of Prodrive took a more philosophical yet pragmatic look at the role of vehicle dynamics in future vehicles. He argued that vehicles nowadays are much more capable than consumers require – a BMW 5-series being more dynamically capable in every way than a 1972 Ferrari Dino. The challenge for modern chassis engineers is to create brand separation for the manufacturers and brand identification for consumers. As such, it was suggested there is scope for cheaper suspension systems that can still meet

customers' requirements yet save the car makers money. In such a way, the dynamics engineer contributes to tackling the increasing burden of CO<sub>2</sub> dependent fines that legislation is heading towards.

The various roles of computer-aided-engineering analysis techniques were central to papers from Exa Corporation, Yokohama and Lotus Engineering. Edward Lanzilotta of the Exa Corporation presented on the CAE process for optimising driving dynamics and energy efficiency. Concentrating on aerodynamics and their effects on both vehicle stability and energy efficiency through drag, Lanzilotta described some of the latest predictive techniques for analysing both drag and cross-wind stability on vehicles. This work is key to optimising performance and fuel efficiency of all vehicles but even more vital for electric vehicle efficiency.

Another aspect of improving vehicle efficiency, low-rolling resistance tyres offer scope for fuel consumption benefits. However, for the vehicle dynamics engineer it is important that there is no degradation in tyre performance. Masataka Koishi of Yokohama presented a detailed look into the complex analysis and simulation techniques his company is now employing, explaining the concept and benefits of a multi-scale approach. Yokohama's analysis techniques model both the microstructure of the tyre materials and the macro-scale tyre and have been used in the development of its latest Eco Tyres. These tyres can offer the advantages of low rolling resistance with no degradation to good handling or steering performance.

Analysis techniques were used interactively in real time in the final paper of the day, as Lotus Engineering demonstrated the impact of electric hub motors and torque vectoring on vehicle dynamics. Malcolm Burgess and Robin Auckland from the Lotus CAE group presented this session.

Recent dynamics studies by Lotus on a vehicle fitted with hub motors as the drive solution have indicated that there is a need for a significant review of suspension layout to counteract the different ways in which forces are applied at the wheel. Auckland showed how Lotus has added a hub motor model to its SHARK analysis software to support these design studies with some very interesting results. Auckland showed several of the analysed data and also used the software to show how the suspension layout could be optimised to reduce the effect of torque motors.

In the second half of this presentation Burgess presented an interactive session where an electric vehicle was modelled using the latest version of Lotus RAVEN software. The initial model was run and the results displayed with the usual RAVEN real time response. The audience were then asked to suggest control strategies for the



torque vectoring (ie deliberately driving the motors with different torques) with the objective to improve in vehicle 'turn-in' response without compromising the stability or limit handling.

Several options were put forward and Burgess then ran these changes demonstrating the flexibility of the software and the speed at which it could generate time history responses in real time. This clearly showed how several options could be solved in quick succession providing invaluable guidance to the analyst and design team.

Burgess also revealed that this latest level of Raven (which is still at prototype stage) is now capable of running without the need to have ADAMS as the solver.

In summary the day reinforced that there is no such thing as the correct answer to efficient cars and that there were huge numbers of different approaches and options. This is good news for the engineers as the analysis and development of these ideas offers huge scope for keeping us all busy. However time, as always, is the enemy and recent issues around the credit crunch have bought the need for these efficient vehicles into much sharper focus. The day provided an excellent insight into how key engineers and teams at many of the major OEMs are working on all aspects of efficient vehicles and all realise that these solutions need to be in the marketplace sooner rather than later.

