



proActive

ISSUE 47 - WINTER 2012

UTURE POWERTRAIN *SIGNIFICANT TECHNOLOGY TRENDS*

HYDROGEN FUEL

AFFORDABLE MANUFACTURE AT POINT OF SALE

NEW LOTUS EXIGE V6 CUP R

NEW TRACK VERSION OF THE EXIGE S



JUST A **TICK**

THE NEW **EVORA SPORTS RACER**

Stunning power and performance. **Tick.**
Motorsport derived design and engineering. **Tick.**
Award winning. **Tick.**
Unique colour scheme and styling. **Tick.**
Fully loaded options. Tick.

EVORA SR 280PS FROM **£57,900**
EVORA S SR 350PS FROM **£65,900**

CONTACT US TO FIND OUT MORE OR TO ARRANGE A TEST DRIVE



Model shown is Evora S Sports Racer with manual transmission at £66,850 on-the-road (OTR price inc. VAT, delivery, 12 months Road Fund Licence and first registration fee). Standard specification includes Tech Pack, Sport Pack, 2+2 seating, Powerfold Mirrors, Reversing Camera and Premium Sport Plus interior trim.



LOTUSCARS.COM

Official fuel consumption, Lotus Evora range in mpg (l/100km): Urban 19.6 - 21.5 (14.4 - 13.2), Extra Urban 37.7 - 42.8 (7.5 - 6.6), Combined 28.7 - 31.4 (9.9 - 9.0). CO₂ emissions: 229 - 210 g/km.



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*GERAINT**CASTLETON-WHITE*

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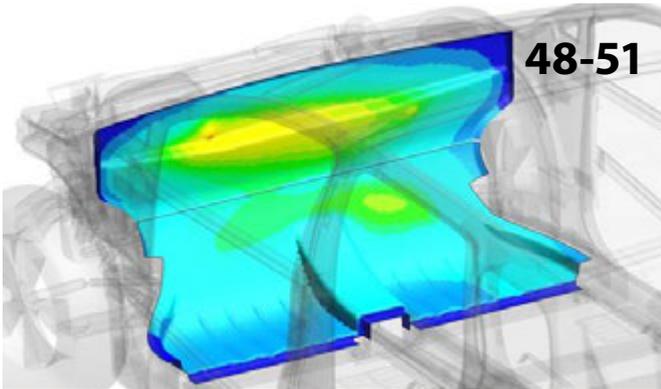
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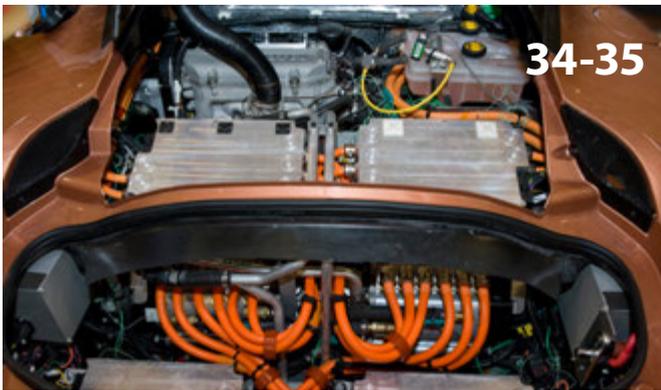
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Determining crashworthiness of a lightweight vehicle



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Future fuel generation by ITM Power



HYBRID TESTING

Use of Lotus EV testing facilities on Evora 414E

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Lotus News



Lotus Evora Sports Racer

The new Evora Sports Racer is a visually enhanced and optimised version of the mid-engined 3.5 litre V6 sports car, available in both naturally-aspirated or supercharged variants. The Sports Racer receives a unique exterior colour scheme with an optimised interior to match, and comes fully loaded, boasting Lotus' ultimate specification. The Sports Racers are more affordable than ever, representing great value.

Aesthetics:

The Evora Sports Racer is available in a choice of four colours: Aspen White, Carbon Grey, Nightfall Blue and Ardent Red.

To stand out from the crowd, the Sports Racer receives unique contrasting accents of gloss black across the roof, front splitter, rear diffuser and side sills, exaggerating the Evora's aggressive stance and sleek silhouette. Further black elements include rear badging, door mirror pods and gloss black forged wheels with a choice of either red or black brake calipers which all work to give the Sports Racer a more dramatic and focused appearance.

Inside, the 2+2 seating option is standard and comes adorned with black leather 'Premium Sports' seats trimmed with red contrast piping and stitching. The dash, doors and centre console receive a liberal dose of Slate Grey SuedeTex™ with red contrast stitching, highlighting the car's sporting character.

Also available is Venom Red leather 'Premium Sports'

seats with black contrast piping and stitching.

All Evora Sport Racer interiors are complemented by gunmetal dashboard panels from the Evora S.

Gadgets:

The Evora Sports Racer comes loaded with optional extras as standard.

The 'Sports Pack' provides switchable sports mode with sharper throttle response, increased rpm limit and sportier setting for Dynamic Performance Management (DPM), sports diffuser and cross-drilled brake discs

The 'Tech Pack' provides upgraded speakers and stereo system, DVD player, 7" WVGA touch screen display, Bluetooth® mobile phone connection, USB connection for various iPod® models, MP3 players and memory sticks, tyre pressure monitoring, cruise control and rear parking sensors. This is topped off with electric power-fold mirrors and a reversing camera as standard.

Price:

Available in the UK and across Europe. Priced in the UK at £57,900* for the Evora with 280 PS or £65,900* for the 350 PS supercharged Evora S.

*Prices shown include local taxes, but exclude OTR costs



Lotus Racing in 2012

2012 has been another successful year for Lotus in Global Motorsport, with black and gold the colours flying high this season.

Lotus achieved its 80th win in Formula One, made a valiant effort in the GP2 championship, scooped the GP3 title, showed our mettle in LMPI, our promise in LMP2, and clearly demonstrated our GT prowess.

Yet that's still not the whole story, we were also a force to be reckoned with in the World Series by Renault, took the German ATS Formel 3 championship by storm plus, more Lotus fans than ever took to the track in the global Lotus Cup series.

Formula One

Formula 1™ has delivered a thrilling season with our team and drivers putting in a fantastic effort from start to finish. Both drivers had their share of podium finishes and fought bravely, earning valuable points for the team. However, it wasn't until Abu Dhabi that Lotus secured its 80th F1™ win. Kimi Räikkönen raged home at the Yas Marina circuit having capitalised on Lewis Hamilton's early retirement in the McLaren and staving off competition from Ferrari's Fernando Alonso who finished behind Kimi in second place. What was Kimi's nineteenth F1 victory, aided the team's ascension and resulted in Lotus F1™ finishing fourth in the Constructors Championship, one place up from the 2011 season. Furthermore, Kimi Räikkönen secured the third spot in the Driver's Championship whilst Romain Grosjean came eighth.



Kimi Räikkönen (top) wins the Abu Dhabi GP, and Romain Grosjean takes second place in Canada (above)



GP2/GP3

The thrills and spills of racing were also clearly demonstrated throughout the season in GP2, where Lotus fought the battle for the title right up to the race finale. Despite a dogged fight and a second finish in Race one for Esteban Gutiérrez, Lotus just missed out on the series title. Never the less, the team came in second overall and Esteban claimed third in the drivers standings with James Calado coming fifth.

In GP3, we followed our own trend with Lotus GP winning the GP3 series title for the third year running. This was confirmed when Daniel Abt took victory in Race one at the season finale at the Monza circuit. Together with Conor Daly's points for fourth place in race one, the team wrapped up the title with a race in hand!

ABOVE: Esteban Gutierrez wins race 2 at Budapest (left) and James Calado wins race 2 at Hockenheim (right)

BELOW: Conor Daly wins race 2 at Barcelona (left), Aaro Vainio wins race 1 in Monaco (middle) and Daniel Abt wins race 1 at Spa (right)





World Series by Renault

The World Series by Renault was another competition where Lotus proved a formidable opponent taking the podium in the third round at Spa, thanks to the skilful driving of Danish driver Marco Sørensen. In fact, he had a

great season and finishing second at the Nürburgring delivered him the rookie classification. With essential points in the bag, Lotus continued to deliver consistent performances both at Silverstone and the Hungaroring rounds.

The team put in a fantastic effort all season, and testimony to their hard work, stamina and tenacity on track, Lotus made a celebrated 5th position overall.



German Formula 3 Series

More celebrations followed in the German F3 series, ATS FORMEL 3 where the up and coming Lotus talent really had something to say. In the first round at Zandvoort Lotus driver Jimmy Ericksson battled hard and took a much deserved win in race one.

Teammate Kimiya Sato followed suit in the third race and romped home for the top spot. Two

victories during the first round was a good portent for the rest of the season.

Both drivers went onto secure wins in the following rounds where some impressive performances led them to outpace their rivals.

The Hockenheim season finale finished in style when Ericksson secured the coveted ATS Formel 3 title.

Jimmy Erickson (left) wins race 1 at Zandvoort and Kimiya Sato at Sachsenring (right)



LMP1

Lotus also showed its stamina in the LMP1 and LMP2 series. For LMP1, Lotus team Rebellion Racing had a phenomenal season, which saw them crowned as 2012 FIA World Endurance Champions, taking home the endurance trophy for private LMP1 teams. It took the 12 hours of Sebring for them to get into their stride and by the 6 hour race at Spa, the second round of the championship, they celebrated first and second place for the privateer teams, coming fifth and sixth

overall in the 24 Heures-du-Mans, the oldest and most prestigious endurance automobile race in the world.

Rebellion rose to the challenge, finishing the highest place petrol car and topping the privateer field.

Overall, they came in fourth place, two places up from last year's ILMH assault. The season continued in a similar vein where successful wheel to wheel battles saw them collect precious points and claim a well deserved title.

LMP2

Lotus LMP2 also made great viewing. This was its first year in endurance racing and the team successfully completed the season delivering a commendable performance. Former F1™ test driver and Lotus works driver James Rossiter joined the team and in the 6 hours of Spa qualified the car a mere 4 hundredths of a second behind the pole sitter, finishing the race in eleventh position. The team went on to take the checkered flag in sixth and eighth place in Brazil and had a good season end in the 6 hours of Shanghai with James Rossiter delivering the best qualifying result of the season. We look forward to seeing the team back in action and aiding their LMP2 offensive for 2013.





GT Racing

Lotus Racing, the motorsport division of Group Lotus really has been in full support mode the year round, aiding competing teams around the world to victory as the demand for Lotus Racing's GT cars grows.

They were on hand when the newly developed Evora GTC raced to triumph in the Britcar MSA British Endurance Champions competition this year. Having secured the class honours in August, the Bullrun Team competed in the final round of the Championship at Donington Park where they were crowned the winners. A world-class result for a great car and team.

Across the pond, another great team Lotus Racing is happy to work

with is Alex Job Racing (AJR) who has been making strides in the American Le Mans Series (ALMS) with the Evora GTE.

Notably, the team came sixth in Virginia, and enjoyed a seventh place finish at Road America in August. Throughout the season the team have developed the Evora, and are excited for next season when they can demonstrate its full capability.

Meanwhile, the Evora GT4, has been out in-force around the world racing successfully in the Brazilian GT, the Iberian Supercar Trophy, Campeonato de España/IBER GT, Campeonato de Portugal GT, the Dutch GT championship and 24-hour races in Dubai, Barcelona and at Silverstone. The Evora GT4

also competed with Lotus Sport UK in the 2012 Avon Tyres British GT Championship. Oulton Park was where it all kicked off earlier in the year, and we started strong with 3 podium finishes from 2 races, proving again just how competitive the Evora is. The second round held in May at the Nurburgring also left the team on a high as after topping times in the free practice, drivers Sailesh Bolisetti and Phil Glew flew home to victory in arguably the most stylish car on the grid! Lotus Sport UK finished in 5th position overall in the championship.

Bullrun team crowned MSA British Endurance Champions 2012 (top), Phil Glew and Sailesh Bolisetti took GT4 Class win at Nurburgring with Lotus Sport UK (left), Townsend Bell and Bill Sweedler with Alex Job Racing's Evora GTE in American Le Mans Series (right)



Lotus opens flagship showroom in Malaysia

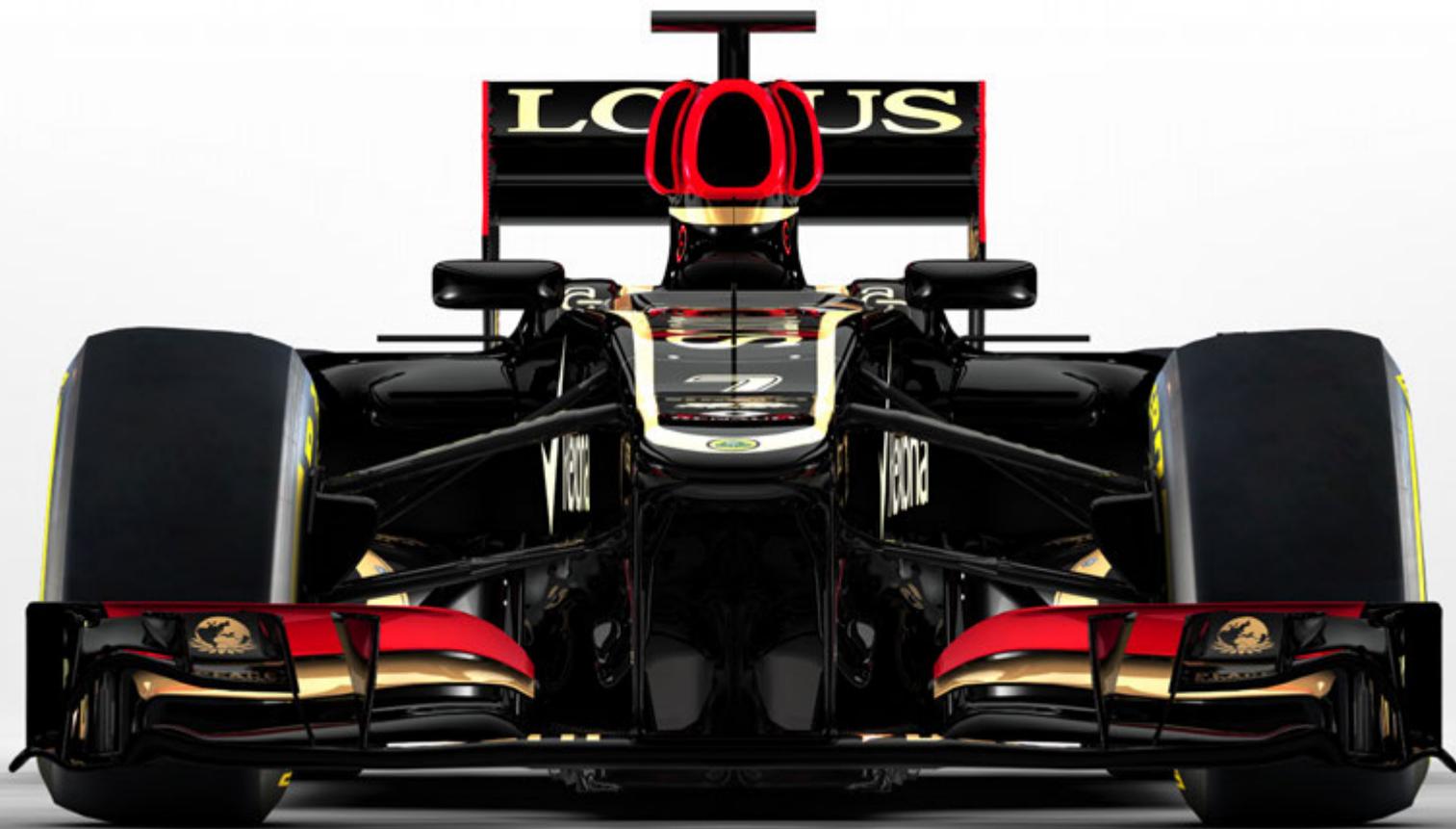
The flagship showroom is built on 10,520 m² of land, and offers a complete Lotus experience with a showroom, customer interactive block and service centre.

