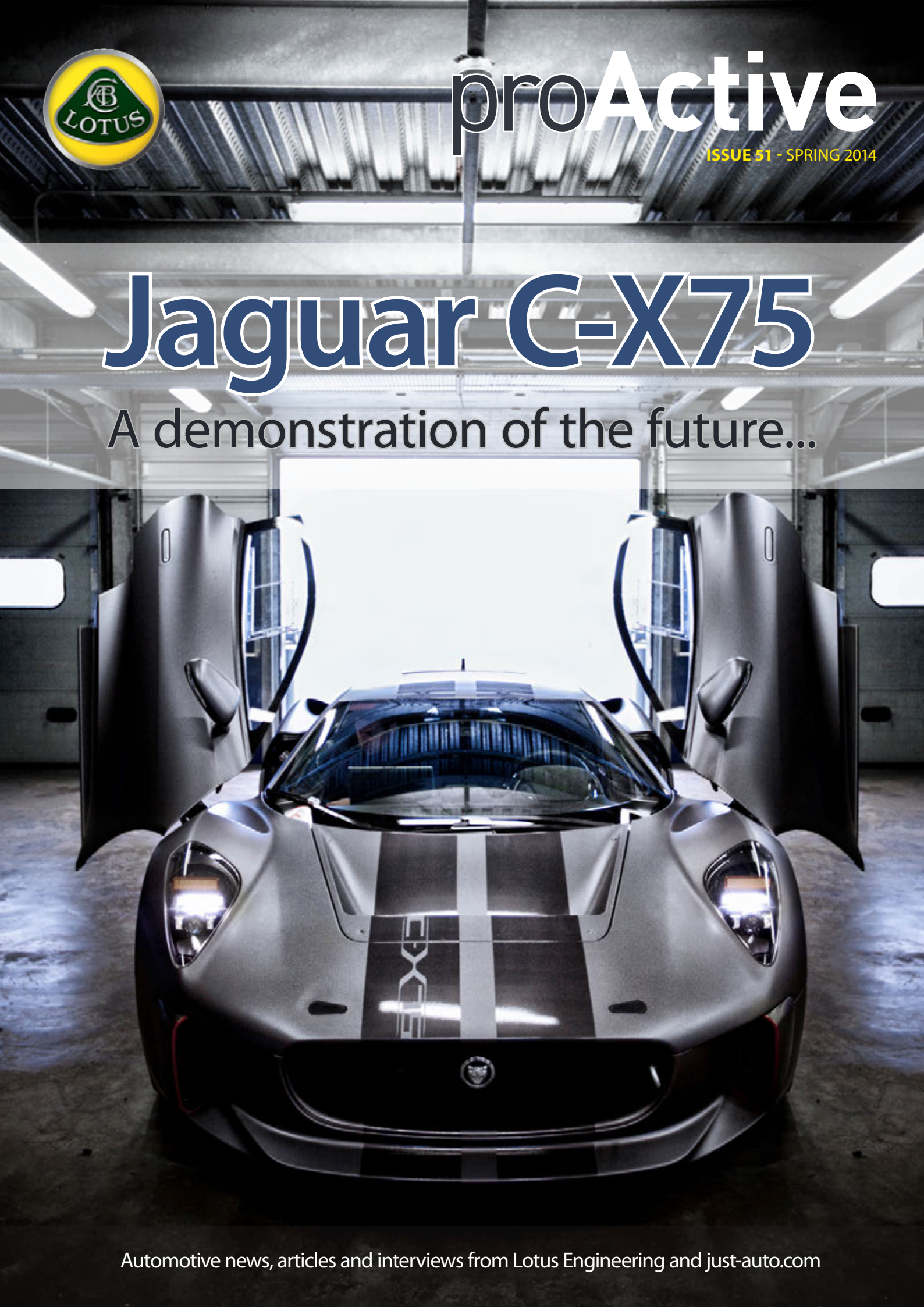

proActive

ISSUE 51 - SPRING 2014

Jaguar C-X75

A demonstration of the future...

Automotive news, articles and interviews from Lotus Engineering and just-auto.com

YOUR FUTURE **STARTS HERE!**

NEED A CHALLENGE? WE HAVE YOUR NEXT OPPORTUNITY...

Lotus Engineering: "Engineering technology solutions for tomorrow. Today"

Lotus Cars: "Tomorrows luxury sports car. Today"

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Do you have what it takes to join our winning team?

FOR DETAILS ON THE NEXT STEP IN YOUR CAREER, VISIT OUR 'CURRENT OPPORTUNITIES'

LOTUSCARS.COM

We celebrate ten years of proactive magazine and look forward to the next ten years

Ten years ago, in April 2004, the first issue of proActive was published with articles focusing on niche vehicles of the future, platform sharing and the development of hydrogen rotary engines, and here at Hethel the 20,000th Lotus Elise drove off the production line, making it the most popular Lotus ever.

Also that year Lotus Cars successfully launched the new Lotus Exige S2 on to the world stage and at the end of January, Lotus launched a new 189 bhp Elise 111R, that was later awarded Best Sports Car 2004 by BBC Top Gear.

Fast forwarding to today, our engineers are working on projects with clients in the UK, Malaysia, France, Turkey, Russia, USA, Canada, India, China, Japan, South Korea, and Germany. The core technologies Lotus is known for are in higher demand than ever.

We are continuing with further developments of our core technologies, combining safety and performance with manufacturing expertise. The powertrain team is looking at ways to deliver exhilarating performance from the smallest possible powertrains using the least amount of energy.

Our engineers are continually finding new ways to enable the implementation of active technologies invented by Lotus more than 20 years ago into today's modern vehicles, developing safe but exciting driving experiences, allowing differentiation in increasingly competitive markets.

These key areas of expertise will allow us to deliver exciting vehicles and sustainable transport solutions that are well aligned with the needs of the global automotive industry.

The speed and dynamics of technology development in the automotive industry are increasing rapidly, just like the variation of models developed by global OEMs, the choice of propulsion systems and energy sources, the interaction of safety systems and the functionality of entertainment and communication systems in the vehicle.

Our newly formed Group Innovations Department will be scrutinising the challenges faced in the automotive industry and looking to identify and develop the next generation of new and exciting technologies that will form the future of both Lotus Cars and Lotus Engineering.

We will discuss more of these innovative and exciting projects over the coming issues as progress is made and results achieved.

These are truly exciting times in an exciting industry!

We at Lotus Engineering are excited to be part of this, and motivated by the opportunity to contribute to developing vehicles that make driving safe, affordable and exciting while continuously improving the use of resources and the environmental impact of transportation.

With so many exciting topics to be discussed in future proactive magazines, I hope you have all enjoyed reading proActive magazine, and continue to do so over the next 10 years.

As always, we encourage you to give us feedback, through our website, in personal meetings with our experts or during the various conferences and trade shows we plan to attend this year.

Please enjoy our latest issue!

Martin Elbs

Martin Elbs
Global Head of Commercial Operations

www.lotuscars.com twitter.com/grouplotusplc youtube.com/grouplotus facebook.com/lotuscars

Official fuel consumption for the Lotus Exige S in mpg (l/100km): Urban 19.5 (14.5), Extra Urban 37.2 (7.6), Combined 28.0 (10.1). CO_2 emissions: 236 g/km. MPG figures are obtained from laboratory testing and may not reflect real driving results. Published MPG figures and performance results are intended for comparisons between vehicles only.

Verification of performance results should not be attempted on public roads. Lotus recommends that all local speed and safety laws must be obeyed and safety belts worn at all times. On the road price includes VAT, delivery, number plates, 12 months road fund licence and first registration fee.

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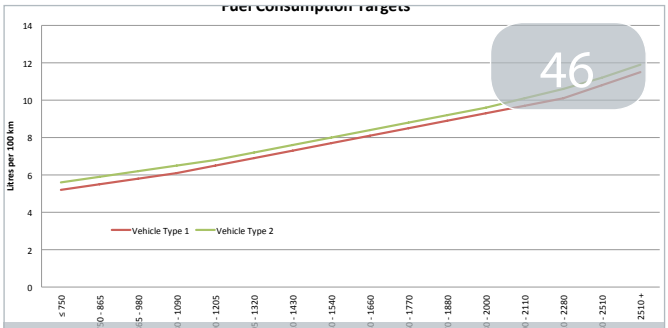