Source: Peter Morgan, Marketing Manager, Lotus Engineering

Institution of Mechanical Engineers  
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# Q&A with Bob Lee

## Chrysler's powertrain head

“ What should be the golden era for powertrain engineers with all of the technical challenges in front of us has instead turned into a kind of 1929 ”

**Chrysler has developed a number of significant partnerships in the area of powertrain. They can help to buffer risk and ensure maximum technology coverage to underpin competitiveness. Bob Lee, Chrysler's VP for Powertrain Product Engineering, tells just-auto editor Dave Leggett how that works and also considers the challenges ahead for both Chrysler and the auto industry generally.**

**DL: What do you see as the main challenges for automakers generally in the powertrain area?**

**BL:** Many challenges have hit at the same time. We are faced with the regulatory environments for emissions and fuel economy across the world in places where we sell our vehicles. Another thing which has received a lot of attention lately is what's going on in financial markets and how that has spread around the world.

So, there's a combination of all the new regulations – particularly related to fuel economy, which require a lot of work and a lot of investment – and then the whammy that comes with the market condition where customers want to buy vehicles but they can't necessarily get financing for them. This translates into a cash-flow problem for us...

What should be the golden era for powertrain engineers with all of the technical challenges in front of us has instead turned into a kind of 1929. It's an interesting collision of events.

What does this mean for powertrain specifically? It means we must be very judicious about the things we work on. We must scan the horizon and select the things we think are most appropriate and then if the risks or capabilities are still not quite where they need to be, we need to partner up with those who have similar interests. That's how we are buffering the risks and trying to ride out this unprecedented collision of forces.

**DL: And how do you feel about how things are going for Chrysler right now?**

**BL:** The overall situation is actually pretty good. It's not great, because people could be buying more cars, obviously, but we've got a really strong leadership team here and an excellent plan for the future. We also have Cerberus as a parent. They have some incredibly bright people and a wonderful way of doing business. That's a kind of hidden thing that not many people realise.



We've got guys who are new to us – like Bob Nardelli and Jim Press – that bring tremendous insights. Mr. Nardelli can open his Rolodex and, it seems like literally, call anybody in the world. When we're talking about doing business deals and we're trying to do things. It's just a different era for us to be able to have that much access and that much insight into what's going on in the world.

**DL: Can you cite an example of how the new ownership and management works differently in practice?**

**BL:** Yes, we were in a planning session talking about various controls systems and software and Bob Nardelli said that he used to run a business that was in that field and suggested we call up so and so. It turns out this guy runs a business that does the control systems for gas turbines and power plants around the world. So the software he was talking about was controlling these things in huge facilities – we're talking about thousands and thousands of lines of code. The applications are very different, of course, but it was interesting how many things we had in common in terms of issues and opportunities. Some of these we have subsequently worked together on.

That's just one example of how something which would never have found its way into Chrysler before did. It all turned out to be about software and controls, experienced people and computer simulations.

It's a way of opening doors that we weren't so familiar with in the past.

**DL: What about the general perception that some people have that Chrysler has not at times built cars to a very high quality? What is Chrysler doing to improve quality?**

**BL:** I think this is a two-element question; one is about quality and delivering to market requirements and the other is specifying those requirements.

To take the quality issue, the data that we have for process control and the ability to do the same things over and over again at our plants are very good. We have improved tremendously over the last ten years and are in the same zone as the best.

Where we have had the 'mis-step' that the press has talked about and, frankly, customers have too, is in specifying the requirements.

We went through some phases a few years ago where we got pretty excited about taking cost out of our products and being able to generate returns for the company by doing that. We did this for many

# Q&A with Bob Lee

## Chrysler's powertrain head

“ It's a very credible vehicle – a really strong competitor to an M-Class, very competitively priced versus an M-Class ”

years in a very systematic and structured way and did it in a way that customers were not offended.

But if you do this to excess, you end up losing touch with where you might need to be. These are leadership and policy decisions as the requirements are set. We misjudged where the market would be, particularly in interiors where the market moved very quickly to a greatly upscaled level.

If you look at our new 2009 Dodge Ram you'll see a very fine example of hitting the market requirements correctly. I'll say the quality was always there in terms of process repeatability. So now we've targeted that market requirement factor and you can see that in the new Ram.