Elegant and minimalist, the showroom was designed to convey the heritage of the Lotus brand with retail areas for car accessories, Lotus Originals merchandise, along with an open deck garden and customers lounge.

There are currently 140 Lotus showrooms around the world, but what makes this flagship showroom extra special is the 372 m² customer interactive block, where owners will be able to get together and 'hang out'. This area will also be used to coordinate events such as Lotus convoys, races, and driver trainings.

The opening also marked the official launch of the supercharged Exige S and Elise S into Malaysia and will be sold alongside the award winning Evora S. Already making waves globally, the powerful Exige S was recently awarded the coveted Car of The Year title by EVO magazine, while the Elise S – the latest addition to the Elise range, is perfect for the enthusiast wanting to enjoy the thrill of the ride with even better performance, without compromising on weight. ■





Lotus F1 Team launches its 2013 racecar, the E21

With only limited changes to the technical and sporting regulations from 2012, the E21 continues the design themes seen in its race-winning predecessor, the E20.

However, it is pushing last year's concepts even further as well as incorporating some innovative technical solutions. The new car also features a slightly tweaked livery, incorporating an extra touch of red.

Joining the team as Third Driver is reigning GP2 series champion Davide Valsecchi, whilst Nicolas Prost will perform Development Driver duties. Jérôme D'Ambrosio will continue with the team as Reserve Driver.

Eric Boullier, Team Principal: *"I think it is fair to say that great things are possible from the team and the E21. The leap we made from 2011 to 2012 showed what we are capable of. Add to this the continuity and potential of our driver line-up and we have a very powerful cocktail for the season ahead. Our ambitious plan to turn ourselves into one of the top teams in Formula 1 is coming to fruition and now we need to harness this with strong and regular podium results."*

James Allison, Technical Director: *"The E20 proved itself to be an effective racing car – particularly towards the*

end of last season – so there is an element of expectation from the E21 and plenty to build upon. We have continued with our design themes and tried to create a more efficient and faster racing car based on all the lessons we learnt last year. How successful we have been in this task will only be discovered when we take to the track at the winter tests and – more significantly – at Grands Prix."

Kimi Räikkönen, Race Driver: *"Of course, I've not driven the E21 yet so it's difficult to say what could or could not be possible for the year ahead. We know we had a good car last season, but everyone is working hard to make the best package. I will be working with the team to help get the car as strong as we can, then in Melbourne we'll have our first taste of results. It's a long season from there. 2012 was a good start; let's see what we can do in 2013."*

Romain Grosjean, Race Driver: *"I can clearly say I want to score a lot of points for the team – everybody knows that – but I think it would be wrong for me to say I want to finish in a particular position in the championship. I really want to jump out of the car as many times as possible thinking that I did a good job. Knowing that everything I could do, I did, and feeling proud of my race or session. I hope to feel that way as many times as possible this year."*

Lotus backs innovative college for Norfolk's future engineers

Much of the success of Lotus is thanks to the skills of its workforce, not least the hard work of the engineers who make innovative ideas into reality. Which is why the company is delighted to be involved in training and nurturing the next generation of engineering stars by partnering with the new Norfolk University Technical College (UTC) opening in Norwich in September 2014.

The flagship college, located in a 5,400 square metre former factory, will provide a unique workshop-based education environment designed to develop the next generation of advanced energy and engineering talent.

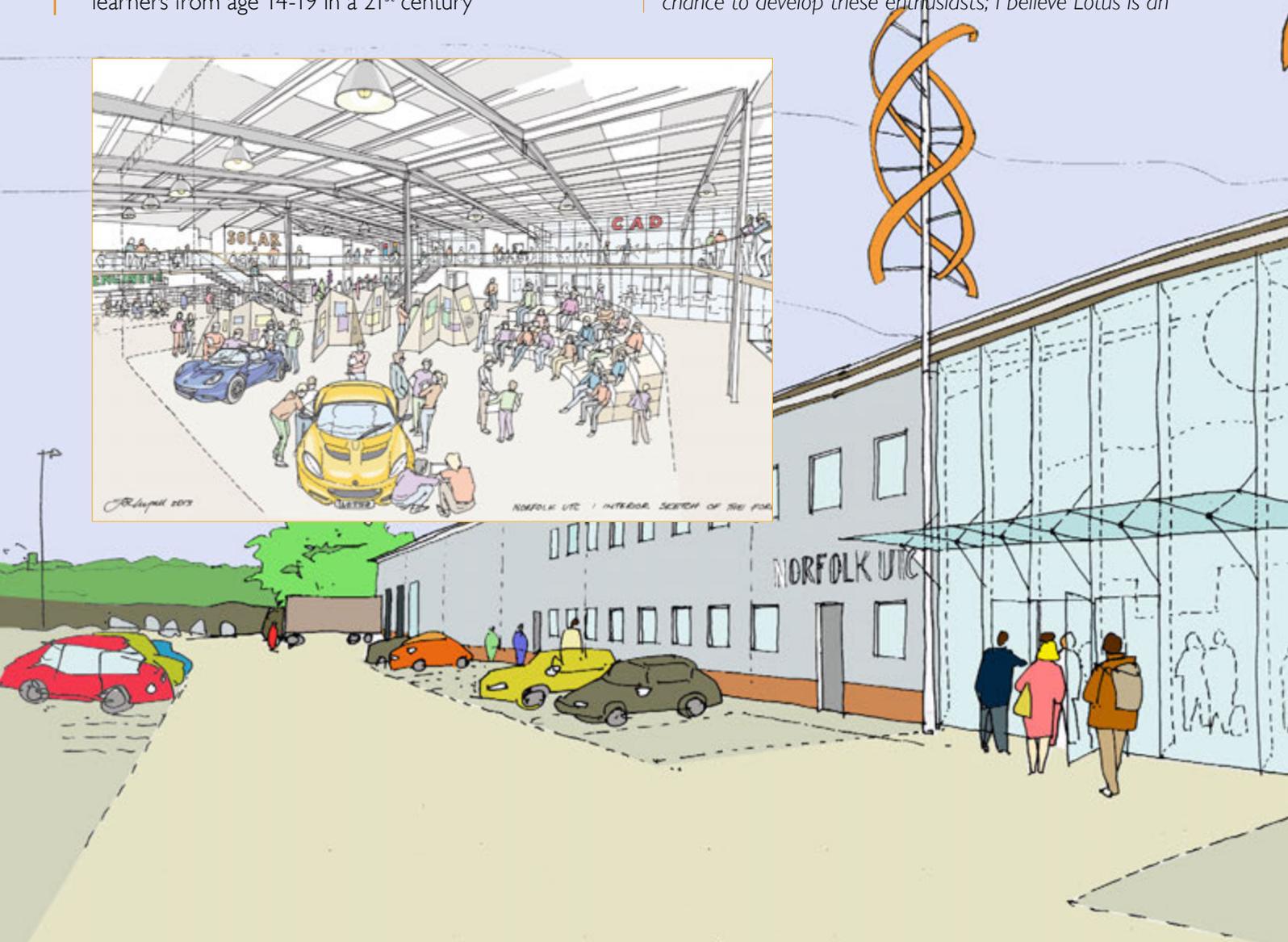
Norfolk UTC will offer a dedicated focus on science, technology, engineering and maths delivered to 600 learners from age 14-19 in a 21st century

work-based environment, and Lotus is one of three major employers in the region to be involved.

The company's support will include shaping the curriculum and teaching methods, providing valuable insight for students into the working world and guidance on careers in automotive and motorsport engineering and the wider industry.

John Vigar, Continuous Improvement Manager at Lotus, is one of five Norfolk UTC board members and will be closely involved in the development and opening of the college.

"This is a unique opportunity to be involved in a brand new way of educating young people who have an interest in developing practical skills for future careers," said John. *"Traditional schooling doesn't always offer the chance to develop these enthusiasts; I believe Lotus is an*



NORFOLK UTC : SKETCH OF NORTHERN ELEVATION

ideal partner for a college which will provide the perfect environment to develop skilled, qualified and work-ready students for the region's industries."

Dick Palmer, the Group Chief Executive Officer of the Transforming Education in Norfolk (TEN) Group, is leading on the creation of the college alongside City College Norwich, the University of East Anglia, in partnership with other leading regional companies Gardline and Future Marine Services.

He said: "Norfolk UTC will give students access to innovative education delivered through what we call 'Technical Challenges'. Students will learn through both academic and practical discovery in a work-based environment to achieve vocational qualifications, as well as GCSE and

A-levels. We want to give our students the choice to move on to Higher Education, Apprenticeships or straight into the world of work. Our students will graduate with the qualifications and practical skills that leading employers in this region have been calling for."

"Half of the space in the college will be given over to a materials, testing and energy area, and non-technical areas will allow students to split their time between R&D and a Design Centre and honing their skills in business development, working with employers and connecting day-to-day learning with the industries they hope to work with in the future."

The Norfolk UTC is set to shake up education in the region and, potentially, find the next designer of an award-winning Lotus car! ■





Industry News

JAPAN: Daimler, Ford and Nissan sign for fuel cell joint venture

Daimler, Ford and Nissan Motor have signed a 'unique' three-way agreement to jointly develop a common fuel cell system "to speed up availability of zero-emission technology and significantly reduce investment costs", the automakers announced on Monday.

They said the collaboration was expected to lead to the launch of the "world's first affordable, mass-market fuel cell electric vehicles as early as 2017".

The unique collaboration across three continents and three companies would help define global specifications and component standards and would, they said, send a "clear signal to suppliers, policymakers and the industry to encourage the further development of hydrogen infrastructure worldwide".

"The goal of the collaboration is to jointly develop a common fuel cell electric vehicle system while reducing investment costs associated with the

engineering of the technology. Each company will invest equally towards the project. The strategy to maximise design commonality, leverage volume and derive efficiencies through economies of scale will help to launch the world's first affordable, mass-market FCEVs as early as 2017," the automakers said in a statement.

Daimler, Ford and Nissan already have over 60 years of cumulative experience developing FCEVs which have logged over 10 million kilometres in test drives around the world in customers' hands and as part of demonstration projects in diverse conditions.

The partners plan to develop a common fuel cell stack and fuel cell system that can be used by each company in the launch of highly differentiated, separately branded FCEVs, which produce no CO₂ emissions while driving.

"Fuel cell electric vehicles are the obvious next step to complement today's battery electric vehicles as

our industry embraces more sustainable transportation," said Nissan Motor EVP Mitsuhiro Yamashita. "We look forward to a future where we can answer many customer needs by adding FCEVs on top of battery EVs within the zero-emission lineup."

"We are convinced that fuel cell vehicles will play a central role for zero-emission mobility in the future. Thanks to the high commitment of all three partners we can put fuel cell e-mobility on a broader basis," said Daimler R&D chief Thomas Weber.

"Working together will significantly help speed this technology to market at a more affordable cost to our customers," said Ford product development head Raj Nair. "We





will all benefit from this relationship as the resulting solution will be better than any one company working alone."

Engineering work on both the fuel cell stack and the fuel cell system will be done jointly by the three companies at several locations around the world. The partners are also studying the joint development of other FCEV components to generate even further synergies. ■

UK: Infiniti's Audi A3 rival to be built at Sunderland



The Sunderland plant in England will no longer manufacture a C-segment hatchback which Nissan had planned to make there in 2014. Instead, the plant will be the sole build location of a new Infiniti model.

Nissan says it will invest a further GBP 250m (USD 405m) at Sunderland towards the costs of adding this additional model. The company claims 1,000 jobs will be created across the UK, of which 280 will be at its factory.

Colin Dodge, Nissan Motor's chief performance officer, stated: *"This milestone, our first premium product to be manufactured at Sunderland, reconfirms our commitment to UK manufacturing and the ongoing success of the plant, which is moving up the value chain."*

"Just as important, the new Infiniti, which will be exported around the world, is being developed with help from our London design centre and our European Technical Centre at Cranfield."

As recently as April, Nissan Europe revealed plans to build 80,000 units a year of an unnamed C-segment model at Sunderland from 2014. That car was thought to be the second generation Tiida, which would have returned Nissan Europe as a mass manufacturer to the Golf segment. Now it seems, that strategy has been abandoned.

The new Infiniti, which Nissan calls an *"all-new premium entry compact"*, is expected to be a rival for the Audi A3 Sportback. The firm is planning annual production of 60,000 units.

The car should be called either 'Q30' or 'Q40'. It will use the Daimler platform that underpins the second generation Mercedes-Benz B-Class, Nissan and Daimler announced at the Frankfurt motor show in September 2011.

By the time the new car comes on line at Sunderland, the plant will also be building the second generation Qashqai, the Leaf, the Juke and the new Note. ■

SOUTH KOREA: Mobis develops 'Intelligent Lighting System'

Mobis says it has succeeded in developing AILS (Active Intelligent Lighting System), Korea's first intelligent lighting system that interacts with navigation to automatically control the lighting system.

AILS receives road information from the navigation, using it to predict the route and thus automatically control the headlights on curved sections/crossroads, without requiring the driver's operation. In other words, the headlamps, which function as the driver's eyes when driving at night, are now capable of reading the road.

AILS minimises lighting dead zones by the prior adjusting of the angle of light to accommodate the direction of driving on curved road sections and also lights an extra lamp on left and right side on crossroads. Plus, it identifies road type and then automatically switches to one of three different lighting modes (general/downtown/highway) to, for example, maximise the visibility range on the left and right side in downtown areas where there is adequate street lighting, while extending the visibility range to the front rather than to the side on the highway.

Through vehicle testing, Mobis has verified that AILS, which took a year and seven months to develop, is able to automatically control the angle of headlight and turn on an extra lamp 40~100m before entering a curved road section/

crossroads and that it thus improves the driver's cognitive ability in terms of the road ahead.

Considering that the driver's visibility when driving at night can be reduced by up to 50% and is heavily dependent on headlights, AILS, which minimises possible lighting dead zones ahead one second in advance, is expected to contribute greatly to accident prevention as it improves the cognitive ability of both drivers and pedestrians at night.