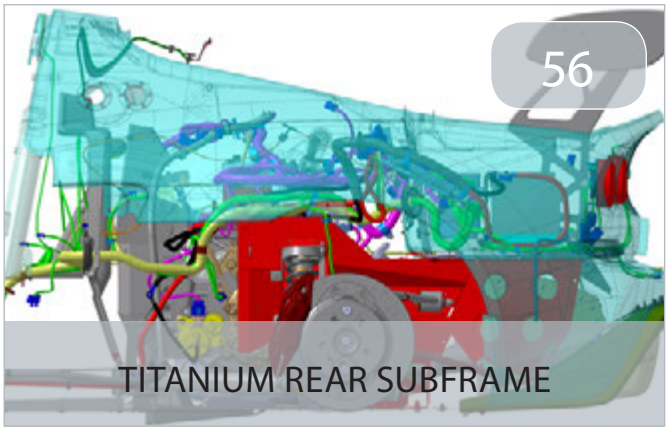

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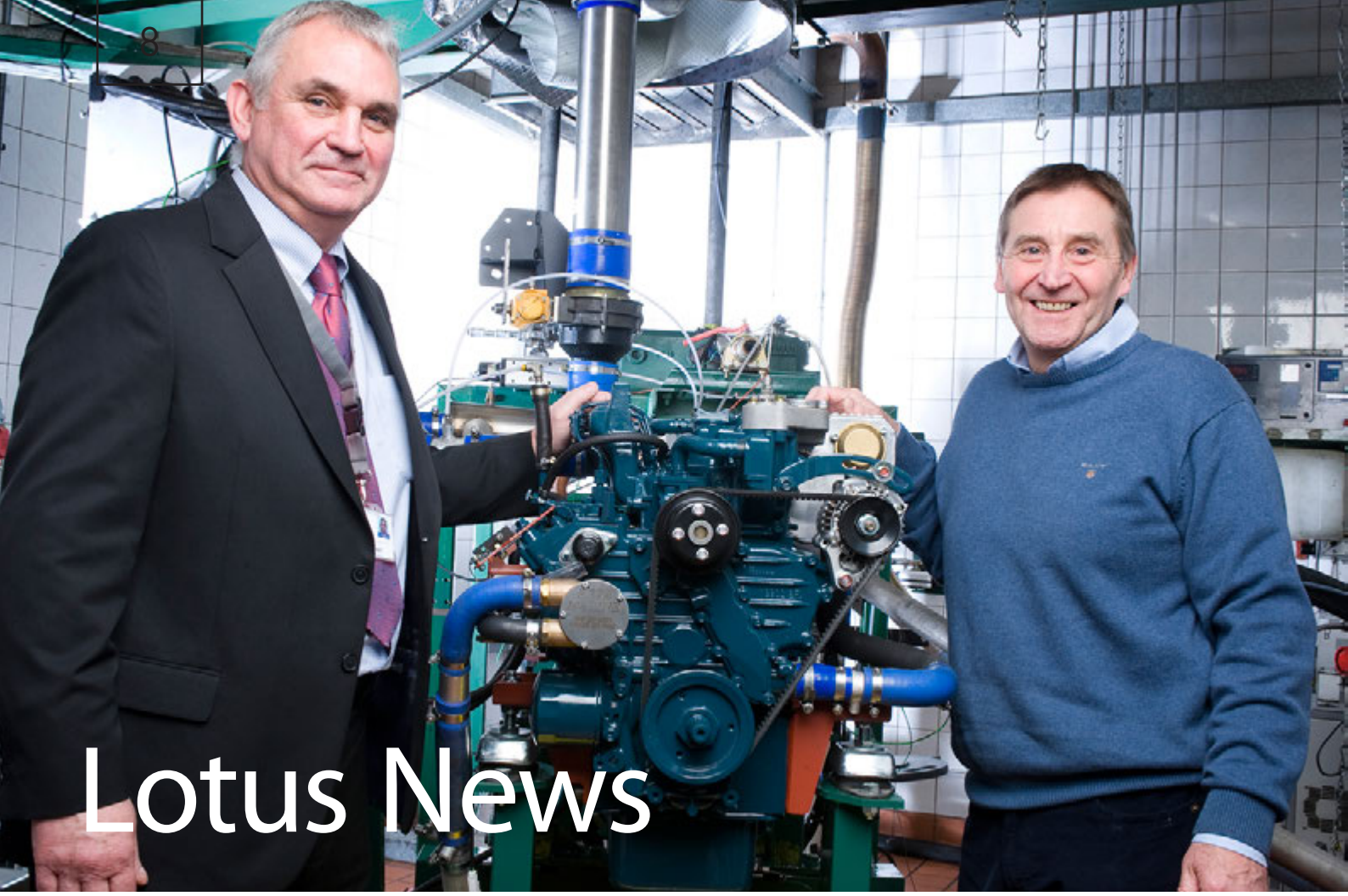


Lotus News

Lotus supports Beta Marine's engines to meet US emissions targets

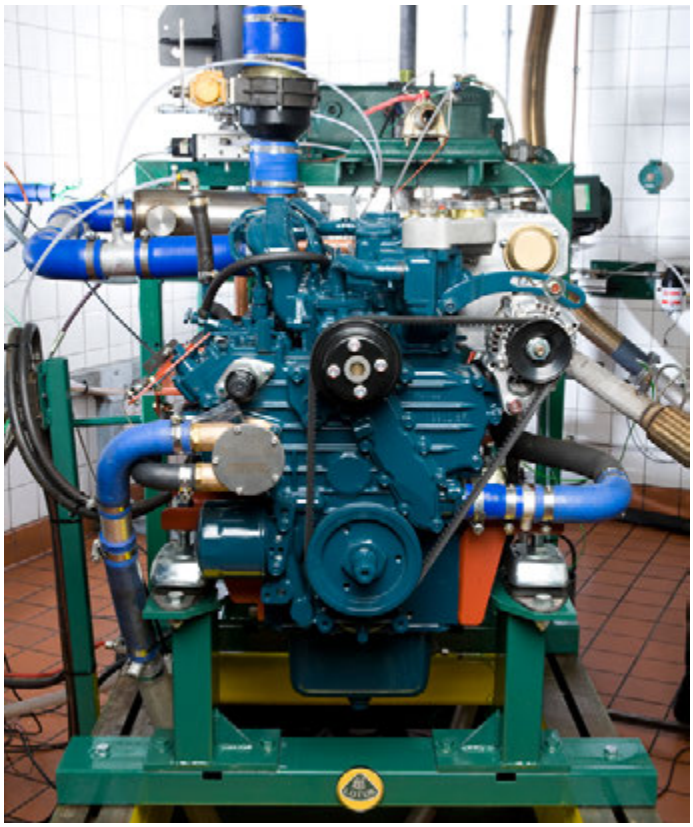
New Lotus Engineering client Beta Marine is a diesel marine engine supplier to the international boat building industry.

During the early part of 2013 Beta Marine approached Lotus Engineering to conduct conformity of production (CoP) emission testing on its USA export product engine family.

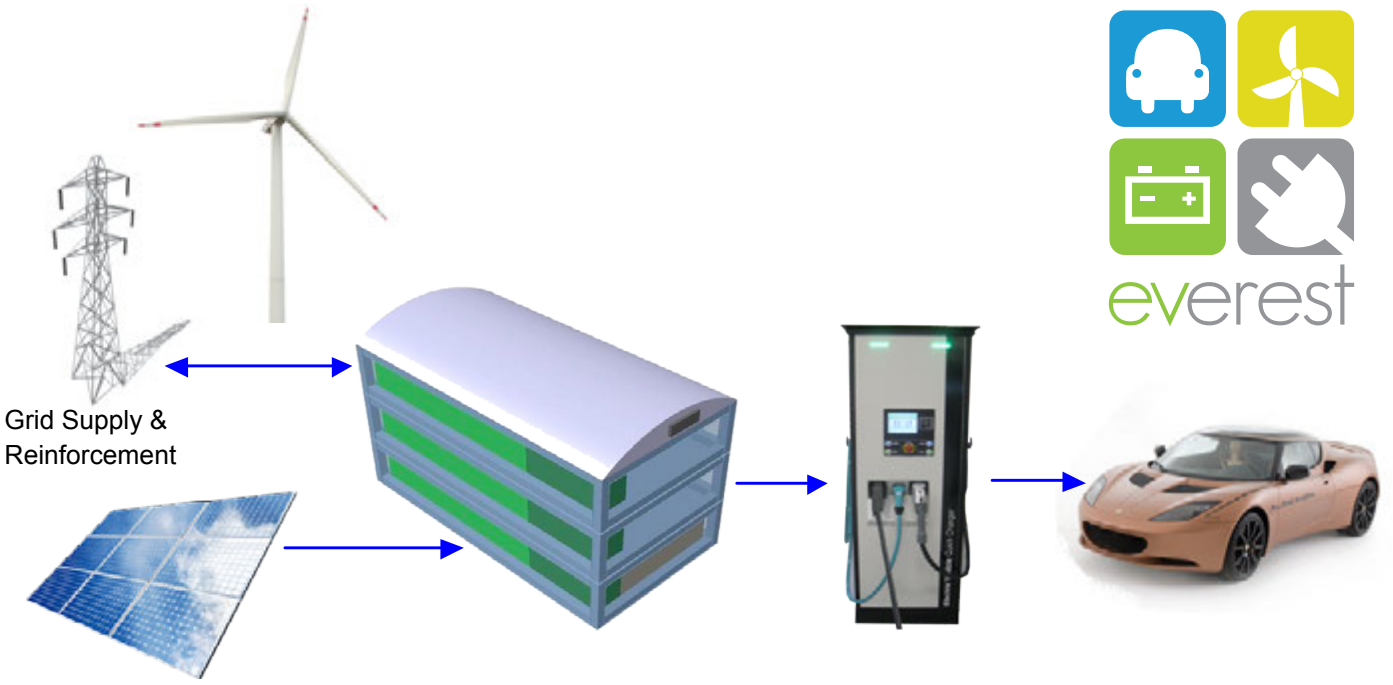
These tests were carried out showing that the engines met the US Environmental Protection Agency (USEPA) marine emission limits.