I think there's good recognition and a good action plan that has been put in place. It's just a matter now of showing what we can do – like with the pickup – and getting the flow through of the right kinds of products as quickly as possible.

**DL: How do you reconcile cost pressures with increasing demands for better-engineered vehicles from customers?**

**BL:** This is the challenge of our business. I don't think it's a secret; it is difficult, especially in these times. We work on efficiencies in process and also work to disciplined cost targets. Efficiencies include organisation and knowledge systems, using more simulation than test properties and employing new tools like design for six sigma, etc. There's no silver bullet, we must push them all constantly, every day and run the business.

Relative to designing to targets, we target what the products must do and we target the costs it must have. We design and engineer to those targets based on customer inputs and if we can't meet the right ratios, we drop the product and move on.

**DL: What's the basis of Chrysler's powertrain strategy?**

**BL:** There are two parts to this: First of all, our basic approach is total vehicle system. I know you said powertrain, but the energy demand of the vehicle is incredibly important. For me to do a good powertrain, it must be precisely matched to the losses and efficiencies of the vehicle.

We use a 'whole house' analogy at Chrysler. If you think of a house and you want a cost effective and energy-efficient solution, you could go out and buy a new furnace. However, if you have cracks in your windows or doors that don't seal well, that newer furnace may be more efficient but you are still not going to get the best overall cost-efficient trade-off. It's very important to look at the entire machine efficiency and make the powertrain match that machine as an integral piece.

So that's one part.

The second part is our emphasis on controls integration and the integration of the powertrain into the programme with software and controls. We do all of our controls ourselves with the exception of purchased powertrain elements such as diesel engines. That means engine and transmission and all interfaces on the vehicle. We think that's a strategic capability that we have and we are going to continue to exploit that as we move forward with new technologies.

**DL: And there's an element of strategic partnering too – I'm thinking about diesel engines in particular?**

**BL:** Yes, we partner to optimise investment and to buffer risk. Another good example in addition to diesel engines is the hybrid-electric programme, we're doing with GM, BMW and Mercedes.

**DL: How do you see prospects for diesels in the US light vehicle market?**

**BL:** I was on record several years ago as being pretty bullish on diesel prospects in the US – I think I said diesels could take 10-15% of the US market by the 2012 timeframe.

I believed that then, but I didn't anticipate an inversion of the fuel costs here. A situation where diesel fuel in the US, which used to be US\$0.12, US\$0.20, US\$0.40 a gallon cheaper than gasoline is now anywhere from US\$0.20 to, in some cases, US\$0.80 a gallon more expensive. Unfortunately, this has really changed things.

We did an experiment a few years ago where the Liberty (known as Cherokee in Europe) was fitted with a diesel for the US market. It did extremely well – we sold more than we had projected. So we hurried about and did a nicer vehicle – a Grand Cherokee – and put that in the US market in '07 and a half, and sales have not met our expectations.



# Q&A with Bob Lee

## Chrysler's powertrain head

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We're on our way and we strongly believe in technology as a part of the total solution

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It's a very credible vehicle – a really strong competitor to an M-Class, very competitively priced versus an M-Class, and even the same engine. The vehicle's overall refinement has won all kinds of praise from the press, but the sales are just disappointing.

The combination of the fuel price and whatever else is going on has really led us to wonder what will happen. I'm told VW is bringing their new diesel vehicles to market here soon and we'll eagerly watch how the market reacts.

But my 10-15% penetration of a few years ago...I'm probably off base by a factor of two.

**DL: More like 5% diesel share then?**

**BL:** 5-6% maybe.

**DL: What do you see as the main pros and cons in working with so many external partners?**

**BL:** The advantages with multiple partners are easy. There's a geographic dispersion of input and experience and we also get an ability to share processes and technology. We get a good understanding of what's going on in the world with multiple partners

What's the problem with that? There can be problems with distributed resources and straining to do things efficiently because not every partner is doing things the same way. We may have two different engines that are calibrated very differently because they come from two different organisations. Things like the electrical interfaces can become more difficult as a result.