Mobis integrated its proprietary advanced lamp technology that it accumulated through the country's first commercialisation of LED Full AFLS last year (2012) after the commercialisation of HID Full AFLS in 2011 and its genuine navigation technology. The company says that

this integration optimises both the navigation and lighting systems to produce a new convergence technology.

"As the automobile becomes digitalised, the convergence of all kinds of technologies is actively promoted and AILS is a successful example that represents such convergence. We hope to build on the momentum generated by this development of AILS to move forward and lead the market with a variety of new convergence technologies," said vice president Lee Bonghwan, head of Mobis R&D centre.

Meanwhile, Mobis plans to hold a briefing session for domestic and international complete automobile manufacturers and actively promote a sales marketing campaign. ■



FRANCE: PSA employs compressed air for new hybrid solution

PSA Peugeot Citroën has developed what it describes as a revolutionary technology called Hybrid Air, a petrol and compressed air full-hybrid solution.

The basic system comprises a petrol engine, a unit to store energy in the form of compressed air; a hydraulic motor-pump assembly and an automatic transmission working with an epicyclic gear train.

It says the new full-hybrid powertrain technology will be fitted on B-segment models starting in 2016.

PSA maintains that the 'Hybrid Air' hybrid set-up, which combines a petrol engine and compressed air for energy storage, is a key step in the path toward meeting a fuel consumption target for a car of 2 litres per 100 kilometres by 2020.

It says that the major innovation lies in the way the powertrain adapts to driving styles, adjusting independently to one of three modes: air, gasoline or combined. Air power would be employed at low speeds and for urban use, automatically activated below 43 mph.

PSA says that its Air Hybrid system adds about 100 kg to the weight of a traditional ICE powered small car, around half of that of a conventional hybrid system. The company claims there are other advantages over gasoline-electric hybrids, such as no need for a lithium-ion battery with its associated high manufacturing costs as well as a simple design that is easier to maintain over the life of the vehicle.

PSA also claims that the use of this 'breakthrough' technology on petrol and diesel vehicles in the B-, C- and D-segments will reduce CO₂ emissions by 15 g and cut fuel consumption by up to 15%.

The technology has been developed in partnership with the French government and Bosch and Faurecia are also strategic technology partners in the project.

Other manufacturers have investigated the possibility of compressed air to power cars in the past, including Tata, but there are a number of technical challenges to be overcome (air has a low energy density, has to be stored at very high pressure and has to also be heated at the point of use to minimise energy loss) and none have yet made it into series production.





JAPAN: Honda launches micro EV commuter prototype

Honda Motor has unveiled the Micro Commuter prototype, a micro-sized short distance EV commuter. This vehicle was developed in consideration of the vehicle categories for micro-sized mobility products that are currently being discussed under the initiative of the Ministry of Land, Infrastructure, Transport and Tourism in Japan as well as for the regulations for the L7 category in Europe.

Using vehicles based on this prototype model, Honda will begin demonstration testing in Japan in 2013. The demonstration testing will verify the potential of the vehicle in various uses including supporting everyday short-distance transportation for families with small children and for senior citizens, home delivery services, commuting and car sharing.

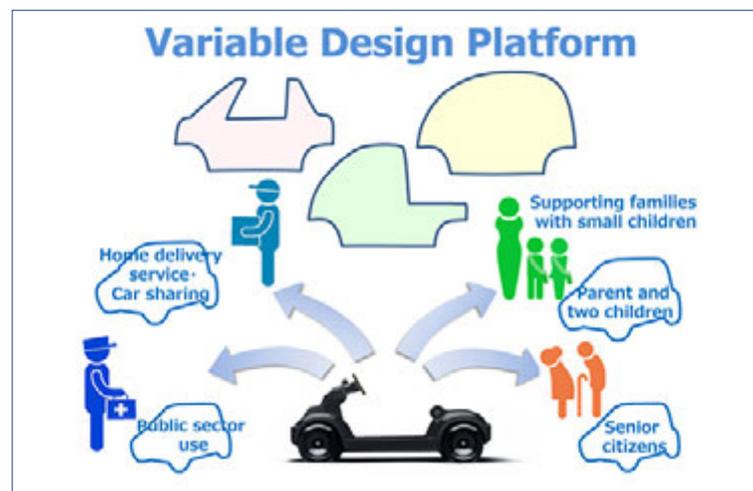
Advancing the Micro Commuter Concept that was first introduced at the Tokyo Motor Show 2011, this prototype model realised a cabin space to seat one driver and two children in the micro-sized body.

The adoption of the variable design platform positions components such as the battery, motor and control unit under the floor and in the rear space to concentrate the vehicle driving functions into a compact space. This made it comparatively easier to develop and produce a body and interior that accommodates various uses and customers' needs than existing vehicles.

Other features of this model include the use of

a user-owned tablet device for the application of functions such as meter display, navigation, audio and back-up camera display, and the ability to charge the battery of the tablet using solar cells mounted on the vehicle roof. Moreover, Honda is continuing research of onboard solar cells to provide solar energy to assist the driving.

Furthermore, through collaboration with the Honda smart home system (HSHS) that has already begun demonstration testing in the city of Saitama in Japan, Honda is planning to verify the CO₂ reduction effect from the optimised energy management in everyday life and the values this vehicle can provide for customers when it is used not only as an EV but also as a household battery.





UK: Jaguar Land Rover announces record sales

Jaguar Land Rover (JLR) announced its best ever global sales performance, with retail sales up 30%. JLR has also confirmed that it will create up to 800 new jobs at its advanced manufacturing facility in Solihull, UK.

In 2012 JLR sold 357,773 vehicles, and were up in every major market due to new model introductions and update programmes.

Land Rover delivered a very strong performance in its 177 markets with retail sales up 36% globally. The brand's top five markets were China, the UK, United States, Russia and Italy which accounted for 65% of sales alone.

A notable product performance was delivered by the Range Rover Evoque with 108,598 vehicles sold in its first full year of sales - more than any other previous Land Rover model. Land Rover has also seen strong performances from its Land Rover Discovery 4/LR4, Range

Rover Sport and has commenced with first deliveries of the all-new Range Rover.

Jaguar's sales for the year were up 6% compared to 2011. The launch of the XF 2.2 Diesel, XF and XJ 3.0 litre powertrains, and the introduction of various new derivatives including the XF Sportbrake, has widened the brand's portfolio and geographic reach. The brand's top five markets were the UK, United States, China, Germany and Russia which combined equated to 71% of sales for the year. The XF continues to do very well with sales globally up 13% and the introduction of the new XJ and XF All Wheel Drive have been well received internationally, particularly in the U.S.

JLR has announced a recruitment campaign for 2013 creating 800 new jobs in the UK to support the

introduction of future model programmes. More than 200 of these roles are supported by the UK Government's Regional Growth Fund.

JLR has also confirmed a GBP 370 million (USD 600 million) investment programme for its Solihull site which includes the installation of a new aluminium body shop for the all-new Range Rover as well as upgrades to paint-applications technologies, trim assembly, warehousing and Jaguar Land Rover's first customer handover centre.



Range Rover Evoque sold 108,598 vehicles in its first year

Future Powertrains

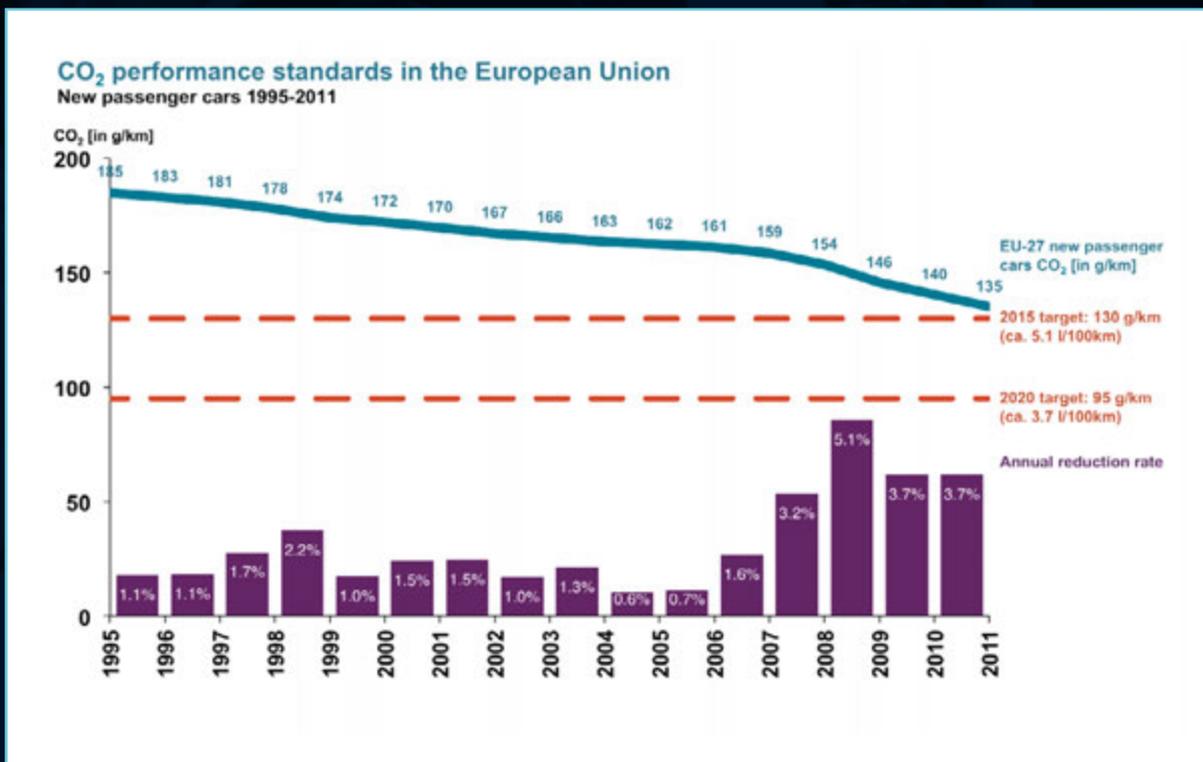
Ian Adcock (just-auto.com)

Reflecting on the Frankfurt and Paris motor shows of 2011 and 2012, respectively, I detected two significant trends that in the future could prove to be seminal in the development of the car in this second decade of the new millennium.

(IMAGE ©Delphi)

Delphi's Stratified Gasoline Direct Injection (GDI) can deliver up to 20 percent CO₂ improvements and even homogenous GDI can deliver 15 percent compared multi-point fuel injection (MPFI).





Left: CO₂ targets in the EU ©ICCT

At a Bosch press conference held somewhere within the vastness of the IAA exhibition site, the company's chairman, Franz Fehrenbach, told the assembled analysts and journalists "...there is no immediate likelihood of electric cars flooding on to the streets," and that in these economically challenging times neither did he expect governments to intervene with fiscal incentives for them, at least, not "until the middle of the next decade."

On a more personal level, during my visit to the Paris Salon last year the only electric vehicles (EVs) I encountered were in the show grounds or exhibited on various stands. I checked with colleagues and not one of us had seen an EV on the streets of Paris.

Whilst these events don't spell the end of the industry's flirtation with EVs it does, I think, have a bearing on the future direction of powertrain developments. Spurred on as it has been by the 2015 regulations, now less than two years away, and, arguably, more significantly by the 95 g/km CO₂ target set for 2020, the industry across the board has been working feverishly to ensure it isn't hit by swingeing fines of EUR 95 for every gram over that target per car sold.

EU targets

A report conducted by the European Federation for Transport and Environment (T&E) says the industry as a whole cut its average CO₂ emissions by three percent in 2011 to an average of 136 g/km, just 6 g/km beyond the 2015 limit.

Some OEMs, Toyota, PSA Peugeot-Citroën and Fiat, hit their targets four years ahead of schedule whilst Mazda with its 12 percent deficit has the farthest gap, claims the group. Assuming this to be the case then 2020's 95 g per km target should be easily attainable, with the European industry in a better position than its Asian rivals.

Based on recent improvements and current positions, the report estimates that the European OEMs only need an annual improvement in fuel efficiency of 3.8 percent to achieve 2020's target, which seems realistic enough given the technological developments we have seen of late and which are in the pipeline.

What might be more difficult to achieve are the proposed fleet averages of 94 mpg for petrol and 108.6 mpg for diesel by 2025 which, in all probability, will involve some form of hybridisation.

Downsizing

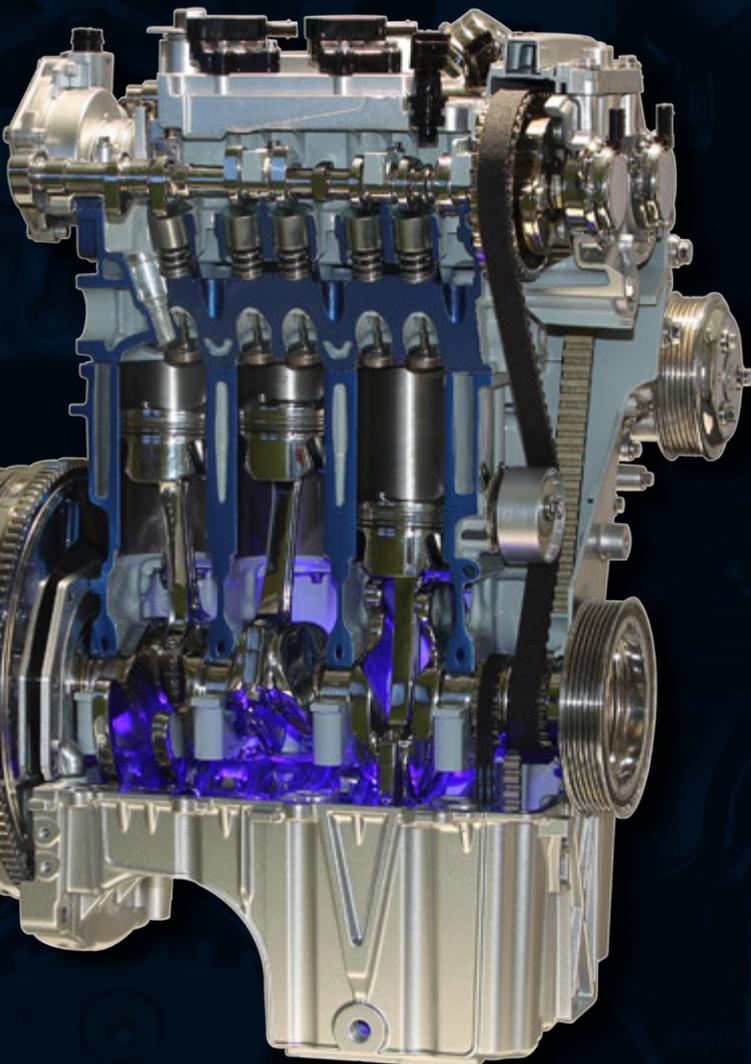
Downsizing is the most obvious route to achieving improved emissions and fuel economy and whilst in the past this resulted in asthmatic performance, the latest smaller capacity engines have power and torque figures that, a decade ago, would have only been feasible in engines twice their capacity. Arguably the most sophisticated of this latest generation of small capacity engines is Ford's one-litre EcoBoost. With a footprint no bigger than a sheet of A4 paper, it produces 100 or 120 PS at 6,000 rpm and an impressive 170 Nm from 1,300 to 4,500 rpm with transient overboost capability of 200 Nm. A key enabler for this performance says powertrain development manager, Andrew Fraser, is its tiny Continental turbocharger which runs at peak speeds of 248,000 rpm and is capable of withstanding temperatures of 1,030 °C.