However, the USEPA limits became more stringent from January 2014. Lotus Engineering discussed with Beta Marine the possibility of conducting experiments by manipulating engine coolant (temperature and flow) to give more effective combustion chamber cooling in an effort to reduce NOx emissions.

Test results were positive and Beta Marine has presented the data as part of their application to the USEPA for certification of emission compliance.



Top: Beta Marine director Laurance Talbot (right) and Lotus Engineering development engineer Steve Restell during a recent visit



New energy storage system for fast charging of electric vehicles

A new energy storage system, which supports the implementation of electric vehicle rapid charging, is to be developed by Lotus Engineering and Future Transport Systems as part of the EVEREST consortium.

The system will be installed at Lotus' headquarters in Hethel as part of a GBP 3.4 million contract from the Department of Energy and Climate Change.

The project is based on using stationary energy storage built from batteries that have reached the end of their useful life in electric vehicles to reinforce the electrical grid when rapid charging plug-in hybrid or electric vehicles. In addition the energy storage device (ESD) can also support renewable energy sources, such as small wind turbines or solar panels, to locally store the energy generated in readiness for heavy demand at peak usage times.

This offers a more cost effective or flexible alternative to network infrastructure upgrades.

The project consortium is led by Evalu8 Transport Innovations Limited (part of the University of Hertfordshire), with Future Transport Systems (FTS) leading the technical side of the project and programme management.

Lotus Engineering is responsible for the design, build, commissioning and development of the prototype charging station ESD, and will be drawing upon its globally recognised design, development and manufacturing expertise developed on its own sports cars and through its many automotive consultancy projects.

Lotus Engineering will also be applying its systems control technology developed from the extensive R&D conducted on electric vehicles to the ESD and charging hub which will be installed at Lotus' headquarters in Hethel, Norfolk and will add to its existing Powertrain and Vehicle Test and Development facilities.

40 drivers set to compete in 2014 LoTRDC season

Organisers are expecting capacity grids for the 2014 season, with two new championships proving to be a hit with competitors.

The FIA-sanctioned Lotus Cup Europe International Series is expected to have 40 drivers set to compete during the season, which visits many of the continent's best circuits.

The opening rounds of the Lotus Cup Speed Championship and the Elise Trophy's inaugural championship season get underway in just a few weeks' time, and with all available places being filled already for the Speed Championship, LoTRDC have extended their commitment for the opening round by five places and will be looking to do the same at all other rounds. The Elise Trophy has 40 drivers placed for its opening round, with the four remaining slots expected to be filled before the end of February. The Lotus Cup UK grid has hit 39 entries and is also expected to be at capacity this month, with two titles on offer to the competitors.

The Lotus Cup Speed Championship heads to North Weald in Essex on 16 March, with an entry list that includes Martin Donnelly. The former F1 star will be competing in a sprint for the first time alongside his son Stefan, who will have his first taste of motorsport at any level. The brand new sprint series has encouraged more new competitors into motorsport, and it is hoped that many will progress further into racing.

Three weeks' later, Snetterton will host the second round of the series, along with the start of the LoTRDC racing season. Lotus Cup UK will race on the Saturday, followed by the first points-paying round of the Elise Trophy. The following weekend, Lotus Cup Europe will feature on the race card for the Bosch Historic, Jim Clark Revival event at Germany's Hockenheim circuit.

LoTRDC's Paul Golding said: *"It's great to have so many entries confirmed for all five of our championships this year. The early commitment by so many drivers has meant we've been able to increase track time for Lotus Cup Europe as well as at the opening two rounds of Lotus Cup UK, while at the other end of the spectrum we've already purchased additional entries at the opening sprint of the season by an extra five places. All three of our current champions, Andy Napier, Simon Deacon and Thomas Dehaibe will be defending their titles, which is fantastic. We're also welcoming Lotus owners and enthusiasts from across the continent to our events and hope to see many of them there."*

Top: Lotus Cup UK kicks off at Snetterton. ©SnappyRacers.com

PB Racing launch the 2014 Lotus Cup Italia season

Lotus Cars dealer and Lotus Cup Italia organiser PB Racing launched the 2014 Lotus Cup Italia season at the prestigious MotorCircus event in Brescia, Italy.

In January, the very special Lotus Elise PB-R was on display at Brixia Expo in Brescia, representing the most exciting race focussed Elise to hit the Lotus Cup Italia series.

PB Racing President Stefano d'Aste says "*We have a very exciting 2014 season planned for Lotus Cup Italia, we have been working in close collaboration with Lotus Racing to produce a very special car exclusively for our customers; the Elise S Cup PB-R which reaches 225 hp, and being lightweight it's the perfect mix for an easy and fun drive! It is our promise to make Lotus Cup Italia easy for teams, dealers and customers to compete in and as such technical assistance will be available on site for all events, with hospitality for partners and sponsors and a fully managed programme, it's the full package for rookies or experienced drivers and anyone in between!*"

Stefano d'Aste, himself a WTCC legend, personally launched the 2014 Lotus Cup Italia series and unveiled the Elise S Cup PB-R on the main stage alongside Marco Calovolo, CEO of Hexathron Racing Systems.

The Lotus Elise Cup PB-R is for sale at EUR 42,000 and has already proved a hit with customers eager to get a head start!

Costs, calendars and full details of the championship are available online www.lotuscup.it.

For full details please contact PB Racing direct; info@pbracing.it +39 035 20396

Industry News

SWEDEN: Volvo Cars conducts research on driver sensors

Volvo Cars is conducting research into driver sensors in order to create cars that *"get to know their drivers"*, something which it believes can bring big safety benefits.

Through systems that can recognise and distinguish whether a driver is tired or inattentive, the car of the future can become even safer, Volvo says. Examples of this include technology that detect closed eyes or what the driver is looking at.

"*This will enable the driver to be able to rely a bit more on their car, and know that it will help them when needed,*" said Per Landfors, engineer at Volvo Cars and project leader for driver support functions.

By placing a sensor on the dashboard to monitor aspects such as in which direction the driver is looking, how open their eyes are, as well as their head position and angle, it is possible to develop precise safety systems that detect the driver's state and are able to adjust the car accordingly. This also means that the car will ensure that it does not stray out of the lane or get too close to the car in front when the driver is not paying attention, as well as being able to wake a driver who is falling asleep.

"*Since the car is able to detect if a driver is not paying attention, safety systems can be adapted more effectively. For example, the car's support systems can be activated later on if the driver is focused, and earlier if the driver's attention is directed elsewhere,*" Landfors said.

Some of the current systems that can be included are Lane Keeping Aid, Collision warning with full auto brake and Adaptive Cruise Control with Queue Assist.

The technology is based on a sensor mounted on the dashboard in front of the driver. Small LEDs illuminate the driver with infrared light, which is then monitored by the sensor. Infrared light is just outside the wavelengths that the human eye can see, which means that the person behind the wheel doesn't notice it at all.

Driver sensors are also opening up other possibilities. By monitoring eye movements, the car would be able to adjust both interior and exterior lighting to follow the direction in which the driver is looking. The car would also be able to adjust seat settings, for instance, simply by recognising the person sitting behind the wheel.

"*This could be done by the sensor measuring between different points on the face to identify the driver, for example. At the same time, however, it is essential to remember than the car doesn't save any pictures and nor does it have a driver surveillance function,*" Landfors said.

The technology is already installed in test vehicles. Volvo Cars

is also conducting research together with partners including Chalmers University of Technology and Volvo AB to identify effective methods for detecting tiredness and inattention.

The analysis of the driver's state, known as Driver State Estimation, in which driver sensors play an important role, is a field that may be key to self-driving cars in the future. The car will need to be able to determine for itself whether the driver is capable of taking control when the conditions for driving autonomously are no longer present. A driver sensor could be of assistance in this.

This technology, Volvo says, is one of the many initiatives bringing Volvo Cars closer to its goal for 2020, that no one shall be killed or seriously injured in a new Volvo.

GERMANY: BMW adds 'laser boost' lighting

Later this year, BMW is to offer its i8 model with a new headlamp lighting technology that it says ensures a high-beam range of up to 600 metres.

The new technology, dubbed 'laser light' is being claimed by BMW as a world first on a production vehicle.

BMW says that the high illumination range of the modern LED high beam is doubled by the laser boost and that it is also possible to increase energy efficiency by a further 30% compared to the LED light.

Laser diodes are ten times smaller than conventional light diodes, saving space and weight, BMW says. They help to save not only available installation space inside the headlamp, but also weight. The size of the reflector surface can be reduced by a factor of up to 10 versus LED light.

The height of the reflector has now been reduced from the previous 9 cm to less than 3 cm. The light of a laser headlamp is extremely bright, similar to daylight, which is perceived by the human eye as *"pleasant"*, says BMW.