So we try to minimise the number of partners yet cover the range of technologies we need in order to be as competitive as we can.

**DL: How important are dual-clutch transmissions and how are Chrysler's DCT plans progressing?**

**BL:** We've identified through our 'whole house' or whole system approach to fuel economy optimisation, that one of the biggest energy parasitic losses is the transmission. Some transmissions are better than others, but in general DCTs are significantly more efficient than step-ratio transmissions.

With a DCT, the first thing we do is eliminate the torque converter and that in itself takes out quite a few percentage points of inefficiency. Then the hydraulics of the internal clutches are eliminated and hence there is a much lower energy demand.

We think DCTs are good. We see typical benefits of 6%-8%. In some cases we see significantly more than that. We have our first DCT in production in Europe on a diesel Sebring vehicle.

We're on our way and we strongly believe in technology as a part of the total solution.

**DL: And that's proprietary Chrysler technology?**

**BL:** Well, yes and no. We actually designed the DCTs ourselves and then we figured out the best business case and trade-offs on the volumes. As a result, we have entered into an arrangement with Getrag and they're building a facility here in the US to produce the DCTs for us.

**DL: Moving on to hybrids, how is the collaboration with GM, BMW and Mercedes going and how fast do you see this hybrid area developing for Chrysler?**

**BL:** Firstly, the collaboration has been the best collaboration I have ever been involved with. I've been around a number of these things in the past and I thought that a three-way (which turned out eventually to be a four-way with the split between Mercedes and ourselves) might present some difficult issues. Much to my surprise, it has worked out very well.

There have been a few bumps in the road of course, but I think Tom Stephens at GM summed it up pretty well when he said that when you visit the Hybrid Development Center you can't tell who is a Mercedes person, or Chrysler, or BMW or GM. They're just all working together. Of course there are boundaries on what information gets shared or stored where, but everybody sits together and works together and it's turned out to be a huge benefit for all of the participants.

As far as hybrids for us are concerned, we started production recently on the Aspen/Durango hybrids with the technology that stems from the cooperation. GM was first to launch in its vehicles, we're next, followed by Mercedes and BMW, in terms of the rollout of the various applications. We're working on other applications, but I'm not at liberty to share these future plans at this time.

**DL: Do you see a 'family' of different-sized hybrid solutions for Chrysler applications?**

**BL:** The cooperation is for three different hybrid machines.

The first one is for trucks. Then there's one for front-wheel drive applications and then a luxury rear-wheel drive version.



We haven't announced when we are going to rollout the usage of any of the others, but we didn't get into the hybrid business for one vehicle application.

**DL: What's your feeling on bioethanol and US market prospects in particular?**

**BL:** Now that's a hard question.

There are a number of studies and a huge range of opinions on this. There are people who think this is influencing food prices, there are people who think the total energy balance from plant-to-wheels is not favourable and there are also a group of people who are quite concerned that the plant species being used to generate some of the material for biomass ethanol are actually invasive and could escape into general vegetation with rather harmful consequences. I think there is some validity to all of these views.

On the flipside is the political environment. The Detroit Big Three have agreed to make half of our fleets E85 capable in the medium-term and the pressure is on because there is a government mandate for a certain quantity of ethanol to be produced and used every year.

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I think the technology is good and we know how to do range-extended vehicles as well as pure plug-ins

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We have E85 capable vehicles, but there are not many filling stations that have the fuel available and there are price support issues, too.

We're doing our part to make the vehicles available, but I honestly do not know where the market is going to go.

**DL: What about electric vehicles besides hybrids?**

**BL:** We showed some concepts from our ENVI group at the last Detroit Show and there's work going on behind the scenes taking that work further.

The good news, much to my surprise, is there is actually capacity in the US to charge vehicles overnight without really affecting the grid appreciably - provided everyone doesn't charge their batteries at exactly the same time.