In what should be an inherently out of balance engine, Ford has adopted the novel approach of carefully unbalancing the front pulley and flywheel to offset most of the shaking forces so it's closer to a five-cylinder, with the rest of the vibrations countered by precisely designed and tuned mounting systems. It's feasible that Ford will stretch the engine to 1.2 litres and 150 PS at some point in the future for applications in larger bodied cars or, simplify the unit to run it as a range extender.

Launched at the last Frankfurt show, this EcoBoost engine was just one example of downsizing, others coming from Kia (diesel) and VW's more conventional three-cylinder for the Up (or up!).

Similarly Volvo is planning a new range of two-litre four-cylinder engines for 2014 to replace its current mix of four, five, six and eight cylinder units. They will be available in a variety of power outputs achieved by employing turbocharging, hybrid drive and even flywheel technology based on Formula One kinetic energy recovery (KERS) system.

But, perhaps, the most dramatic example of downsizing whilst not sacrificing performance came from Audi and Bentley. The VAG siblings revealed a jointly developed four litre twin-turbo V8 featuring cylinder deactivation, a technology that Bentley uses with effect on its 6.75 litre V8, albeit with a central camshaft and pushrods, rather than the new engine's quad-cam layout. With power outputs ranging from 313 kW and 549 Nm in the base Audi application to 373 kW and 660 Nm for Bentley this is hardly a planet saver, even so Bentley's director of powertrain, chassis and motorsport, Brian Gush predicts 40 percent fuel saving over the company's W12.



Left: Ford 1.0 litre EcoBoost engine



Left: Audi 4.0 litre twin turbo V8 features cylinder deactivation

Cylinder deactivation

Although cylinder deactivation is a relatively complex and costly solution, economies of scale within VAG have enabled it to be applied to the group's 1.4 litre TSI four-cylinder engine with the aim of reducing consumption in low and medium load conditions by 0.4 litres per 100 km in the NEDC combined cycle and 0.6 litre when allied to stop-start. Dr Ulrich Hackenburg, Volkswagen's research and development director, is even suggesting it could be installed on the prototype three-cylinder turbodiesel, as seen on the XLI concept, where an electric motor would drive the car up to an engine speed of about 1,400 rpm, thereafter the combustion engine would take over.

Forced induction

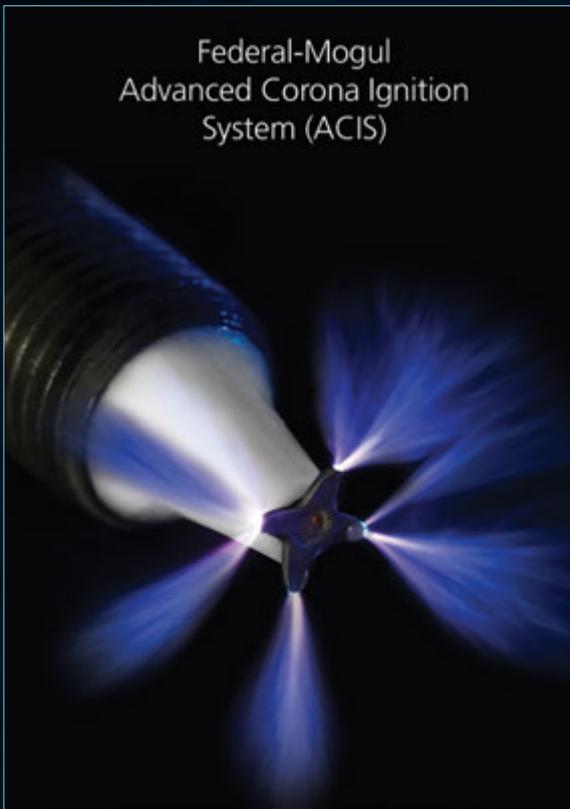
A key enabler to downsizing will be forced induction, either turbocharging or supercharging, especially when the latter is combined with an electrical motor or similar device as seen in the Controlled Power

Technologies system it acquired from Visteon and sold onto Valeo for further development and industrialisation last year.

There are two schools of thought emerging for this solution to downsizing: Valeo has a prototype Renault turbocharged 1.2 pfi running with a 25 percent increase in gear ratios that would normally cripple the car's performance. However, with the electric compressor spooling up from an idle speed of 4,000 rpm – at an engine speed of 800 rpm to 70,000 rpm in a matter of milliseconds (Valeo refuse to declare a time, but Visteon originally claimed it took 0.3 milliseconds to reach 50,000 rpm), turbo lag is eliminated until the engine reaches an operating speed of 1,800 rpm by which time the turbo is fully boosted.

Utilising a separate 48 V system that harvests energy under braking to drive a generator to charge a capacitor ensures the supercharger isn't a drain on the car's 12 V network.

Whereas Audi, which is trialling three electric supercharging systems including Valeo's, is employing it to boost top end and mid-range



performance on its three-litre TDI V6; series production is predicted within the next two to three years timeframe.

The challenge meeting all OEMs is that the big gains have virtually all been realised, it's now about chipping away at the margins to gain an extra percentage point, or fraction thereof, that will steadily accumulate to deliver a meaningful saving.

Ignition systems

Federal Mogul, for instance, has a new take on the humble spark plug that, claims director Kristopher Mixell, allows manufacturers to run higher levels of exhaust gas recirculation (EGR) resulting in up to 10 percent fuel savings. Its Advanced Corona Ignition System (ACIS) features a four-pointed star transmitting a low current 25,000 volt discharge. Running at 1 MHz the high intensity plasma stream excites the air-fuel molecules into combusting whereas a conventional sparkplug relies on ignition.

One of the main challenges going forward to Euro 6 is meeting particulate numbers in gasoline engines which are likely to be the same as for diesels, says Delphi's engineering director Europe, Dr Sebastian Schilling: "Stratified Gasoline Direct Injection (GDI) can deliver up to 20 percent CO₂ improvements and even homogenous GDI can deliver 15 percent improvement compared with multi-point fuel injection (MPFI)."



Left: Managing director of Ford's European Research Centre, Andreas Schamel

The Delphi technology differs in that it runs an outboard opening injector and a solenoid rather than the more costly Piezo system, yet it's still capable of controlling the injector stroke between fully opened and closed.

Schilling believes that stratified GDI will "dominate" in the future "as you can inject the fuel in the same position every time to achieve a really lean mixture and fuel atomisation."

Technical challenges

But downsizing brings its own technical challenges, especially when combined with stop-start. Whilst typical cylinder pressures of 180-190 bar for diesel and 120 bar for petrol, combined with higher engine speeds, aren't in themselves problematical, Federal Mogul's director application engineering bearings, Gerhard Arnold, does see challenges when

the engine is started. As the engine is started there's a high coefficient of friction which changes to mixed lubrication at 100-200 rpm to full hydrodynamic conditions at around 800-900 rpm (the Stribeck curve).

Before the advent of stop-start, explains Arnold, an engine would start "30,000-40,000 [times]", that could now increase more than ten-fold with stop-start to half a million and double that for a full hybrid, he claims.

To cope with this, Federal Mogul has developed a new series of polymer IROX coated bearings that combine a Pal (PolyAmidelmide) overlay that contains a number of additives dispersed through the matrix for wear resistance, mechanical strength etc. but still resulting in a CO₂ saving of 1 or 2 g per km.

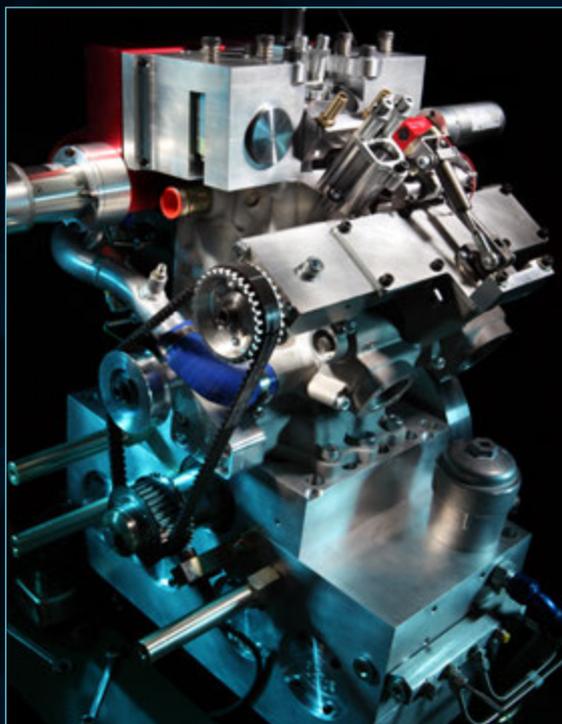
Euro 6 legislation

It's generally agreed that the forthcoming Euro6 legislation will impact on diesel engines and, predicts the managing director of Ford's European Research Centre, Andreas Schamel, shift the balance towards diesels being used more in heavier, commercial vehicles rather than passenger cars – well, at least in their current format.

"Ford is seriously looking at 42 V and 48 V systems for diesels. The attraction being that, we can recoup the energy from braking and use it



Left: Polymer IROX coated bearings by Federal Mogul



Left: Lotus Engineering has researched HCCI combustion and alternative fuels, with research engines like the 2 stroke variable combustion Omnivore engine

to power a 10-15 kW electric motor for low-speed manoeuvres and city driving," says Schamel. The diesel engine would take over for motorway cruising, for instance, where its flatter efficiency map delivers minimum fuel consumption.

Ricardo's chief technical officer, Neville Jackson is in agreement, adding that diesels will almost certainly require closed-loop particulate traps in the exhaust system to meet future demands.

Whilst Professor Hongming Xu, chair of the Energy and Automotive Engineering at Birmingham University considers the benefits of homogenous charge combustion ignition (HCCI) better suited to petrol rather than diesel engines. He goes further, in fact, by suggesting that future generations of 'smart' fuel injectors, somewhat analogous in operation to an ink jet printer, would minutely control the combustion process allowing both port and direct fuel injection that could lead to multi-fuel engines capable of identifying and then running on diesel, petrol, biofuel or some form of fuel property modifier.

Alternative fuels

The possibility of running multi-fuel engines at some point in the future might be Professor Xu's 'dream' but closer to reality is compressed natural gas (CNG) as an alternative to renewables. Toyota showed a new one-litre DI twin cylinder engine at last year's Geneva Salon that could run on CNG and emit only 38 g/

kms whilst Ford's Schamel admits to "Watching the uptake of natural gas...with interest," adding "Because CNG is very knock resistant, you can get to diesel – or better – levels of efficiency." The downside being it's a dry fuel lacking any lubricity which makes it tough on the valve train and other reciprocating engine components.

Nevertheless Audi is committed to launching a TCNG version of its third generation A3 Sportback this year. In the longer term, its joint venture with US start-up, Joule Unlimited expects limited production of synthetic e-ethanol and e-diesel to start in May 2013 and 2014, respectively. By using a combination of sunlight, CO₂ and waste water to feed cyanobacteria to generate continuous streams of ethanol or long-chain alkanes, which are important constituents of diesel, it can then be added to fossil gasoline or as a basis for E10 or E85.

Summary

Clearly the emission targets being set for the industry are going to get ever more stringent. But, with increasingly powerful electronics to monitor and control combustion strategies, new materials and a raft of yet to be fully developed and matured combustion strategies then whatever legislation is laid down before the industry, the probability is that OEMs and suppliers will rise to meet them. ■



Jeremy Deering

New CEO of Torotrak, UK developer of gearless traction drives

Jeremy Deering joined Torotrak in 2006. Prior to being appointed Chief Executive Officer on 31 August 2012, Jeremy was Finance and Commercial Director and played a key role in the Company's licensing agreements and diversification strategy.

What is your background with Torotrak?

I was previously the company's finance and commercial director with responsibility for several significant areas of strategy development. The move follows the departure of Dick Elsy, who has left to take up a new role as the first CEO of the UK's High Value Manufacturing Catapult, a Government supported programme designed to boost the UK's ability to transform engineering innovation into economic value.

Torotrak has been around for over 15 years and started out as a specialist developer of infinitely variable transmissions (IVT). In the period since then what has the company done in terms of developing the business?

Torotrak as a business was floated around 15 years ago. It had developed a new form of gearbox based toroidal technology that was designed to save fuel. At the time there were high expectations for its use in passenger cars and SUVs. However, it was a new technology that was vaguely concept ready but

A change of CEO marks a change in strategy for Torotrak. Vanessa Scholfield, talked to new CEO Jeremy Deering, to understand his plans for the future and how his new strategy, will shape the future direction of the company



somewhat before its time. There was no pressure to save fuel in those days and the vehicle manufacturers were wary of new technology that was unproven. The company struggled to get sufficient interest in the concept and there was little interest in investment in fuel saving technology from the car companies.

What has changed since then for the company?

About 4 to 5 years ago the company got a second lease of life. It started to look at different markets such as commercial vehicles and several new technologies. These included variable superchargers and mechanical hybrid drives. This strategy paid off. The commercial vehicle market is particularly sensitive to fuel costs and any technology that can help save fuel is of interest to fleet and private operators alike. Hence there was a strong interest in our Infinitely Variable Transmissions (IVTs) and we also started a programme with Allison Transmission (Allison) in the US. Allison is the largest Tier 1 supplier of automatic gearboxes to commercial vehicle manufacturers.

At this time we went to shareholders and also approached a major European commercial vehicle manufacturer. Torotrak has completed a substantial test programme with the company that also holds a licence for heavy duty applications. Performance testing in typical long-haul applications proved positive and demonstrated that using our technology fuel savings of 20% are achievable in city buses and distribution trucks. Being able to demonstrate that we can deliver fuel economy gains in European long-haul truck cycles means we have a broader market for our technology which is an important development. This coincided with us reaching a commercial tipping point with Allison.

What is the relationship with Allison today and where will it lead in the future?