Several high-performance diodes emit a strongly bundled beam via special lenses onto a fluorescent phosphorus substance inside the headlamp. This substance transforms the beam into an exceptionally bright white light.

Due to their highly intensive and virtually ideal beam properties, laser diodes render the overall system even more efficient, it is claimed.

BMW maintains that "*in conjunction with the camera-aided digital high-beam assistant, dazzling of oncoming traffic or vehicles ahead is reliably eliminated*".

The company says that it will add the new technology to more BMW models.

GENEVA: Apple launches CarPlay for Volvo, Ferrari and Mercedes

Apple launched the CarPlay in-car application for its iPhone operating system at Geneva in Volvo, Ferrari and Mercedes models.

The automakers and Apple said CarPlay brings all the features and services familiar to iPad, iPhone or iPod users directly into the car via the centre console touch screen display.

Volvo is linking them to a specially-developed interface that allows drivers to use voice and steering wheel controls to access features and services, ensuring the entire interaction is always safe and easy to use.

"*The interaction between Apple's operating system and Volvo Cars' newly-designed in car software and interface promise to transform the look and feel of a car's interior. Interiors will be characterised by their simplicity and functionality,*" the pair said in a statement.

The redesigned XC90 will introduce CarPlay later in 2014.

Users will have basic iPhone applications, such as phone, messages, music and navigation and the package initially will offer third party audio apps including music streaming service Spotify.

The Volvo portrait screen gives users the benefit of having both car and Apple content co-existing simultaneously, removing the need to switch between a dedicated car and iPhone screen.

Visually, it becomes part of the on-board system, displaying well-known icons for Apple applications.

"iPhone users will feel completely at home. We have created a wholly-integrated user experience in our large portrait-oriented touch screen that takes the in-car mobile device experience to a new level. That, coupled with the obvious driver safety benefits of an advanced voice control system like Siri, made Apple a perfect match," the automaker said.

Ferrari introduced the system on its California T and FF.

"*CarPlay provides iPhone users with an incredibly intuitive way to make calls, use maps, listen to music and access messages with just voice commands or by touch. Users can easily control CarPlay from the car's native interface or just push-and-hold voice control button on the steering wheel to activate Siri without distraction,*" the sportscar maker said.

Daimler's Mercedes-Benz said it was the only German premium automotive manufacturer which is planning to support the system from the outset and is demonstrating how it works in Geneva in a new C-Class.

Covering all bases, Mercedes said: "*As soon as Google brings its own in-car infotainment system to market, Mercedes-Benz customers will also be able to enjoy the world of Android in their cars.*"

CarPlay connects through Apple's Lightning cable (introduced with the iPhone 5) with Wi-Fi "*coming in the near future*".

CarPlay will be available in forthcoming Volvo models based on the new scalable product architecture (SPA).

Apple is competing with Google in the area of integrating personal connectivity devices with cars and the driving experience.

At January's CES in Las Vegas, Audi, GM, Google, Honda, Hyundai and NVIDIA announced they have joined together to form the Open Automotive Alliance (OAA), a global alliance of technology and auto industry leaders who'll start bringing the Android platform to cars starting in 2014.

GERMANY: Audi launches CNG and 'e-gas' powered A3 g-tron

An Audi A3 equipped to run on compressed natural gas or a specially produced ultra-clean 'e-gas' has been launched in Germany. Audi says it provides the most environmentally friendly form of long-distance mobility.

The A3 Sportback g-tron can be powered by ultra-clean Audi e-gas produced using green electricity, or by compressed natural gas, both of which are available to drivers in Germany.

If a driver uses conventional CNG to power the car, Audi can feed an equivalent volume of e-gas into Germany's natural gas network via a special card, so that environmental performance is maintained. An Audi spokesman told just-auto that the e-gas and CNG can be considered interchangeable in terms of the running of the car, so it's a question of what gas is available to the driver at different gas outlets. The e-gas card ensures that, in effect, the car's environmental footprint in use is always that of the ultra-clean e-gas.

Audi says the A3 g-tron forms part of a new, integrated and sustainable mobility concept.

Its 1.4-litre TFSI engine develops 110 PS and can be operated using either natural gas, e-gas generated by Audi or petrol. In pure e-gas mode the g-tron is entirely CO_2 neutral, Audi says, meaning that customers who use the Audi e-gas fuel card can opt to power their A3 g-tron without impacting on the environment if they wish.

The A3 Sportback g-tron will be priced from EUR 25,900 in Germany. Due to the lack of infrastructure required to fully implement natural gas filling stations, there are no plans for Audi to introduce this model in the UK.

Audi e-gas is a synthetic methane that is produced at the Audi e-gas facility located in Werlte in Lower Saxony, Germany, the world's first industrial power to gas plant. Green electricity is used in the production of Audi e-gas, and the process of generating it actually binds as much CO_2 as is released when the Audi A3 g-tron is driven in gas mode, giving it exceptional ecological credentials, Audi claims.

On average the Audi A3 g-tron consumes between 3.2 and 3.3 kilograms of gas per 100 kilometres. Fuel costs at present start at around 3.50 euros per 100 kilometres.

The buying principle for Audi e-gas corresponds to how green electricity is distributed: Audi records the quantities of natural gas that the customer pays for using their Audi e-gas fuel card and ensures that exactly this amount of Audi e-gas is fed into the German natural gas network.

Customers who choose this option can obtain an Audi e-gas fuel card for a flat price of EUR 14.95 per month. In addition, the costs for the quantities of gas refueled by each customer are deducted via the Audi e-gas fuel card. The card can be used to purchase Audi e-gas at over 650 fuel stations in Germany.

Prof. Dr. Ulrich Hackenberg, Board Member for Technical Development at AUDI AG, said: "*In addition to our e-mobility developments, the Audi e-gas project is an important pillar of our sustainability strategy, as is the development of other synthetic fuels.*"

Audi is already operating a research facility for the production of Audi e-ethanol and e-diesel with its partner Joule in Hobbs, New Mexico. Moreover, the company is conducting research into the synthetic manufacture of Audi e-gas in cooperation with Global Bioenergies.

CES SHOW: Toyota scopes out hydrogen vehicle plans

Hydrogen fuel cell vehicles will be on the road earlier than many predicted with Toyota joining South Korean makers Hyundai and Kia in targeting small volume production by next year.

Bob Carter, senior vice president of automotive operations for Toyota in the US said at the Consumer Electronics Show in Las Vegas: "*Fuel cell electric vehicles will be in our future sooner than many people believe, and in much greater numbers than anyone expected.*"

Toyota displayed its FCV concept and a camouflage engineering prototype which has been road testing in North America for more than a year. Carter said the prototype has consistently delivered a driving range of about 300 miles, 0-60 mph acceleration in about 10 seconds, with no emissions, other than water vapour. Refuelling of its hydrogen tanks takes, he added, three to five minutes.

"Hydrogen works beautifully with oxygen to create water and electricity and nothing more. For years, the use of hydrogen gas to power an electric vehicle has been seen by many smart people as a foolish quest. Yes, there are significant challenges. The first is building the vehicle at a reasonable price for many people. The second is doing what we can to help kick start the construction of convenient hydrogen refueling infrastructure."

Toyota has been testing and developing a series of fuel cell prototypes in North America since 2002 covering more than 1m miles. Cost have also come down.

Toyota estimates a 95% cost reduction in the powertrain and fuel tanks of the vehicle it will launch in 2015 compared to what it cost to build the original prototype in 2002.

Toyota's FCV will be launched first in California where it has been working with the University of California Irvine's Advanced Power and Energy Program (APEP) to help map out potential locations for new hydrogen fueling stations.

This has produced an initial cluster map that requires only 68 station sites in the San Francisco Bay area and Silicon Valley, as well as Los Angeles, Orange and San Diego counties. If implemented, the mapped system could handle a fuel cell population conservatively estimated by APEP at about 10,000 vehicles.

California has already approved more than USD 200 m in funding to build about 20 new stations by 2015, 40 by 2016, and up to 100 by 2024.

Dave Leggett takes an alternative look at Geneva

Here in Britain, the mood has noticeably lightened of late. The big news is that spring has arrived. After a winter of seemingly relentless wind and rain, we've finally had some warm and dry weather. Up and down the land shorts have been dug out of drawers and covers have come off the barbecues. You see, we just never know how long a nice spell of weather will last.

For some of us in the automotive business who have been around the block, it's not just the daffodils that remind us spring is here. There's also the annual Geneva Motor Show that always falls in early March. I was there this year and my Geneva attendance seemed to follow the usual pattern.

Most years I leave it too late to book a hotel (book now for 2015 if you want something reasonably priced and in Switzerland rather than across the border in France) and I end up flying EasyJet out of London Gatwick for the day trip. On the plus side, it really is eminently doable as a day trip. The show ground (Palexpo) is just 10 minutes walk from the airport.

To be honest, unless I have been invited on a special programme by a vehicle manufacturer (it does happen, but is a bit rare) then I reckon the lean and mean day trip works pretty well. In between interviews, there's the chance to catch a few press conferences and walk the halls.