I think the technology is good and we know how to do range-extended vehicles as well as pure plug-ins.

But, while there has been progress in batteries, they still cost a lot and there are issues with infrastructure and producing them in quantity. Also, ultimately there are still some unanswered questions with the business model for things like disposal, leasing them, reselling, etc.

We're certainly not slowing down in this area though. GM's making a lot of noise with its Volt but we think we have products coming which will be very competitive also.

**DL: You're going down the range-extended route?**

**BL:** There are certainly benefits with that approach. We know that duty cycles are incredibly important to what we give the customer. The customer doesn't want to be stuck with the wrong vehicle for his particular duty cycle. There's clearly a lot of work still to be done on range, for example in cold weather operations. We're going through those trade-offs now.

There's no doubt we're going to see electric vehicles in the Chrysler family and maybe sooner than many expect.

**Source:** just-auto editorial



**Bob E Lee Vice President** - Powertrain Product Team, Chrysler LLC

Bob Lee was appointed Vice-President – Powertrain Product Engineering Team on 1 January 2004. Lee is responsible for directing the design, development and release of all powertrain systems and components for Chrysler products. This position reports to Frank Klegon, Executive Vice-President – Product Development.

Lee joined the company in 1978 as an engineer-in-training in the Chrysler Institute of Engineering programme and has since held a variety of positions of responsibility in various areas of Powertrain Engineering.

Recent accomplishments include leading the all new 3.7L, 4.7L and 5.7L HEMI engine programme.

Lee was born 17 January 1956, in Chillicothe, Ohio.

Major elements of his professional and academic background include:

- Vice-President – Powertrain Product Engineering, 2004
- Director – Powertrain Systems & Controls, 2003
- Director – Rear Wheel Drive Engine Engineering, 1999
- Executive Engineer – RWD V-Engine Engineering, 1997
- Senior Manager – Jeep and Truck Base Engine Engineering, 1993
- Supervisor – Advance Engine Systems Development, 1987
- Senior Engineer – Engine Performance Development, 1984
- MBA, Michigan State University, 1993
- MSME, University of Michigan, 1980
- BSME, Ohio State University, 1978

# Lotus Evora design story

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The brief we were given by the Lotus Board was simply to design a stunning 2+2 mid-engine sports car

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Evora, designed in-house by Lotus Design, is our first all-new Lotus since the iconic Elise and represents the first stage of an exciting three-car model line up on which we are hard at work.