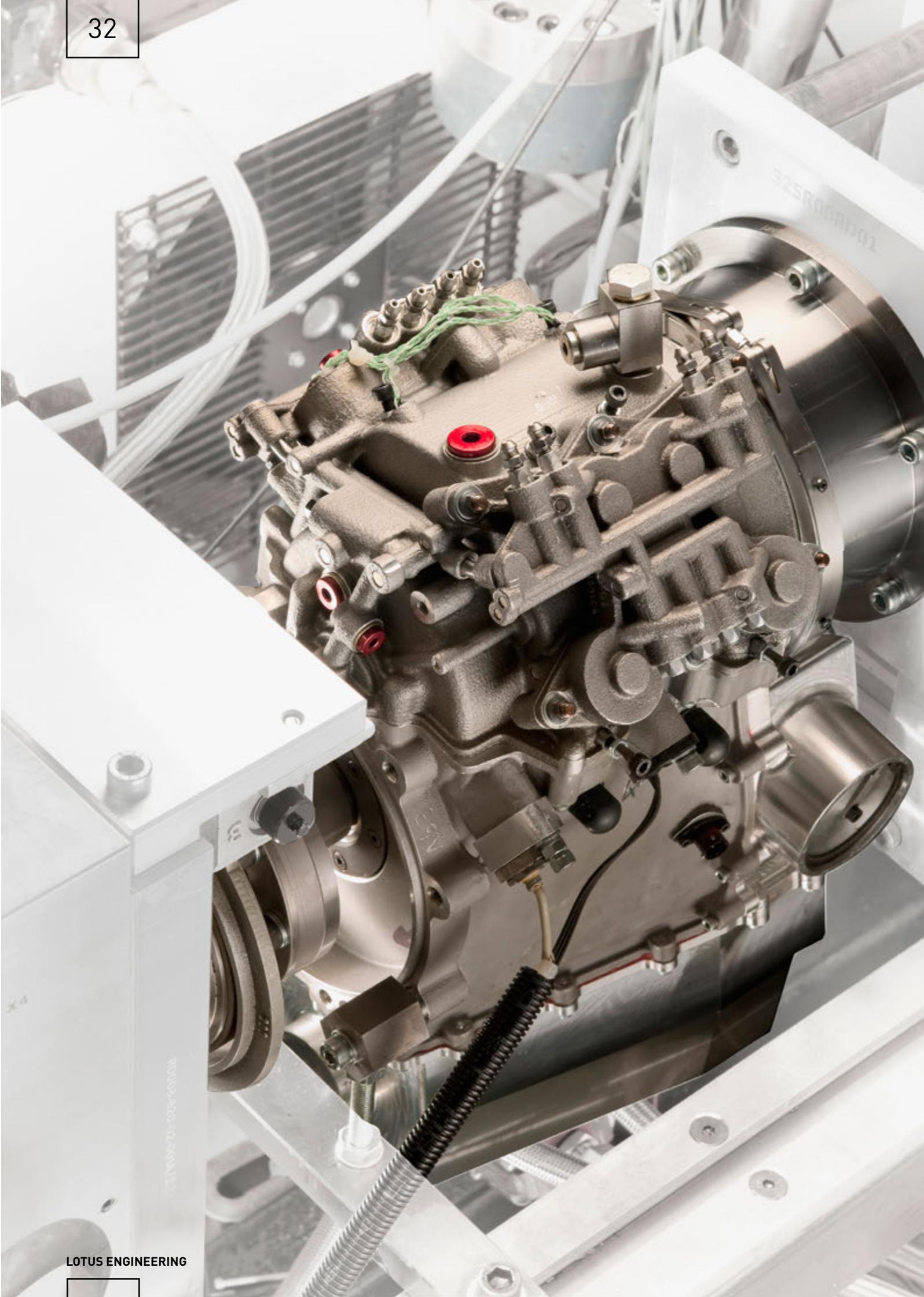
Allison's production-intent programme will receive additional development resources from Torotrak following its payment of GBP 2.5 million as an advance payment against its 2013, GBP 10.6m option to secure final exclusive rights to main drive transmission applications in heavy-duty commercial vehicles. This includes GBP 1.25m for Torotrak specialist engineering support. The new funding will be used to enhance the design and analysis programme currently led from Allison's headquarters in Indianapolis. We have



already undertaken more than 25,000 hours of testing specifically for Allison in the past twelve months. They have paid around GBP 20m over the past few years for exclusivity with regard to our technology. Allison floated in the US this year and is a very growth oriented company.

What other development programmes do you have with partners?

We have completed a preliminary development programme with Ricardo, the UK based consulting engineers, Allison and major bus company Optare in the UK. This programme has confirmed that Mechanical Kinetic Energy Recovery System (M-KERS), using a flywheel controlled by Torotrak's variable drive, can deliver fuel economy and emissions benefits. Testing with first-stage prototypes has allowed Torotrak to independently develop a system specification suitable for fleet trials, which is predicted to deliver a fuel saving of up to 20% for urban buses and trucks. Compared with comparable battery and supercharger hybrid systems, the Torotrak-equipped M-KERS is expected to cost around a fifth the price and to be significantly lighter, allowing for additional passengers or cargo. Legislation is also pushing manufacturers to make savings and will continue to do so for the foreseeable future.



Does M-KERS have an application in passenger cars as well?

Following positive results generated by the Flywheel Hybrid Systems for Performance Vehicles (FHSPV) programme with partners that include Flybrid Automotive, Jaguar, Prodrive and Ford, Torotrak technology was selected for a passenger car M-KERS research programme with Volvo. This programme has progressed well and is moving to prototype vehicle trials.

Furthermore, Torotrak has secured an additional GBP 600,000 payment from Tata Motors to extend its licence to secure options on M-KERS in heavy-duty vehicles and passenger cars and on V-Charge.

Looking ahead how will the Allison relationship continue to benefit Torotrak?

Allison is a shareholder with a 9% stake in Torotrak. However, looking ahead the company will have to pay for continued exclusivity despite being a shareholder. It is an important and very helpful relationship and one that we look forward to developing in the future. Vehicle manufacturers can substitute our product for an existing automatic and benefit on fuel economy and other attractive performance characteristics all for a competitive marginal cost. If Allison does take the final step and bring our transmission to market, we will get a royalty on every transmission produced. This forms one of the major planks of our strategy moving forward and one that helps underpin the company's share price, with the company currently capitalised at around GBP 50m.

Are there any developments of note in other product areas?

We have a joint venture with Rotrex in Denmark. Rotrex makes specialist superchargers for high performance applications. Given the trend towards downsized engines in fleet vehicles and passenger cars, there is a strong need for higher performance, more controllable pressurechargers to provide the required performance and fuel economy. We looked around on the market and could not find a single device that would provide the necessary characteristics – which continue to become more demanding - at a price that

would be attractive for volume applications. By putting our compact variable drive with a compressor we can get to full boost in 0.3 of a second at a price that will be very competitive against alternative solutions such as twin-turbo and turbo-supercharger systems. And because it is on the cold side of the engine, it also helps solve other issues such as back-pressure and keeping the exhaust gasses hot for the aftertreatment. This is an exciting development for us as it opens a new market by solving an increasingly pressing challenge for powertrain engineers.

The product we will bring to market will be outside the JV, which gives us the flexibility to work with Tier 1's and 2's and several are very interested. Discussions show that they are interested not just for applications focussed on affordable emissions reduction, but also for high performance applications. We are going to invest in four demonstrators to show a range of these applications and take the technology to the OEM's and Tier 1's for further trials.

It sounds like you have a pretty full development programme lined up. Can you sum up the major changes that you will oversee now that you are CEO?

Torotrak's central strategy remains to develop and then licence its core technology. To accelerate this process, we will be increasing our ability to manufacture in low volumes, taking away much of the risk and investment for our customers developing and validating products that use our systems. In low volume markets such as off-highway, combining our capability with that of our specialist manufacturing partners now provides a route through to market introduction with higher revenues for Torotrak, bringing benefits to all parties.

We are also going to strengthen our advanced engineering services business, increasing its scale significantly. The time is right to adjust our approach to one of more aggressive, accelerated growth in order to supply products and expertise that capitalise on the substantial opportunities ahead that will allow us to introduce our clean technology into mainstream commercial and passenger vehicles worldwide. ■

IMAGE: Torotrak M-KERS system on test

Hybrid Testing

Lotus testing facilities essential for 414E development

Following the successes of progressively more complex hybrid vehicle projects, including the hydrogen fuel cell taxi, Lotus Engineering's EV test cells satisfied a high demand for the development of the Lotus Evora 414E REEVolution prototype.

Complete testing facility for hybrid systems

Lotus EV test cells played a key part in developing the complex hybrid drive capability, including pairing twin motors to corresponding twin inverters on a common drive to power one of the vehicles rear wheels. This complexity is magnified by a mirrored, synchronised system driving the second rear wheel.

Range extender engine validation

Whilst electrically less complex, the range extender relied on successful development in the high voltage test cell. Using a battery simulator and dynamometer the program coupled the engine with an adaptable control strategy to a generator with a previously unpaired inverter. The test cell answered many questions regarding operating strategy, from mechanical variables associated with the combustion engine (including fueling and timing) to managing the electrical energy generated across the operating range of the engine.

Integration

Integrating the high voltage, high power systems required extensive testing and debugging and the test facility revealed essential changes to hardware and software. This allowed part suppliers to modify

components before they became critical to the success of the project.

A success factor for the off-line testing was that in addition to traditional test cell capabilities the HEV test facility at Lotus Engineering included a high powered battery simulator. Supplied by AVL, the unit is capable of managing 200 kW of power flow up to 600 V, sinking or sourcing 600 A.

As the system has a programmable bi-directional power supply, the simulator emulates automotive energy storage systems, including super capacitors, fuel cells and for this project, the vehicle's high performance battery. Simulating the vehicle battery permitted any operating point to be available for any length of time – there was no down-time due to battery charging cycles. Additionally, the consistency and repeatability of test results was essential and the simulator offered increased safety for prototype development.

Evolving a working system

An objective of the testing program was to develop a control strategy and characterise the electric drivetrain across its entire operating range. Early on in the project test data revealed many technical challenges to overcome.

For example, preliminary testing of the motor and inverter pairing produced unexpected results where approaching peak performance conditions, the inverter failed on over-voltage and over-current faults before reaching operating speed.

Findings from each test were fed back to the inverter supplier

and several revisions of firmware were released and retested, until the traction motor could deliver the speed and torque required to enable the vehicle to achieve its performance targets.

Torque compensation

The electrical drive-train powers the rear wheels independently using dual stage motors. In order for the vehicle to pass stringent safety case criteria it is imperative that the amount of torque being produced at each wheel is accurately predicted and controlled such that cross axle difference does not lead to instability.

The system is controlled via CAN using an interface developed by Lotus and Rinehart that includes monitoring and safety functions

Early test cell validation revealed that whilst the Lotus vehicle dynamics controller requested a specific torque from each stage, the actual torque produced did not match the demanded value.

Typically a look up table embedded in the inverter is sufficient to regulate the torque output but for this high performance vehicle with independently driven wheels a standard open loop control system was insufficient.

In order to satisfy the safety case criteria, Lotus was able to use the test facility to derive an innovative adaptive mathematical function to correct the torque errors in the drive-train, effectively creating a dynamic motor map in the Lotus controller.

Writer: Gary Spinks

Equation accuracy

The EV test cell proved instrumental in developing the control algorithm by replicating a dual stage motor with two inverters, i.e. a single axle of the 414E vehicle installation. Over two hundred measurement points were recorded throughout the motor's torque and speed operating range, yielding an equation that takes into account measured motor variables and accurately predicts the torque produced for a given torque demand.

Testing showed an accuracy to +/- 5 Nm for over 90% of the test points, with more than 98% within +/- 8 Nm.

The vast majority is with +/- 4 Nm, with a few regions slightly outside of that. All the results outside the +/- 4 Nm region occur at higher speeds with higher demands, so the net percentage error is relatively low.

Complete series hybrid testing

With two test cells configured back to back, the driveline from the range extender to traction motor was validated in a controlled environment.

Both stages of the traction motor were connected to two 100 kW inverters and the range extender system in one test cell is electrically coupled to the traction motor load in a nearby test cell. Both test cells are linked to the battery simulator.

In parallel with the test cell development activities, a mathematical model of the vehicle and hybrid drivetrain was constructed. This allowed a virtual development programme to be conducted for proving the

functionality of the drivetrain. Additionally, simulation work with the virtual car made it possible for Lotus Engineering to optimise the vehicles' energy management strategy and compare it to previously simulated software models. The output of the simulation work could be directly copied over to the vehicle controller hardware which meant significantly reduced vehicle development time with improved overall vehicle safety.

Energy management

The vehicle is capable of running multiple NEDC cycles on pure electric from a battery pack that is fully charged (100% SoC). The vehicle has an option during this charge depleting mode such that the range extender can be used to boost acceleration performance upon driver request. After the energy stored in the battery is considered depleted by the vehicle controller the vehicle is switched to charge sustaining mode. The energy management strategy manages power flow from the battery and APU to maintain the battery SoC within a predefined band. To optimise emissions performance and running costs the battery is only permitted to return to its maximum charge level via external charging from the power grid.

As part of the strategy to reduce rapid depletion of the battery during high energy consumption events there are two additional triggers to switch on the range extender irrespective of SoC. The triggers are based on consumption and change of power consumption, if definable values for either are

exceeded the engine is used to generate the rate of power being consumed (subject to max engine power). When the range extender is activated by this part of the strategy, the SoC based power demand correction is disabled and the power demand is purely load following i.e. matching as close as possible the driver demands.

Summary

Using the test cells to support design and build of the 414E allowed the team to identify problems and develop solutions as early as possible in the program. In addition to the areas previously mentioned, looking further into the project would reveal how the test cells were used to also tackle issues with component performance, electromagnetic interference, CAN error frames, software development, engine tuning, thermal management and almost as critically, how Lotus Engineering benefited from the experience and intellectual property generated from creating solutions.

Looking to the future and based on the success of the current HEV test facility, Lotus Engineering is planning to grow its capability with a battery simulator dedicated to supply hybrid and electric vehicles on a rolling road.

Using the knowledge gained and the facilities invested in the programme, the benefits of reduced programme delivery time and cost have been realised and these can be carried forward to future complex hybrid and electric vehicle programmes internally and for third party clients. ■



Hydrogen

The future fuel

Hydrogen is well known for being clean at the point of use as when it is burned it does not release any carbon or greenhouse gases. It is important to also consider the supply chain when assessing its green credentials. The vast majority of today's hydrogen is derived from natural gas via steam reformation before being transported by road and/or sea to where it is needed.

Thankfully, there are other routes to produce hydrogen. The best understood is electrolysis – using electricity to split water into hydrogen and oxygen gases. The attraction of electrolytic hydrogen is owed to the fact that the electricity used to power the process can be derived from renewable sources (such as wind and solar). In addition, the hydrogen can be generated on site where the fuel is needed, avoiding complex and costly supply logistics and the associated carbon footprint. This is the cleanest and greenest form of hydrogen production available.

The HFuel system

ITM Power has developed a hydrogen generation and refuelling platform called HFuel, which offers a sustainable supply of hydrogen for transport vehicles. It is modular, based around water electrolysis, and

integrates all of the equipment necessary to turn electricity and tap water into 350 bar hydrogen and dispense it rapidly into vehicles. As an integrated package, it contains input water purification, AC to DC power conversion, hydrogen generation using PEM (proton exchange membrane) electrolysis, compression, storage and dispensing, together with an overarching control system and backup power provision. The systems are packaged in standard ISO shipping containers for ease of transport and to minimise civil works associated with refuelling station construction.