What's not too like, I hear you ask? Just one thing, really: a streak of selfishness among some of my professional press colleagues. Allow me to explain. The hanger of a press room at Geneva is pretty big, but demand for space to, er, sit down and actually write some copy greatly exceeds supply. Space is at a premium. The problem is worsened because people 'reserve' spots on tables by dumping a laptop or hanging a jacket on the back of a seat. They then disappear to the halls confident that their space is still waiting.

Hot desking it ain't. You can hunt high and low for a free spot that hasn't been 'claimed'. It annoys me every year and there's a sense that many people acquiesce in this strange understanding, but arguments inevitably break out.

"Excuse me, but is this space free?" "No, it isn't, Harry will be back shortly." Yeah, right. Towels and swimming pool loungers on your holidays spring to mind. Rant over.

I do actually enjoy Geneva, even if there's never quite enough time to see everything (there never would be, of course). The default position of most people is relatively cheery and, hey, even Western Europe's car market is showing signs of life. I liked some of the small cars on show, like the Toyota Aygo (tagline: "Go Fun Yourself") and new Renault Twingo. And the air bumps on the Citroen C4 Cactus.

Not sure why, but I do. There's always something to make you smile at Geneva, Europe's 'neutral' show. It's Paris in the autumn this year (alternates annually with Frankfurt). Oh heck, the press room at Paris is even more rammed and it's a case of just forget any notion of sitting down in there and instead look for wi-fi inside the halls. And stop your complaining Leggett.

Ten Years of proActive!

Dave Leggett looks back at over 50 issues of Lotus Engineering's magazine

It is hard to believe, but a full decade has passed since the first issue of Lotus Engineering's proActive.

I have just had a flick through past issues and a few things stood out which I'll list here. In particular, thinking about the interviews I have done triggered some unusual memories on the production side of things that I thought I'd also share.

Do you remember the APX concept car that Lotus produced? The 'Jekyll and Hyde' car that delivered performance, but with safe MPV-style functionality. It showed off Lotus design capabilities. Nice styling, I thought at the time *(Issue 15, 2006)*.

Ah, the Lotus Exige 265E biofuel. Naughty but environmentally responsible. I loved the idea encapsulated in a neat article header: *"British, racing and very green"*. Well done to whoever thought that one up *(Issue 16, 2006)*.

I interviewed then Lotus CEO Mike Kimberley in his office at Hethel in 2007. That was a real pleasure as not only was Mike able to lay out, very openly, the business strategy for the company, but he also shared some historical anecdotes with me (and Mr Kimberley has Lotus history and DNA in spades). Charming and considerate bloke also *(Issue 22, 2007)*.

I recall interviewing Trevor Rudderham, Carbon Motors Corporation VP in 2008. It was a telephone interview and he was sitting outside somewhere in the afternoon sunshine near Atlanta, Georgia, with some delightful birdsong as a background accompaniment. Fascinating project, too, to design and build a purpose-built police patrol car that would be better suited for purpose than a converted Ford Crown Victoria. Alas, this was a start-up for whom things did not go altogether smoothly, so the idea is still out there *(Issue 26, 2008)*.

The Lotus Evora is, by all accounts, a very good car. I remember Jeremy Clarkson on Top Gear being very complimentary about it. Evora was launched in 2008 and proActive carried some interesting articles on its development and engineering *(Issues 27 and 28, 2008)*.

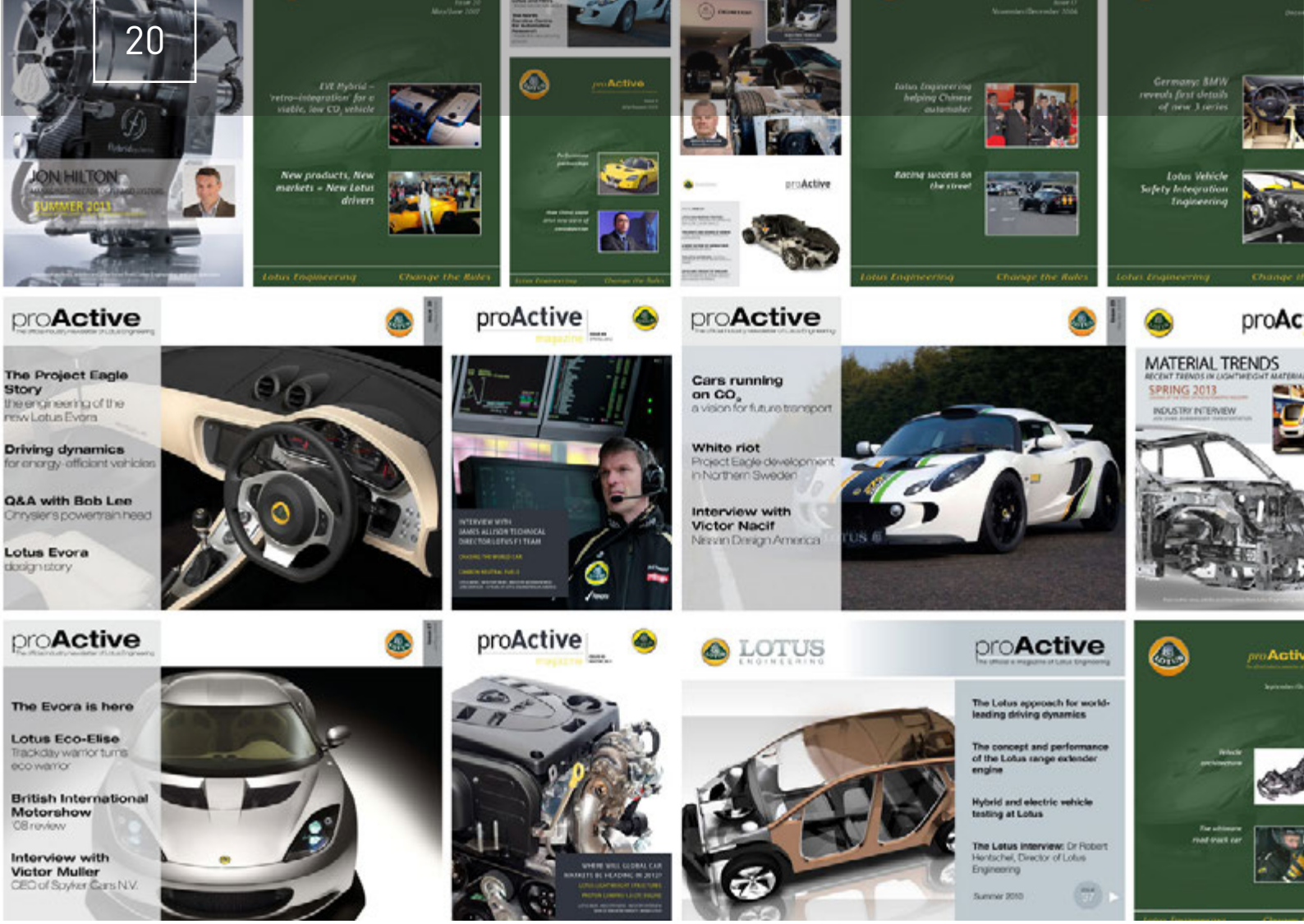
Mahindra's head of automotive, Dr Pawan Goenka, was a most charming fellow when I interviewed him down the telephone, he in India, me in UK. I was particularly relieved to get this one 'in the can' as I had made a schoolboy error with the time zone difference that meant I had kept him waiting for my call at the end of his busy working day. I offered profuse apologies, but his PA was pretty furious with me. Dr Goenka, however, was perfectly fine and cheerfully gave full answers to all of my questions, which was something of a relief at the time *(Issue 31, 2009)*.

Another fine interviewee was Oskar Goitia of Mondragon, an automotive components maker in the Basque area of Spain. I got a little bit of a history lesson on how the Mondragon cooperative came into being and also some interesting insight into how the broad-based cooperative works. It's a fascinating business model, a socially responsible or collectivist take on capitalism that works particularly well in certain circumstances *(Issue 34, 2009)*.

I conducted an interview with Richard Parry-Jones (he of the first Ford Focus and now heavily involved with the UK's Automotive Council) in 2010 that was a real joy. Part of the joy was the sheer crispness of his answers. This engineer can express and order his thoughts very clearly indeed. Perhaps that's not a surprise, for a talented chap like that. What amazed me was that he was able to perform so well with his answers while driving a car.

We began the lengthy call with him in Wales, near his home. When we ended it, he was pulling into a suburban London Underground railway station to park up. And the call duration perfectly fitted his journey time. Ah, the neatness of it all, the perfectly calibrated symmetry. Great insights, also *(Issues 36 and 37, 2010)*.

The Paris Motor Show in 2010 will go down in the annals as one where Lotus pushed the boat out a bit. Several future model concepts were rolled out and there were celebs present including supermodel Naomi Campbell,



Hollywood actors Mickey Rourke and Stephen Baldwin. Interesting times ahead were certainly promised on that evidence. I'll say no more, but you can read an account of the Paris razzmatazz at the time in proActive *(Issue 39, 2010)*.