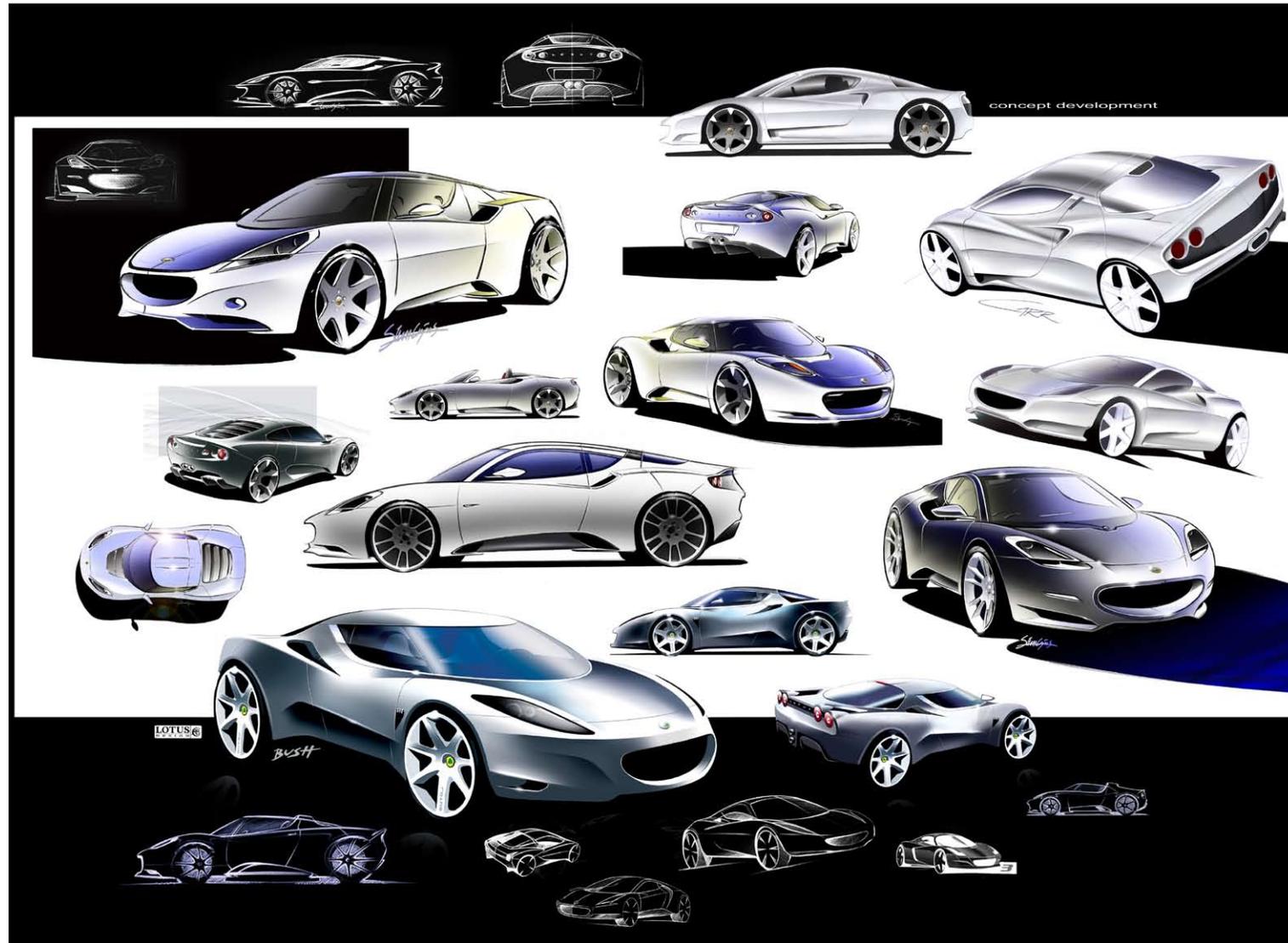
The bold decision to create a unique 2+2 mid-engine layout was all part of our strategy to broaden the Lotus customer base by offering a vehicle that offers greater everyday usability and cabin accessibility without compromising looks or driving experience. However, we are not about to abandon Lotus' unique performance through light-weight philosophy and will continue to develop the Elise-based product lines (Exige and 2-Eleven) for those customers who demand the purest driving experience. Whereas Elise was originally conceived as a track car for the road, Evora is perceived as a road car for the track.

The brief we were given by the Lotus Board was simply to design a stunning 2+2 mid-engine sports car which also offered the everyday usability demanded by modern customers.

We knew that we had to move the game on and create a progressive and dynamic design statement that also retained strong Lotus DNA. Although aggressive aerodynamic and packaging criteria dictated that the form would have to complement the function, we never lost sight of the fact that sports cars are, above all, emotional purchases that seduce the customer through beautiful design. Therefore we ensured that the 2+2 capability became a hidden bonus rather than the dominant feature of the design. It was also important to consider the longevity of the production life and avoid fashionable themes in favour of designs that were contemporary with a classical twist.

## Exterior

We kicked off the programme in the autumn of 2006 with a plan to start production in January 2009. A three-week exterior sketch programme, involving all the design team, was concluded by the selection of the three designs from Anthony Bushell, Steven Crijns and myself. These themes were then developed into 1/3 scale models for review in December 2006. During this phase, the studio worked closely with the vehicle architect, Richard Rackham, and the packaging group to optimise the proportions around this tight package and challenging 2+2 layout.