Hydrogen generation

The hydrogen is generated in electrolyser stacks at up to 80 bar and is accumulated in a buffer store. An electrically driven compressor draws from the buffer store and progressively fills higher pressure storage vessels to levels appropriate for either 350 or 700 bar refuelling. Hydrogen, unlike batteries, enables energy to be transferred into a vehicle in minutes rather than hours.

Crucially, the electrolyser technology is able to start and stop rapidly and as such, can accept an undulating input power profile typical of renewable energy generation.

The economic case

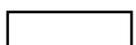
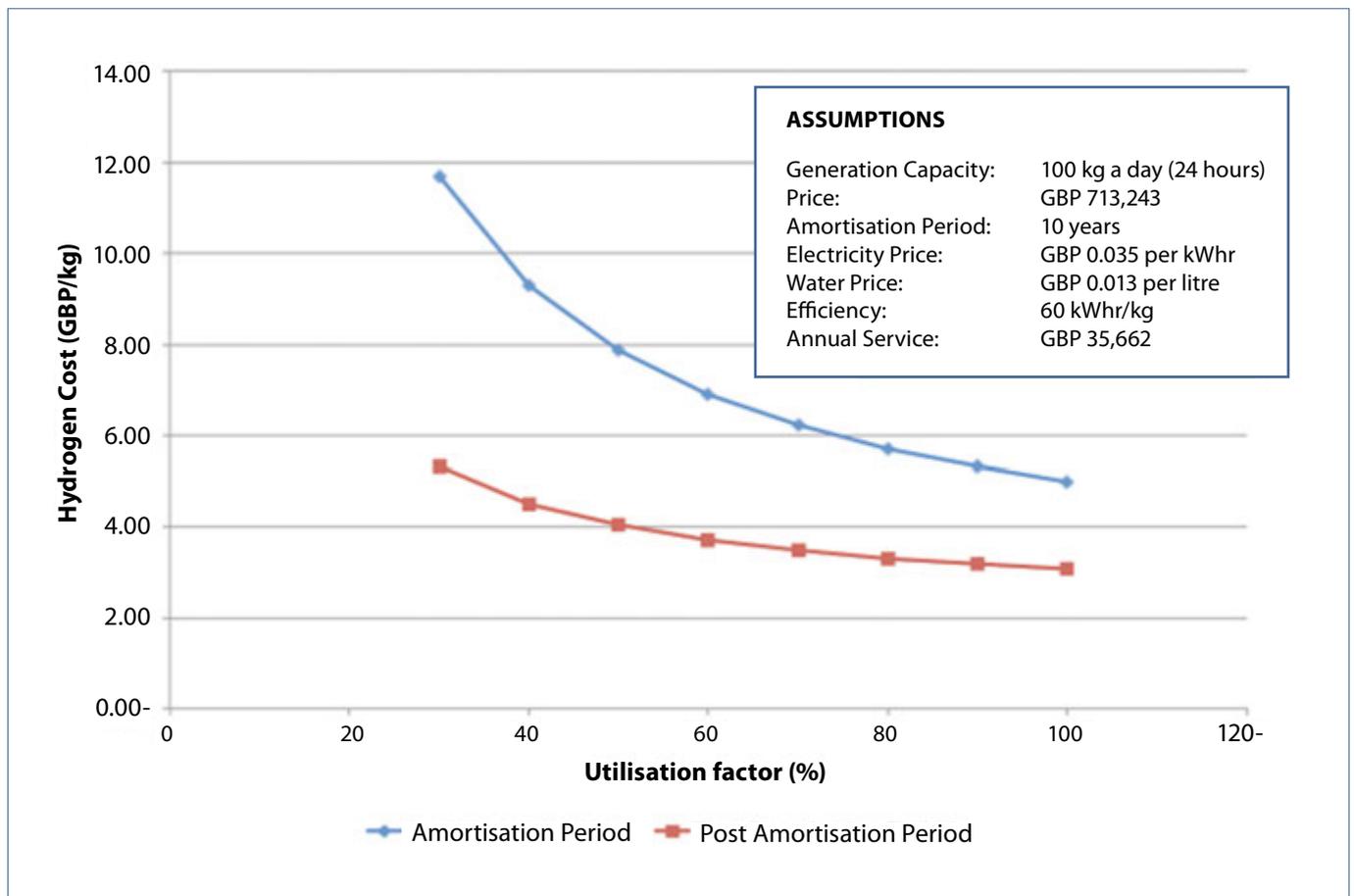
While there can be no argument over the environmental benefits of 'green hydrogen' or the independence of a locally produced fuel, the economics are clearly of vital importance. Hydrogen costs are best expressed in GBP per kg and reflect both capital cost amortisation and electricity cost.

Based on a hydrogen generation module capable of producing 100 kg of hydrogen per day, with a one-off price of GBP 713,243, an amortisation period of 10 years, efficiency of 60 kWh per kg, and an indicative annual service cost of GBP 35,662, the hydrogen cost is projected at GBP 6.23 per kg within a 10-year capital amortisation period and GBP 3.49 per kg after capital amortisation assuming 70% utilisation factor.

Increasing the utilisation factor to 100% reduces the hydrogen cost to GBP 5 per kg during a 10-year capital amortisation period and GBP 3 per kg thereafter.

The European cost targets for hydrogen generation are EUR 9.90 per kg (GBP 7.92) in 2015 and EUR 5.50 per kg (GBP 4.40) in 2025 (Source: McKinsey, a portfolio of powertrains for Europe: A fact-based analysis). Owing to the ability of HFuel to turn on and off rapidly, and to be demand side managed as a smart load, electricity prices of GBP 0.035 kWh have been assumed, but they may be lower or even negative.

Analysis of this case has revealed that a utilisation factor of 50% or higher will enable hydrogen to be generated for a cost matching, or even beating, the EU target for 2015 (when most automotive OEMs intend to release their fuel cell electric vehicles) as well as being significantly cheaper than diesel (on a cost per mile basis) bought on the high street in the UK today.



Lotus Engineering was the vehicle integration partner for the London Hydrogen Fuel Cell Taxi project

A UK Government's Technology Strategy Board (TSB) supported research programme aimed at producing a series hybrid Taxi with a hydrogen fuel cell power source. The benefits of using hydrogen in a taxi are zero emissions at point of use, important in an urban environment, along with quiet operation. Practical considerations give further advantages for technology implementation in a taxi in that return-to-base usage gives simpler infrastructure requirements, achievable in the near term, and taxis are a practical environment in

which to legislate and incentivise.

The programme delivered a number of demonstrator vehicles powered with a hydrogen fuel cell power generator. The project tackled the challenge of delivering real world fuel cell vehicles capable of achieving a realistic operating range and reliability targets. Innovation was essential for the fuel cells and their packaging, energy management, integration and condition monitoring, together with applying new industry standards for safety critical fault detection and mitigation.

There were significant packaging constraints that had to be overcome but the end result was five demonstrator vehicles showcasing electric drive systems, battery and controls technology and hydrogen fuel cell and storage.

The vehicle performance is even improved over the base vehicle. The hydrogen can be refuelled in a comparable time with diesel and at the point of use, generates zero CO₂ emissions.





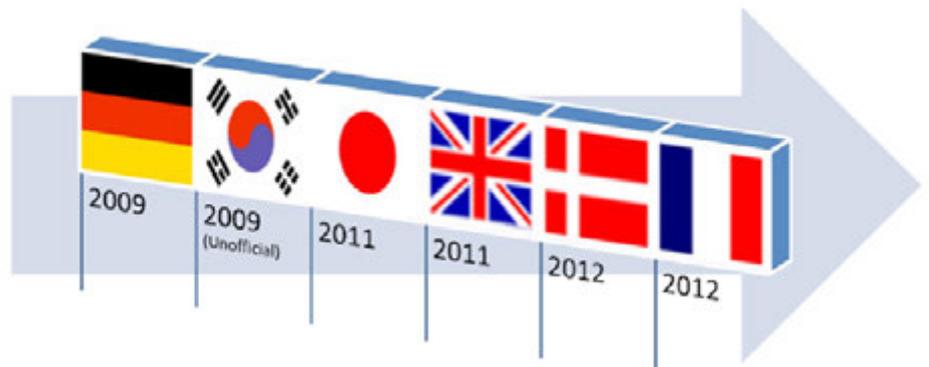
ABOVE: Inside the H-Fuel container

Infrastructure roll-out

There is no question that in Europe, Germany is leading the way. The German H2Mobility programme will see the investment of EUR 2.6 billion towards the deployment of hydrogen refuelling infrastructure across the country. A key date in this scheme is 2015 – a date shared by most automotive OEMs (original equipment manufacturers) as coinciding with production quantities of hydrogen-powered fuel cell cars hitting the streets. The Clean Energy Partnership (the organisation with the responsibility for installing the hydrogen refuelling stations) is seeking 'green hydrogen' to be dispensed by 50% of the infrastructure put down in Germany. Hydrogen derived by electrolysis is 'the' way to satisfy this.

The UK government is following suit. January 2012 saw the official announcement of UK H2 Mobility by the then Business Minister Mark Prisk – a programme which brings together three government departments (the Department of Energy and Climate Change, the Department for Business Information and Skills, and the Department for Transport) and industrial participants from the utility, gas, infrastructure and global car manufacturing sectors.

The group will evaluate the potential for hydrogen as a fuel for ultra-low carbon vehicles in the UK before



NATIONAL H2 MOBILITY INITIATIVES

The development of a national hydrogen plan

- 2009: Led by Germany and South Korea
- 2011: Japan and UK follow
- 2012: Denmark and France getting going

developing an action plan for an anticipated roll-out to consumers in 2014/2015. This is an important commitment, signalling that the UK recognises hydrogen as a fuel of the future and the intent to ensure the UK is well positioned for the roll-out of hydrogen fuel cell vehicles. ITM Power is one of 13 industry signatories of the UK H2 Mobility Memorandum of Understanding.

Author: Rebecca Markillie
(ITM POWER)

For more information on ITM Power, please visit the website www.itm-power.com or email Rebecca Markillie rlm@itm-power.com



Lotus Exige V6 Cup R

Launched at the 2013 Autosport International show were two new derivatives of the award-winning Exige S; the Exige V6 Cup, the latest Cup version for track or road and its race-bred sibling, the Exige V6 Cup R.

Bred solely for racing, the Exige V6 Cup R remains true to Lotus genealogy, distinctly recognisable as offspring of the award-winning Exige S. Visually compelling is the car's bespoke liveries and interior, courtesy of the skilled team at Lotus Design. The Exige Cup R is further distinguished from the Exige S and Exige Cup with its extended front splitter and you can almost anticipate the downforce just by looking at its bruiser of a rear wing. Powered by a 3.5 litre supercharged V6 engine generating 366 PS, and because Lotus is about lightness, the Cup R has an unladen mass of 1,040 kg, some 120 kg lighter than the original Exige S.

UK price from GBP 62,495.00 (excludes VAT, local taxes and on-road costs).

TECHNICAL SPECIFICATION

PERFORMANCE SPECIFICATION

0-100 (km/h)	3.8 seconds*
0-160 (km/h)	7.9 seconds*
Max speed	274 km/h / 170 mph*
Max power	366PS @ 7200rpm
Max torque	413Nm/295 lb ft @ 5000rpm
Unladen vehicle mass	1040kg

* Likely to change







As Head of Asia Operations for Lotus Engineering, Geraint Castleton-White's current role has a major focus on the strategic development of the third party engineering business in China.

Geraint Castleton-White

Head of Asia Operations for Lotus Engineering

The role is varied and encompasses meeting customers, building relationships, developing capabilities and supporting activities required to grow the business in a very challenging and dynamic region. The customer base in China is wide and varied.

After graduating in 1979 from Southampton University with an Honours degree in Mechanical Engineering and completing the Ford Motor Company Graduate Trainee scheme, he joined Engine Engineering at the Dunton Research and Development centre. During this period he was involved with advanced engine development.

In 1984 Geraint joined Lotus and was given responsibility for managing the engine development of the LT5 V8 engine project for the highly successful General Motors Corvette ZRI.

This was followed by a move to the TWR Group as General Manager, where he set up an Engine Engineering Consultancy Division incorporating design, development and manufacturing capability. The division undertook a number of projects including, the engine for the Jaguar XJ220 supercar delivering a specific output of 159 bhp/litre with full emission compliance, at the time a first, and the engine for the original DB7. A number of other exciting high performance engine

projects were also designed, developed and manufactured, the company achieved ISO 2001 and also produced the engines for the TWR racing teams.

His career then focused on General Management in manufacturing, working as Divisional Director for Automotive Products and then Manufacturing Director for Cosworth Racing.

Eventually returning to Lotus again in 2004 where he has worked in various roles including Head of Powertrain with responsibility for current and future technologies, including alternative fuels, low CO₂ solutions and hybrid/electric vehicles.

What kinds of things are you working on at the moment?

I work on a great variety of things; my role is very diverse and covers many aspects of Lotus Engineering activities. We are developing Lotus Engineering China (LEC) at the moment and consequently there are numerous facets to my day. I can be involved in a long-term strategy meeting and then flip to solving a short term project issue, arranging customer visits, interviewing new staff or resolving a finance issue. In the main the local team runs the day to day Chinese operations and my role is to support their growth and ensure they have support from HQ.

It is a very exciting time at the moment as we are transitioning from a sales office in China to a local engineering delivery centre. This brings with it a number of challenges. I am based in the UK at our HQ in Hethel but travel extensively, mainly to China, so the time difference of eight hours is an added challenge. I am probably based in Hethel for around 50% of my time, but that varies according to needs. There is a lot of time travelling, not just between the UK and Asia, but also within the region. We have clients spread all over China.

When I am in the UK my day starts at around 05:30 when I wake up and check overnight emails. I try to deal with any immediate issues on my way to the office over the phone and then the morning is usually a mixture of conference calls and sorting day to day urgent business. The afternoon when China goes home I use to close any open issues. The time difference has some advantages; if there is something really urgent I can talk to someone in China late UK time and then pick it up at the end of their working day when I wake up. It is not quite 24-hour working, but when it works well it is a very efficient way to work.

How do you see the general business environment in China currently?

It's very busy for us as an engineering services provider to the automotive sector. Vehicle sales growth in China may have slowed but the desire of OEMs in China to develop new product is very buoyant. The local OEMs wish to rapidly increase their engineering capabilities, and foreign joint ventures are also localising product. It seems like everyone needs our support somewhere.

Can you describe the main customer types for Lotus Engineering in China?

The market is very interesting because there are a number of different players with slightly different requirements. There are some very large state owned OEMs who have very strong relationships with JV partners and at the same time are developing their own indigenous product. We work with these companies to help accelerate their in-house capabilities and develop their engineering teams.

We also work with Western OEMs who wish to localise or build unique Chinese products, and then there are smaller privately owned OEMs who have great ambition and wish to compete at the highest level as quickly as possible. Our work with suppliers tends to be limited, and associated with developing specific components or systems for projects we are already working on.