What can you say about Bob Lutz? The guy's a living legend and he's still pretty active. I interviewed him for proActive down the telephone one Saturday evening in the summer of 2011.

After communicating via his personal hotmail account, he gave me his home telephone number to ring at a certain time on Saturday. I was now calling at the prearranged time. A woman answered. *"Good evening, this is the Robert Lutz residence. How may I help you?"* I explained who I was and why I was calling. She seemed to know nothing of the arrangement but put me through anyway. I wondered what to expect.

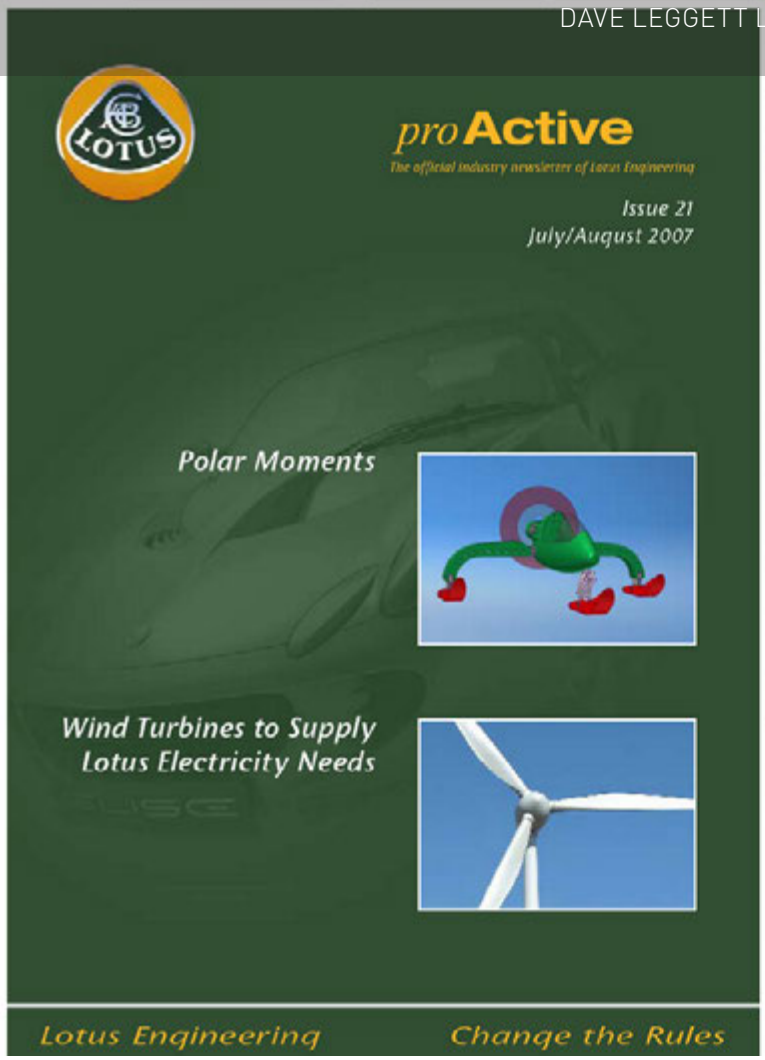
I need not have worried. Bob Lutz was superb value for money as an interview subject. I recall that he was full of praise for the Obama bailout of General Motors and full of criticism for those who mocked GM as Government Motors.

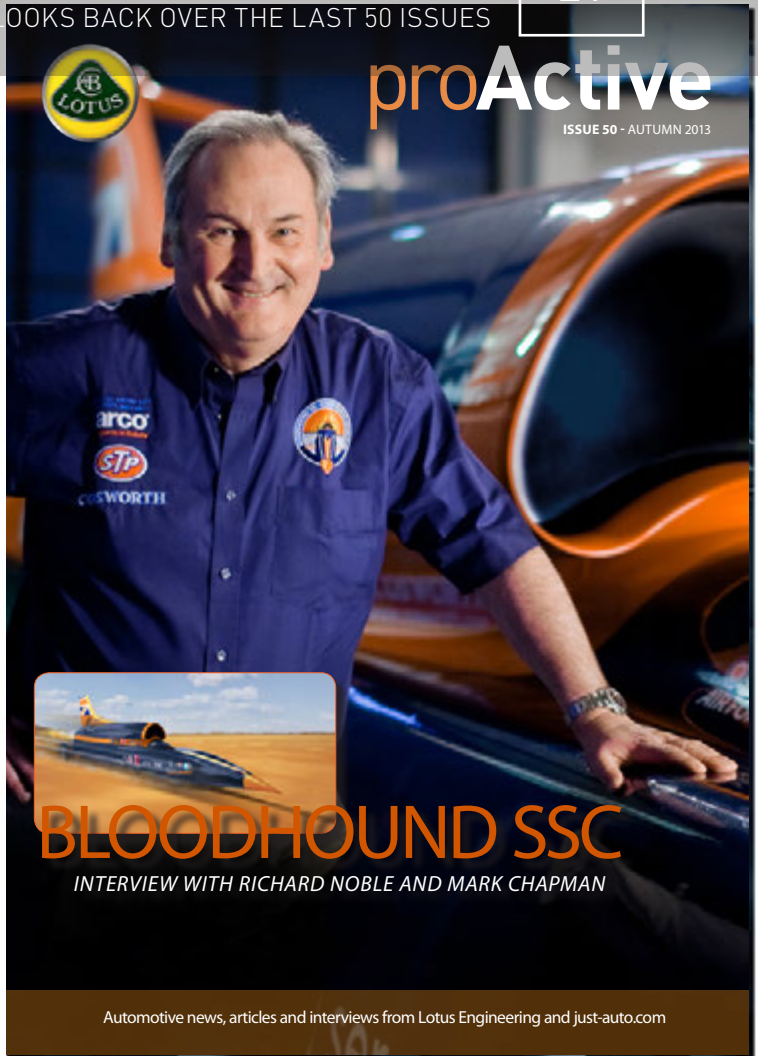
He also wants European-style taxes on fuel to encourage people into smaller cars. And I had the chance to ask him about the 'global warming is a crock of shit' remark. After we were done, he said he it was nice afternoon over there and was going for a ride on his motorcycle. Maximum Bob! *(Issue 41, 2011)*.

What does a technical director at a Formula One team actually do? I got the chance to fire a whole load of questions at Lotus Team F1 Technical Director James Allison and that was certainly a fascinating insight into a glamorous but extremely hard-working world.

Does he like the travelling to those exotic places where the F1 races take place? He likes it when he gets there, but the travelling itself, he loathes that. Truth is, he likes being at home (Issue 44, 2012).

Richard Noble held the land speed record for quite a few years. In the interview with him





and his colleague Mark Chapman, we learned a fair bit about the business of going very fast, dealing with sponsors and how to make the whole shooting match work. More importantly, I thought, there was the notion of trying to get kids interested in engineering. And I learned about somatographic illusion *(Issue 50, 2013).*

Well, that's a highly selective window on the last ten years of proActive. I could highlight loads more but space won't permit. I've very much enjoyed working with Lotus on proActive and I'm looking forward to helping put together future issues. Obviously, I hope you enjoy reading proActive. C'mon, of course you do, it's free to subscribe to!

On this tenth anniversary let me just say also that Lotus is a company and brand that it's hard not to feel great affection for. There's the history, the racing heritage, the cars, the Lotus ethos going back to founder Colin Chapman and the sheer resilience of the company, and it's all centred in rural Norfolk just outside the fine city of Norwich (where I went to university back when dinosaurs roamed).

Besides the sports car business, there's the considerable engineering expertise held in the Lotus Engineering division, a kind of unsung hero that works mainly under the radar. If only they could talk publicly about some of the projects they work on! But there is a serious point here: Lotus is an automotive OEM as well as an engineering services company.

Any truly successful company has good people working for it and Lotus is no exception. As a Lotus manager Peter Morgan put it succinctly in one of the early issues of proActive: *"Lotus is unlike any other company and it has a unique culture of its own".*

Long may that continue to be the case. Happy reading.

Writer: Dave Leggett

△ just-auto.com

Jaguar C-X75

A demonstration of the future...

Introduction

The concept of the Jaguar C-X75 was born to symbolise the future of Jaguar Cars and to create a vehicle that was indicative of the future.

The timing of this automotive engineering project was to celebrate the significant milestone of 75 years of Jaguar Cars and to emphasise to the world how the innovative heritage of Jaguar and the UK car industry can lead the next generation of powertrain and vehicle development.

This project was not only a showcase in technical innovation but also in rapid product development, strategic partners such as Williams Advanced Engineering and Lotus can raise the bar in project delivery technical complexity and timescales.

The platform for the launch of this vision to the world was Paris. The show car was presented at the 2010 motorshow, drawing attention from the media, competitors, suppliers and the public to its blend of classic beauty and innovation. The thinking behind C-X75 is to provide an owner with a unique car, capable of being driven as a road vehicle showing style with economy, then on occasion, take it to the race track to unleash its performance and power.