# Lotus Evora design story

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Although we don't have a rigid corporate design language there are some common visual philosophies which guided the early designs

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Although we don't have a rigid corporate design language there are some common visual philosophies which guided the early designs. Firstly, the design should reflect the unique driving experience of our cars, and therefore it needs to be athletic, agile and sleek. Secondly, we like where appropriate to make a feature of functional details. Thirdly, and most obviously, we have a distinctive front intake, the 'Lotus Mouth', which has evolved from the simple elliptical device applied to our road and race cars of the 1950s.

Unsurprisingly then, the three themes clearly showed some consistent design ideas but were subtly differentiated by surface language and window graphics. The themes convey agility through a strong stance which is created by the short rear overhang and 'cut away' sill that push the large (larger than the front), rear wheels to the extremities of the body. Athleticism comes from the taut body that wraps tightly

over the package and the strong 'Coke bottle' form that highlights the muscle of the rear fender. Sleekness is communicated by the fast, visor screen graphic that sweeps around the tear-drop cabin and by the fluid surfaces that draw the eye effortlessly over the length of the car.

The ingenious treatment of aerodynamic criteria such as the downforce generating, top exit radiator vent, diffuser and rear wing clearly demonstrate the integration of form and function. Elsewhere intakes, such as the shoulder scoops have been located in the optimised position. However, form and function is also evident in the distinctive, cutaway sill that not only improves stance by removing visual weight from the bodyside but also improves ingress and egress.

The scale model from Steve Crijns was selected in December 2006 for development as fully feasible full-size clay which achieved sign-off in early August 2007. Everyone is very proud of the whole design but I think the greatest success is the way in which we were able to work with the proportions of a 2+2 layout. We had to play a few tricks to disguise the length of the wheelbase (the kicked shoulder line and sill cut) and the height of the cabin (the 'crossover graphic' between the side glass and rear screen) but they have, ironically, become some of the car's signature features.

## Interior Design

In order to be instantly recognisable as a Lotus, the Evora's interior had to be sporty, pure and driver-focused. However, within this market segment, the race car inspired technical minimalism of the Elise and

# Lotus Evora design story

Exige was inappropriate. The cabin had to feel more luxurious, special and surprising. We have played on our skills as a low-volume manufacturer by using soft hand-stitched leather trimmed surfaces but juxtaposed them against precision-engineered metal inserts to give a contemporary but classical, British hand-crafted ambience.

Tactile quality is incredibly important within this segment and so we wanted the interior to use honest premium materials. Much of the switchgear is bespoke, and every component that looks as though it is made from metal genuinely is made from metal. High-quality features abound such as the flush-mounted metal momentary switches that sit within the metal panels. They feel special to use and their edge-lit design is reminiscent of a high-end hi-fi

The fluid surfaces and crisp feature lines of the interior perfectly harmonise with the forms of the exterior design. From the outset the team wanted to create a cockpit-like environment that would connect the occupants with the driving experience. To achieve this, careful attention was paid to both layout and form. Inspired by the dramatic sweep of the visor screen, the interior surfaces, which are highlighted by a contrast band of colour, wrap seamlessly around the cabin and cosset the passengers. The flat-bottomed steering wheel, figure-hugging sports seats, contemporary instrumentation and ergonomically-positioned controls provide an intuitive connection between driver and car, ensuring that it becomes a natural extension of their body.

Prior to the London launch, I was frequently asked whether I was nervous about the public and press reaction. Designing a new Lotus obviously carries a significant responsibility but I was uncharacteristically confident because I was 100% sure that as a team we had met and exceeded the expectations of the brief.

So far my confidence does not appear to have been misplaced and the car has received generous praise from press, industry and customers. The initial feedback appears to confirm that we have successfully extended our brand beyond the enthusiast market while retaining the DNA to make the car instantly recognisable as a Lotus.

**Source:** Russell Carr, Head of Design, Lotus Engineering



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