The engineering team's work is very much the same with all types of customer, although with the local and private OEMs there is a greater emphasis on knowledge transfer.

Can you describe the range of work that you are undertaking in China and how it is conducted?

Lotus Engineering in China has had a great deal of success with delivery of projects based around our core competency of driving dynamics; these can range from a simple vehicle assessment, to a benchmarking exercise and to full chassis tuning projects.

We have also undertaken a number of vehicle/powertrain integration exercises. This is particularly relevant in China where local component content is very important, so adapting existing vehicles to accommodate cost effective, localised sub-systems is very desirable to our customers.

Manufacturing support has also proved very popular. We have undertaken supplier development for example, and our manufacturing engineers have project managed an entire factory build and commissions through to a few days consultancy at the customer plant.

An increasing amount of work is now delivered in China and this is driving our strategy to build up an engineering team in China.

Work on alternative powertrains, EV and HEV

projects are usually undertaken by the expert teams in the UK, often with the client's engineers embedded in the team.

Are there particular segments of the Chinese automotive market where you are seeing a lot of growth and demand for Lotus capabilities?

The car buying public in China is becoming more discerning and is demanding higher quality and performance targets in a great variety of segments. This has led to an increase in the demand for Lotus Engineering's services. The common theme is that as the products are maturing rapidly, there is a desire to have new product on the market quickly.

How is Lotus Engineering resourced in China?

It is not our intention to make Lotus Engineering China a standalone organisation. There will be an increasing level of local delivery, particularly driving dynamics, chassis and powertrain integration projects. There are some areas where we will rely on our expertise in the UK or the USA. It is possible that in the future LEC will become a centre of excellence and will then export its services to other parts of the group.

From an operational viewpoint, how self-contained are Lotus' Chinese operations?

It is not our intention to make Lotus Engineering China a standalone organisation. There will be an increasing level of local delivery, particularly driving dynamics, chassis and powertrain integration projects. There are some areas where we will rely on our expertise in the UK or even the USA. It is possible that in the future LEC will become a centre of excellence and will then export its service to other parts of the Group.

China's auto industry is obviously developing rapidly. How do you see the level of local engineering capabilities currently and how will that develop in the future?

The local capability is increasing quickly and we are able to fill capability gaps in most programmes. What is still lacking are local engineers with 10-15 years plus experience and engineers who have worked through

more than two or three new vehicle cycles. The current local engineering base has a very good academic grasp of automotive engineering but lacks some of the real-world experience that engineering demands. One of our key roles is to support this wealth of talent and impart some of our experience gained from having worked through and solved all sorts of engineering concerns. Lotus is in a particularly fortunate position as we develop and manufacture our own vehicles so our engineering teams have first hand experience of vehicle production.

I have the impression that there is very little collaborative activity in R&D between Chinese companies currently – for example in areas like fuel cell technology, or EV batteries. Do you see any sign of that changing?

In the same way, the established European and Japanese OEMs are collaborating in certain areas of advanced technology, I think there will be more collaboration within China's auto industry, especially for smaller OEMs. However Chinese OEMs are fiercely independent and competitive so by working with Lotus Engineering, they are able to have access to world leading innovations without collaborations with other OEMs. We continue to be able to accelerate the knowledge of these OEMs by delivering engineering projects with significant levels of technology transfer.

Another factor to bear in mind is funding. As consolidation takes place, certain larger OEMs will be able to undertake more internal research. We see our role developing as in Europe and America, where we can lead or support a consortium of stakeholders to undertake research in specific areas. This can include government, OEMs, academic organisations and suppliers.

Do you think the JV foreign partners will eventually be shown the door as Chinese automakers develop their own models and brands or do you think they will still need access to Western technology and therefore keep them on?

No, I don't think that there will be a 'them and us' situation in the future. The motor industry is already global and I think that there will always be a place for

JVs. The Chinese market has the potential to be able to accommodate a huge number of brands – already it has the most diverse car fleet in the world, a good mixture of European, American, Asian and locally designed product. Right now, the prestige of the Western type brands commands a premium and will probably do so for some time to come. However, customers will ultimately decide what they want.

Of course, it will not be long before Chinese car brands will arrive in Europe with products that the European customer wants to buy.

Do you think, in general, that they will follow the market-entry strategies of the Japanese and Koreans when looking to develop a presence in Europe? Build share with cheap low-end vehicles to begin with?

I don't think it will be quite the same and I don't necessarily think they will start with low-end products and move up. Look at Geely, Volvo and SAIC, for example. They have been able to develop a presence in medium and executive segments of the car market by purchasing brands. I also do not believe that the Chinese OEMs will be constrained to a certain segment when looking at export strategies; they will be well-placed to develop a range of products in different segments and look for opportunities across world markets.

Are you doing much work in the area of electric drive (including hybrids) in China?

There is a considerable amount of interest in alternative powertrains, but demand is still mainly for volume built on 'conventional' technology. In general, electric vehicles and hybrids also come with added cost. The OEMs are, however, very interested in employing the best of what can be done – in terms of low CO₂ and efficiency – with conventional technologies and I expect those demands to increase. That's where we can help.

Do you see electric vehicles as a big future growth segment in China?

Based on China's size I believe there will be a considerable market, but as a proportion of the total vehicle fleet it will be relatively small and limited to

captive local fleets - 'city cars' for instance. Right now, hybrids and pure electric vehicles are best suited to mature markets. There's a need for more investment in battery charging infrastructure, too. There is an official strategy to support electric vehicles, but I see real significant growth for electric vehicles as mainly a long-term proposition.

What about the problems of chronic traffic congestion and problems of air pollution in major cities?

That is actually driving growth for innovative conventional powertrain solutions for vehicles. There's a clear need for enhanced fuel efficiency, lower CO₂, reduced emissions and the need for advanced engineering technologies. There are a lot of old vehicles on the road and replacement demand will be rising from the expanded vehicle fleet. It's important to replace the older vehicles with cleaner ones. It's also the case that new car demand is continuing to rise in China's interior cities and it makes sense to develop vehicles that are cleaner, less polluting and more fuel efficient, while also meeting rising aspirations for mobility and motorisation as real incomes rise.

Vehicle emission regulations are moving in one direction only and the recent highly publicised air quality problems may add to pressures for a further tightening and incentives for cleaner, more fuel efficient vehicles.

From the point of view of working styles and patterns, how does working in China compare, say, with working in the UK? Are there cultural differences that make delivering engineering services very different, or are things basically the same?

The basic engineering is the same. When we talk with a mature Chinese OEM it is surprising how close our understanding of the engineering process is. They will also put in the hours and effort to get the job done – they have a very strong work ethic. The differences are not all that great, though in China you may find yourself socialising with the clients more in a formal way, at a restaurant, for example. This is something that is considered a natural part of the job.



ENGINEERING



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Lotus Engineering is at the forefront of efficient performance and clean fuel technologies, and leading the way in hybrid and electric vehicles.

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- Engine test cells
- Emissions lab (Euro 5+)
- Metrology
- Component rig test
- Instrumentation lab

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GERMANY: Car-to-X-Communication standards ready from 2015

Twelve vehicle makers are working in a consortium to create common standards for vehicle-to-vehicle and vehicle-to-infrastructure communication (Car-to-Car and Car-to-Infrastructure, also known as Vehicle-to-X) ready for series production in 2015.

The goal of the manufacturers is to offer initial cooperative systems from 2015 that allow vehicles from different manufacturers to communicate with each other and exchange data with the infrastructure.

Continental sees vehicle communication as a key technology for mobility in the future. "If vehicles can communicate with each other and the infrastructure, this opens up a wide field for new functions. With smart applications, we can make driving a much safer, more eco-friendly, and more comfortable experience," explains Helmut Matschi, member of the Executive Board at Continental and Head of the Interior Division.

"The step made toward systematically continuing to work on industry-wide standards is one that we warmly welcome as an associated member of the Car to Car Communication Consortium. Only through industry-wide cooperation can we succeed in allowing vehicles to speak the same language in the future," he adds.

GERMANY: Ford introduces 'Fiesta Active City Stop'

Ford has introduced a low-speed collision avoidance system on the Ford Fiesta in Europe.

First launched on new Focus and ordered by more than 70,000 European customers to date, 'Active City Stop' is already available on C-MAX, Grand C-MAX and the new B-MAX. It received a Euro NCAP Advanced reward on Focus in 2011.

Active City Stop constantly monitors the gap to vehicles in front, calculates the risk of hitting a stationary or slow-moving object and pre-charges the brake system to deliver maximum braking response. If the driver does not respond, either by braking or evasive steering, the system simultaneously applies the brakes, reduces engine torque, and activates the rear hazard lights.

US: Bosch sees bright prospects for 'clean diesels' in USA

Bosch has announced that its clean diesel technology will be featured in four new Audi TDI models now on sale in the US – the Audi A8, A7, A6 and Q5. It also forecasts that diesel volumes in the US will rise sharply.

Bosch says its technology will provide significant benefits to Audi's line-up, including improved fuel efficiency, better performance and lower carbon emissions. Bosch maintains that today's diesel vehicles are increasingly advanced, delivering up to 30% better fuel economy compared with

traditional port-fuel-injected (PFI) gasoline engines, while providing 50% more torque and up to 25% lower CO₂ emissions.

As a result of these benefits, Bosch says it anticipates the market penetration of clean diesel-powered engines in the US to grow to 10% by 2018. The recent announcement from Audi further solidifies this growth.

SWEDEN: Volvo starts diesel plug-in hybrid production

Volvo has started production of the world's first diesel plug-in hybrid powertrain which has gone into its V60 model.

In initial batch of 1,000 cars will be delivered during 2013. This will be ramped up to 4,000-6,000 cars from model year 2014.

Assembly of the diesel plug-in hybrid has been integrated on the same production line as regular powered models at Volvo's Torslanda plant in Gothenburg, something of an achievement considering that the sophisticated plug-in hybrid technology includes two complete drivetrains and a battery.

Peter Mertens, Volvo's research and development head, said: "We are first in the industry to integrate a plug-in hybrid in an established production flow together with other car models.

"The integration in the standard production flow gives the plug-in hybrid buyer the possibility to choose in principle all options available for the standard V60."

JAPAN: Toyota develops high speed collision avoidance

Toyota has developed a pre-collision System (PCS) with collision avoidance assist that is effective in helping mitigate even high-speed collisions.

The newly developed PCS uses millimetre-wave radar to detect the risk of a rear-end collision with a preceding vehicle with the system warning the driver via sound and display alerts to prompt braking when such a risk is detected.

When the driver applies the brakes, PCS enables deceleration of up to 60 km/h by greatly increasing the braking force up to twice that of the average force applied by drivers. If the brakes are not applied, automatic deceleration of 15km/h to approximately 30km/h is possible.

More than 90% of rear end collisions occur when the difference in speed between the preceding and following vehicle is within 60 km/h. TMC aimed to develop a system based on real-world collision data, and has, with its newly developed system, achieved rear-end-collision reducing-effects at the highest level in the industry. The new PCS was developed to be used in a wide variety of models, and is to be rolled out starting with soon-to-be-launched models.



Hitting Barriers

Determining the crashworthiness of a lightweight vehicle

In Issue 38 we published an article about Lotus Engineering USA's development of a lightweight vehicle based on a Toyota Venza.

The project was born out of the ever brightening spotlight on fuel economy and emissions and its relationship to vehicle mass.

Phase one of the program was a great success, yielding a 38% mass reduction in non-powertrain systems with a cost increase of just 3%.

However, reducing the mass of a vehicle is only one piece of the puzzle. Vehicular safety is of great concern as well, with several safety standards becoming more stringent and more automotive manufacturers debuting advanced active collision avoidance systems.

So what happens when the Lotus lightweight structure actually crashes? It may be a surprise to the public, but it turns out that despite the reduced mass, the structure actually fares as well as, if not better

than the Venza it's based on.

Phase one review

California Air Resources Board (CARB) commissioned Lotus Engineering to design a mass reduced crossover vehicle based on the 2009 Toyota Venza with the intent of highlighting reducing mass as a way to increase fuel economy and reduce emissions.

The results showed that it is possible to reduce the mass of a common crossover utility vehicle (CUV) by 38% with only a 3% cost increase by using a holistic approach to vehicle design.

This mass reduction study was continued in Phase two with crash test analyses and a further cost study.

Methodology

Crash analyses started with a topology analysis based on derived suspension loads (using 50% bending and 50% torsional loading) of an FEA model of the lightweight

body in white (BIW) developed in the Phase one study.

From Lotus' experience, this leads to lighter weight solutions due to material selection, than immediately applying crash loads.

Three topology analyses were conducted on single material BIWs using aluminium, magnesium, and steel.

These results were then used in conjunction with mass, cost, and recyclability concerns to further optimise the material selection of the Phase one model for crash modelling.

A variety of manufacturing processes were considered including casting, extruding, injection moulding, hydroforming, electromagnetic forming and stamping, as well as variants, e.g., brake bent and welded extrusions.

The processes were selected based on their contribution to reducing mass and cost.

Joining processes are also integral to building a BIW as they affect

the weight, durability, strength, and cost of the BIW. Ultimately, an adhesively bonded and friction spot joined (FSJ) body was selected. For dissimilar metals where galvanic corrosion was of concern, rivets and mechanical fasteners were selected.