The decision was made in May 2011 to go forward to the next stage of the supercar development and engineer the concept into a production solution, based on 250 vehicles. Jaguar's Programme and Vehicle Manager, Rob Atkin with Paul Newsome, Head of Williams Advanced Engineering led the programme and engineering activities from Grove Oxfordshire under the guidance of a steering committee chaired by Bob Joyce, Jaguar's Engineering Director.

To deliver this task the newly formed Jaguar/Williams project team carefully selected key suppliers that were competitive, experienced and focused on delivery. Lotus were selected as a key partner to develop two major function groups: the chassis system and the engine management system. This technical delivery was managed under the guidance of Paul Pywell, Head of Operations Lotus Engineering UK.

To deliver the chassis and engine management systems meant working closely with the core programme team. Lotus brought its 60 years of motorsport, car production and engineering collaborative consultancy experience with OEMs to bring a blend of process and flexibility to meet the challenge.

The strategic fit with Lotus allowed Jaguar and Williams to draw into Lotus's DNA and adopt some of Colin Chapman's key values for the challenge

- If you're not winning you're not trying
- To add speed, add lightness
- To finish first, first you have to finish
- Adding power makes you faster on the straights
- Subtracting weight makes you faster everywhere
- The least number of parts effectively deployed

Management

Each of the Lotus teams interfaced with other cross functional teams, managing interfaces within function groups, such as the transmission, engine and body systems.

A challenge for management was identifying robust design freeze points for the teams. Each team was developing their systems in parallel and relied on robust data to meet the tight deadlines right first time. Key relationships built rapidly to ensure this worked.

A challenge for the Williams manufacturing team was to provide the designers with production input from virtual data for a unique innovative vehicle that was still a paper exercise. The Jaguar/Williams team worked with Lotus to study manufacturing processes so that design for manufacture (DFM) supercar best practice could be implemented ensuring right first time was achieved for the first build.

Focused meetings were held at key locations on a regular basis with skilled staff in a structured manner to manage progress, accelerate problem solving and keep the project on track. The mutual respect between the chosen partners encouraged an open dialogue between industry experts which allowed for technical issues to be brought to a head and resolved quickly.

Key vehicle attributes

One of the major challenges for the automotive industry is to drive down CO_2 emissions.

The key enablers for this are to engineer cleaner downsized engines coupled with hybrid technology and lighter vehicles to get more power per kg. It was important to think outside the box to capture the right technology content, reduce time to market and cost whilst improving performance and customer appeal. This is what the team set out to do.

After a review of the Paris concept car the technology moved away from the idea of micro gas turbines which uses jets to generate electricity for the battery and extend the range of the car. The technology direction was to develop a plug-in hybrid electric vehicle solution (PHEV) with a unique liquid and battery pack for this performance vehicle. This direction change allowed alignment with current production technology trends for CO_2 reduction.

Coupling boosted engine performance with additional power delivered from the battery through twin electric motor drives delivered additional performance.

The partners were challenged to deliver: 'a hybrid supercar with no equal'.

Project targets

- Performance of the Bugatti Veyron (0-160 kph in less than 6 seconds)
- CO_2 emissions of a Toyota Prius (less than 89 g/km)
- Electric range of a Chevrolet Volt (60 km)

Specification

- Supercharged 1.6-litre turbo petrol with 500 bhp
- Power output 313 bhp/litre compared to the Bugatti Veyron, 125 bhp/litre
- Twin electric motors developing more than 175 bhp electric motor on each axle
- Total power more than 850 bhp
- Torque more than 738 lbft
- Range of up to 60 miles on electric-only power
- Engine and rear electric motor drive coupled to seven speed automated manual transmission
- The vehicle can be driven electrically or as a hybrid with four-wheel drive
- High level of technology leveraged from Formula One including engine, high voltage battery, vehicle control system and aerodynamics
- Electric front axle drive, driving through a single speed reduction gearbox

The story from the chassis team

Thanks to a small team of passionate, driven and focused engineering experts, Lotus successfully designed and released all C-X75 chassis systems in less than 16 weeks.

The work scope included the design and integration of the entire vehicle suspension, steering and braking systems along with wheels, tyres and various mounts throughout the vehicle.

Defining the required attributes during the feasibility and concept phases was crucial to the success of the C-X75 production intent phase. From vehicle, system and component target setting to supplier benchmark and selection, Lotus were key partners in all the chassis engineering activities. The goal was to ensure that the foundations were in place before the start of the production intent design phase.

In addition to being a technology showcase, it was important that C-X75 delivered ride, handling and refinement befitting to the Jaguar brand. Delivering this would require the highest performance from the suspension, steering and powertrain mounting systems, achieved within minimum weight and time constraints.

The unique nature of the C-X75 powertrain and chassis composite structure meant that traditional attribute mule evaluation of the suspension targets would not be practical, and the first evaluation drive would not occur until a complete prototype was finished.

To give confidence in achieving the desired performance Lotus leveraged it's supercar vehicle dynamics experience and employed their virtual benchmarking and target cascade process to validate kinematics and compliance attribute targets through virtual comparison with suitable benchmarks in Lotus RAVEN vehicle simulation software.

Lotus utilised its SHARK interactive simulation tool to achieve rapid development of the suspension and steering system geometries. Alternative system types

were quickly evaluated and optimised within the vehicle package, enabling robust system selection decisions at the early concept stage.

The various technical challenges offered by the C-X75 programme gave Lotus the opportunity to showcase its knowledge and expertise in chassis and vehicle design while remaining true to one of our core value: 'to add speed, add lightness'. From the design and optimisation of the bespoke front push rod suspension system to the exceptional stiffness and compliance compromise of the rear suspension, every single technical aspect has been pushed. Thanks to this approach, Lotus managed to design and deliver a vehicle suspension system that is 10% lighter than the original benchmark target whilst maintaining all other product attributes including stiffness.

The Lotus chassis team also developed innovative mounting systems optimised for the unique C-X75 hybrid powertrain, overcoming the packaging and performance challenges of the front drive motor and rear power unit.

Working closely with all chassis suppliers, using Lotus's robust product development process and adopting a cross-functional approach to vehicle design were key factors to the on-target and on-time delivery of the C-X75 chassis systems.

Lotus's experience of delivering projects across the globe for a wide range of OEMs allowed them to be flexible, proactive and responsive to change. These elements definitely helped in building a strong and successful relationship with Jaguar, Williams Advanced Engineering and other partners involved in the C-X75 programme.

Everyone at Lotus was extremely proud of the achievement and realised that this would have never been possible without the full commitment of every single member of the chassis team.

The story from the engine management team

Working closely with the engine developers, Lotus engineered a system that would be capable of meeting the control demands of the engine.

Whilst a motorsport ECU solution could have been developed to support the initial demonstration phase, the Lotus solution was to build the required control system on an already proven production platform, assuring compliance with the emissions, diagnostic and quality standards required for a low volume production vehicle.

The C-X75 program required a sophisticated control system. The system controlled 2 throttle bodies and a supercharger bypass (effectively a third throttle), the supercharger clutch, turbocharger wastegate, the port and direct injectors, fuel pumps and pressure regulation (for the two systems), intake swirl flaps, twin cam phasers and an exhaust silencer bypass. The system was also protected for secondary air injection (using the supercharger as a pump) and emissions control.

Because the Lotus EMS systems solution is developed in house we were able to react quickly to changing project requirements. An example of this was the addition of functions to limit engine speed and torque at cold oil/coolant temperatures, protecting the engine and prolonging the life of development engines. This was achieved through the use of model based software with timescales from request to implementation measured in days rather than the normal weeks or months normally required.

Although the engine and initial calibration met all of the torque and power targets, Lotus, working in conjunction with the engine design partner, were able to increase the low and mid speed torque above target levels whilst respecting the cylinder pressure limits which assured engine durability.

Calibration of the complex system and its interactions provided significant challenges, and Lotus used its facilities along with those at Jaguar to optimise performance, fuel consumption and emissions.

Cylinder pressure acquisition equipment was used in the calibration process for both basic setting optimisation and calibration of the full torque structure.

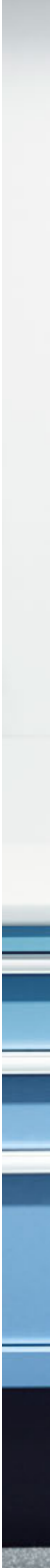
A major challenge was the management of the supercharger clutching. The supercharger is required at low engine speeds to meet the torque targets, it also needs to be clutched out at higher speeds, where the supercharger would otherwise over-speed. Lotus implemented various control strategies and techniques to manage the re-clutching of the supercharger in a way to optimise driveability.