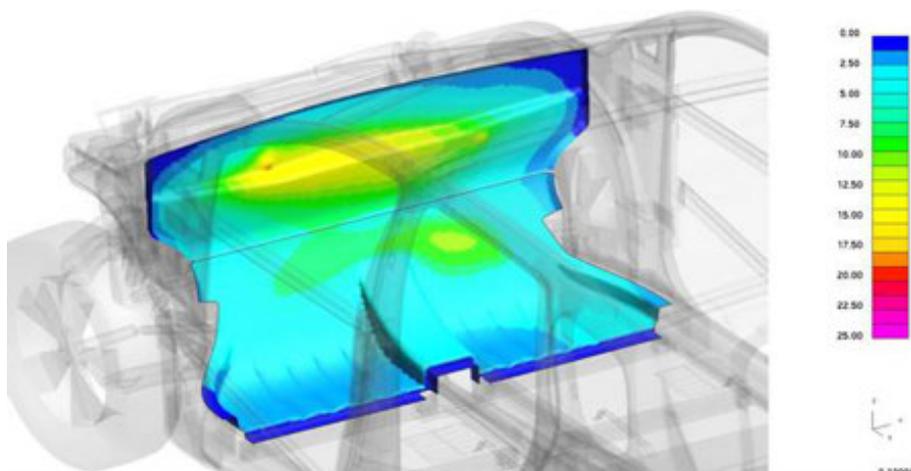
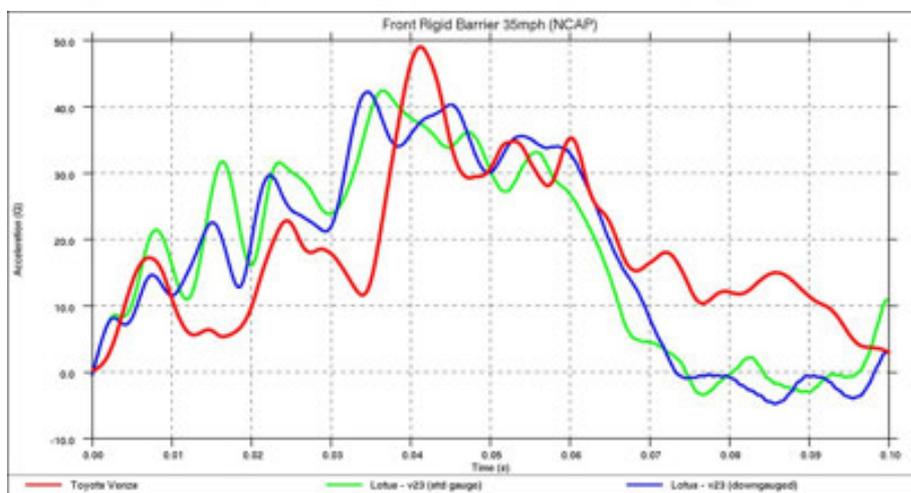
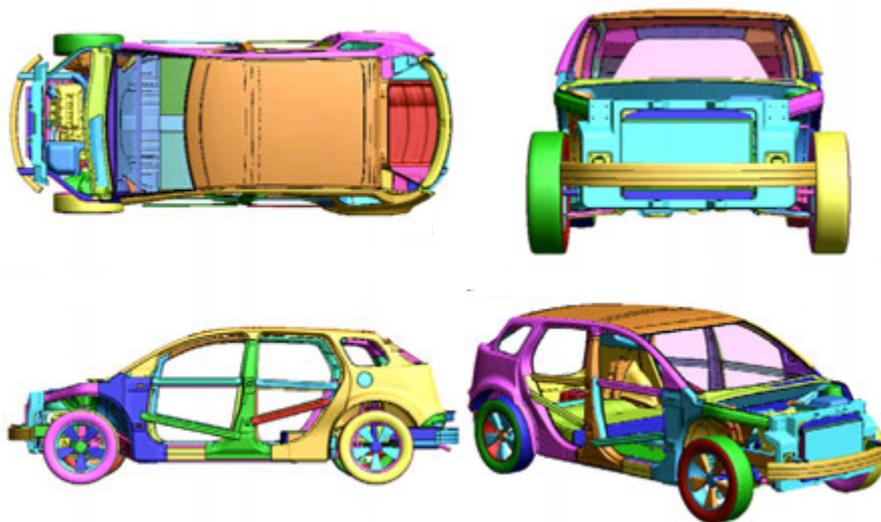
Modelling results

In total, over 500 design refinements were made to the original Phase one model across 26 different versions as testing continued. This yielded what is predicted to be one of the stiffest vehicles on the market with a torsional stiffness of 32,900 Nm per degree and a BIW that is predicted to perform as well as, if not better than the baseline Toyota Venza in every crash category. Model V26 predicts the lightweight BIW meets or exceeds every load case defined by the customer, CARB.

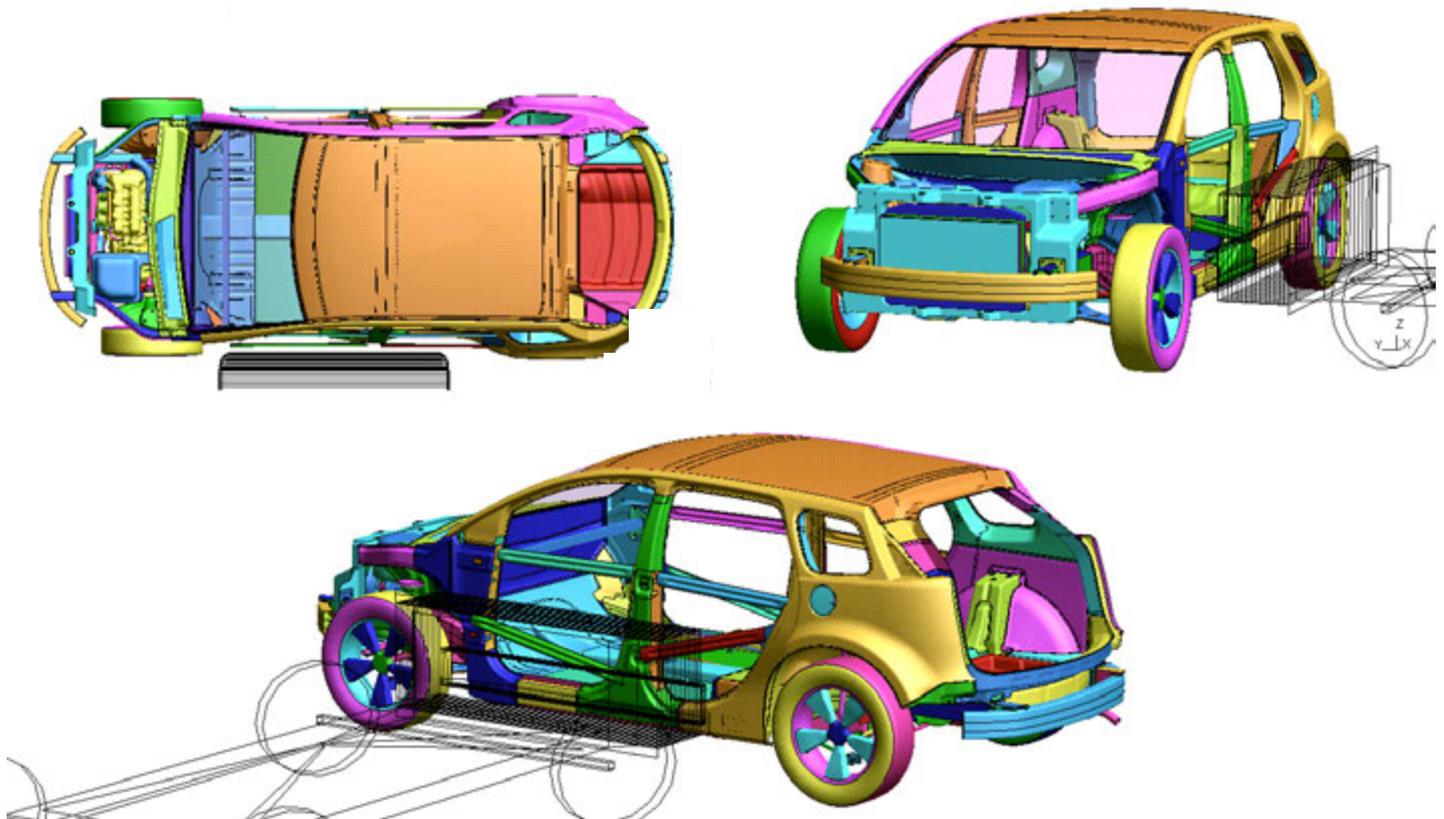
FMVSS 208

FMVSS 208 represents a variety of frontal collisions and the particular FMVSS 208 test shown here is a straight-on test with no offset. The Toyota Venza, recorded a peak deceleration of 50 g-force in this test, this result was used as the baseline, with a target no more than 10% lower. This translates to a maximum deceleration of 45 g-force allowed. The results of this test are shown below along with the baseline Venza.

After the initial crash, Lotus and TRW, a tier 1 safety restraint system supplier, examined the data and determined the crash pulse was conventional in the automotive industry and would not require special tuning of the restraint systems. Lotus further refined the BIW after it performed a sensitivity analysis and determined that reducing the material thickness by 10% would yield a 30% reduction



Top to bottom: A number of simulated crash test were run, The top image shows the model for FMVSS 208, a straight on frontal collision, the graph below shows the g-forces experienced by the vehicle. The bottom images shows that intrusion to the footwell was less than 10mm



in acceleration levels during the first 30 ms of the impact.

Also cause for concern are intrusions into the passenger compartment. In this regard, the lightweight BIW fares well with a maximum dash intrusion of just 20 mm in the upper dash. Maximum dash intrusion in the passenger compartment footwell was less than 10 mm.

FMVSS 214

This U.S. federal crash test involves a side impact with a deformable barrier and a pole at two specified locations – one where the pole impacts the seating location of a 5th percentile female and the second impact location is where a 95th percentile male would be seated. The two pole locations ensure that the vast majority of drivers will be safe in the event of a side impact. The case discussed here involves a 75-degree impact with the pole located at the 5th percentile female location. The diagram below shows the pole location relative to the vehicle.

The ultimate measurement criteria for this side impact test are intrusion levels into the passenger compartment. The test allows the vehicle to have a maximum intrusion level of 160 mm at the door beltline and 142 mm at the driver's pelvis.

For reference, the seats are 300 mm inboard of the zero reference of the pole, indicating the seats were still 140 mm away from the maximum intrusion point.

FMVSS 216

FMVSS 216 is a roof crush test designed to ensure occupant safety in the event of a rollover accident, whereby the BIW is required to protect the occupant headform envelope at three times the vehicle curb weight. The Insurance Institute for Highway Safety (IIHS), an independent safety organisation in the U.S. requires vehicles to withstand four times the vehicle curb weight, which was the target for the lightweight body.

The lightweight body exceeded all requirements – both FMVSS and IIHS, by withstanding six times the

vehicle curb weight.

One of the key factors in obtaining such performance is the high strength steel B-pillar, which is the main load-bearing structure under the plate.

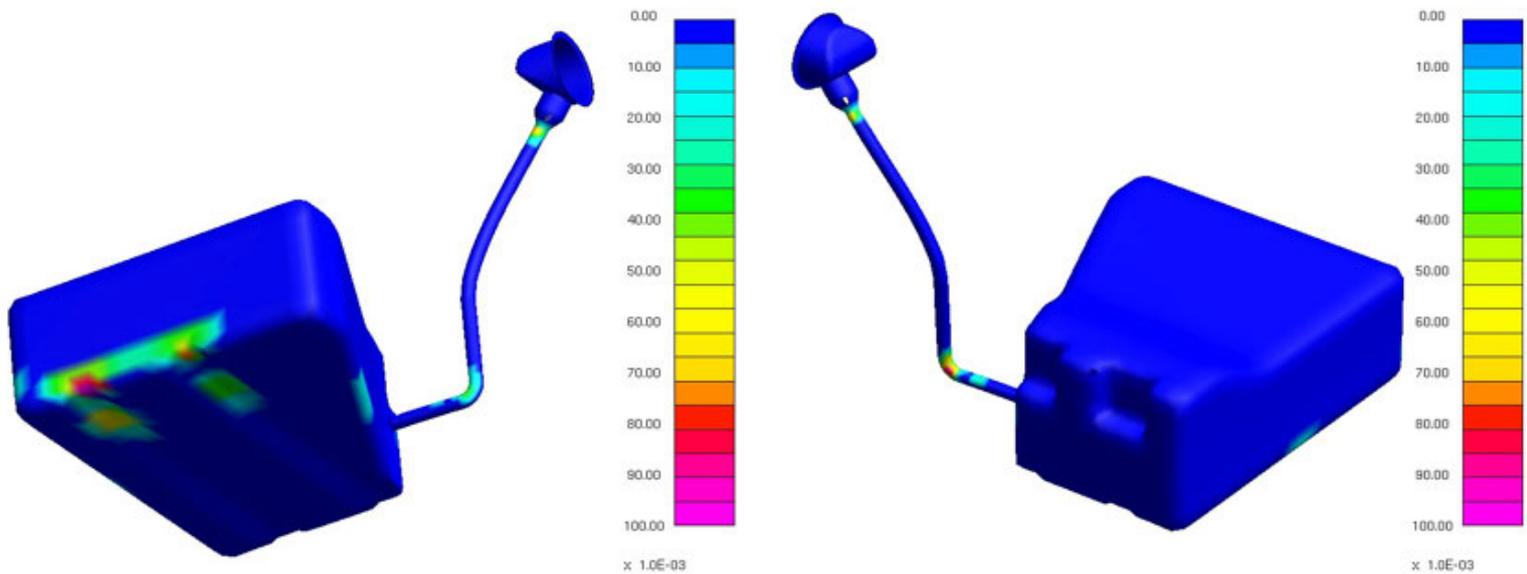
FMVSS 301

In order to provide a basic, 360-degree view of the safety of the lightweight vehicle, the last standard reviewed here is a rear impact to the integrity of the fuel storage and delivery system. However, designing all the ancillary components of a full fuel delivery system were beyond the scope of this vehicle, so only the fuel tank and filler neck were tested.

With a maximum plastic strain of 10 percent in the fuel storage system, the results indicated there should be no rupturing of the tank or filler neck.

Changes

Magnesium was used extensively in the front structure, roof, and A-pillar design of the Phase one HD design, but the metal proved



too brittle to meet crash standards. The validated Phase two HD model uses primarily aluminium for all these structures. The lower A-pillar inner however, is integrated into the magnesium dash casting and the move to an aluminium A-pillar allowed for an increase in cross-sectional area to stiffen the body and increase torsional stiffness. Changes were made to the C-pillar design as well, moving from a magnesium structure to an aluminium and steel structure for the same reasons as the A-pillar.

Cost analysis

As part of this study, a detailed cost analysis was conducted – including developing the manufacturing plant and costs associated with the assembly process.

The cost analysis was broken down into categories: piece cost, assembly, tooling, paint, and NVH materials.

With the aid of EBZ Engineering (a manufacturing plant engineering firm who has worked with

companies such as Porsche and Audi) and Intellicosting (a manufacturing and piece cost estimation company whose clients include many of the world's large automotive manufacturers), Lotus developed accurate full vehicle cost estimations. The assembly plant, with the exception of the building, was designed from scratch for this assembly process and the assembly costs based on this; tooling costs were based on low-volume tools; paint and NVH materials were derived from the Toyota Venza benchmark and held constant across both vehicles; and piece costs were derived based on CAD models of the BIW. In addition to determining the total cost of producing the vehicle, a variety of amortisation schedules were looked at.

The 'recommended schedule' includes amortising all investment over five years with the exception of the coordinate measuring machine (CMM), which is amortised over seven years. The three and five year schedules are straight

amortisation over those time periods.

Whilst the BIW is more expensive than the reference vehicle, the overall cost is only USD 130 more expensive to manufacture due to reduction in parts count and cost savings elsewhere in the vehicle, as identified in the Phase one study.

Conclusion

Mass reduction is one of the best ways to begin to reduce emissions and increase fuel economy, as these vehicle attributes come under increasing scrutiny. But by using a holistic approach to vehicle engineering, the phase two study shows that reducing mass does not reduce vehicular safety, and in some cases can provide greater safety.

Writer: Andrew Peterson

TOP LEFT: FMVSS 214 side impact with deformable barrier. TOP RIGHT: FMVSS 301 showing strain on the fuel storage system



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Official fuel consumption, Lotus Elise S in mpg (l/100km): Urban 27.3 (10.3), Extra Urban 47.6 (5.9), Combined 37.5 (7.5).
CO₂ emissions: 175 g/km.



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