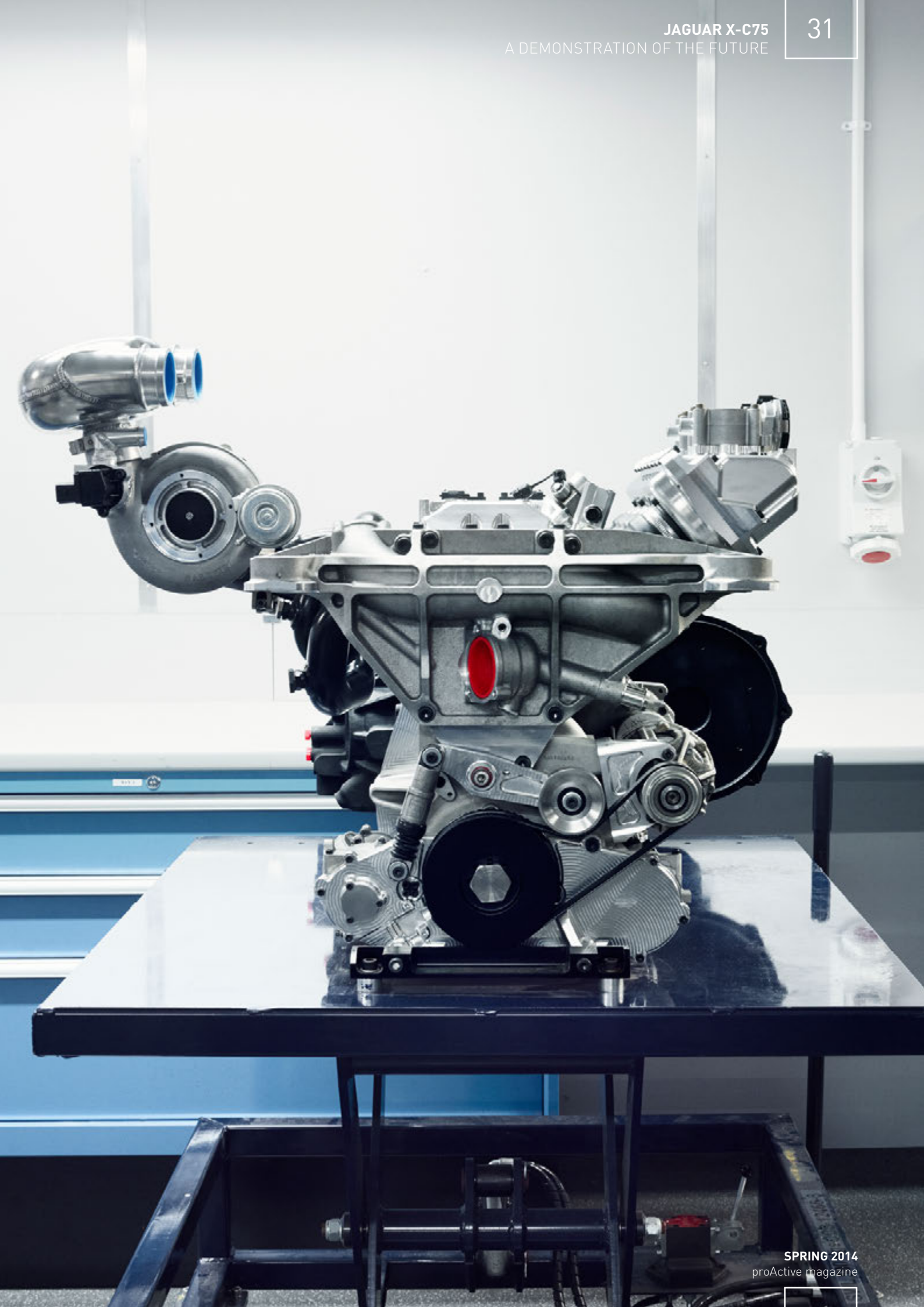
The vehicle platform is a full hybrid system, the task for the engine was to deliver the torque requested by the vehicle's hybrid controller. As there is no physical link between the accelerator pedal and the engine, the engine control is managed purely through torque requests behaving as a slave module to the vehicle controller.

In addition to engine calibration and development at Hethel, Lotus also supported transient development on the dyno at Gaydon. This facility allowed the transmission, rear motor, vehicle controller and engine management system to be developed and proven before the first application in the vehicle. Lotus worked closely with Williams' vehicle control engineers to develop vehicle launch, gear shift and dynamic response on this rig before ramping up to the aggressive vehicle tests.

Lotus also provided significant support to vehicle testing and development and, although the EMS system was proven to be reliable throughout the vehicle development phase, Lotus were able to assist with rapid diagnosis of development issues thanks to the diagnostic functions carried over from the Lotus production control system.

The success of the program is measured not only in the phenomenal performance of the engine and vehicle, but also in the delivery of an extremely technically challenging project on time and within budget. Lotus is very proud to have supported the development of one of history's highest specific power output engines, with 313 bhp per litre, and to have provided an engine control system capable of not only producing this level of performance but also to have produced a system which produced the prototype vehicles with a good level of refinement and driveabilty.





C-X75 delivered

The combined, collaborative project team delivered an outstanding fleet of five prototype supercars that has showcased many of UK's car industry capabilities.

This car exceeded the expectations of many and proved throughout its development and public appearance phase to be an effective and robust demonstration of the exceptional capabilities. One of the key moments for the C-X75 was being driven up the hill with the legends at the Goodwood Festival of Speed in June 2013.

Writers:
Andy Wright, Andy Green, Steve Williams, Fabien Dall'ara, Gareth Jones and Roger Tudor

During the Silverstone C-X75 team event in April 2013, hosted by Jaguar and Williams Advanced Engineering, Lotus was recognised by Bob Joyce, Jaguar Engineering Director, as one of the major contributors to the programme.

Key points were Lotus' strengths in utilising experience and knowledge, producing high quality work, delivered with effective communication and management.

3D Printing

The 3rd Industrial Revolution?

It has been dubbed as the *'third industrial revolution'* by the likes of 'The Economist', a technological breakthrough that could have the same lasting impact on manufacturing as the mechanisation of the textile industry did in the latter years of the 18th century, writes Ian Adcock.

It's being billed as having the game-changing potential of Henry Ford's first modern production line for the Model T just over a century ago in 1913.

'It' is direct digital manufacturing (DDM) or 3D printing. That's certainly the view held by Stratasys CEO, David Reis, when he unveiled the company's biggest 3D printer, the Objet 1000 in Frankfurt at the end of 2012.

Of course, as boss of one of the world's leading manufacturers of 3D printing machines you would expect him to say that, but there's increasing evidence that manufacturers and governments alike, are similarly convinced.

"3D or Additive Manufacturing (AM) is seen by the US Government as a means of repatriating jobs back to the USA from the Far East and Asia," says Reis. *"It's a parallel situation here in Europe with comparable investment funding 3D printing and research. Three million jobs from Europe were lost to Asia with similar numbers in USA, and governments think that 3D printing is one of the pillars to bring manufacturing back home. There's a lot of excitement about it."*

As part of his Administration's 'We Can't Wait' initiative, President Obama announced steps to launch a pilot institute to serve as proof-of concept for the National Additive Manufacturing Innovation Institute (rebranded as 'America Makes' in October 2013) based in Youngstown, Ohio. Five federal agencies: the Departments of Defense, Energy, and Commerce, the National Science Foundation, and NASA, jointly committed to invest USD 45 million in a pilot institute on additive manufacturing. The announcement of an initial USD 30 million award under existing authorities is matched by USD 40 million from the winning

consortium.

Meanwhile, the UK Government is committed to investing GBP 15 million to establish a national centre for 3D printing at the Manufacturing Technology Centre (MTC) in Coventry.

Reis is bullish, naturally, about the future, predicting the market will have more than tripled in size to USD 6 billion by 2019 with new entries coming into the market with various technologies to solve problems in both metal and plastic printing. Venture capitalists are said to be eager to jump on the AM bandwagon.

To date 3D printing has been largely used to make prototype parts or products for testing, and it's this requirement in the automotive industry that led to the development of the Objet 1000.

It has a large (1,000x800x500 mm) envelope that, says Reis allows users to produce bigger assemblies, of up to 200 kg, in one piece. Combine that with a selection of 123 materials, including those that simulate ABS plastic, and a flexible range with Shore A values from 27 to 95 and a capability to combine up to 14 materials in a single model and its versatility is immediately apparent.

"Before the Objet 1000, automotive users had to produce fascias in two halves and glue them together, now they can do a 1:1 model straight off," explains Reis.

The Objet 1000's design was influenced by automotive users who were taken to see early prototypes. *"They told us they wanted easier material handling and a window at the side to ensure everything is working as it should."*

Reis sees a future for smaller desktop 3D printers that will allow small engineering and design jobs to be reproduced quickly and easily before full scale versions are produced by a rapid prototyping centre. *"I think if we do our job properly in the auto industry, we will deepen our penetration to the rapid prototyping centre but, at the same time, bring the technology to the engineer's desktop."*

Stratasys has already moved ahead with the announcement earlier this year at the Las Vegas

Consumer Electronic Show of its ground-breaking Objet500 Connex3 colour multi-material 3D Printer, the first 3D printer to combine colours with multi-material 3D printing. It features a unique triple-jetting technology that combines droplets of three base materials to produce parts with virtually unlimited combinations of rigid, flexible, and transparent colour materials as well as colour digital materials, all in a single print run. This ability to achieve the characteristics of an assembled part without assembly or painting is a significant time-saver. It helps product manufacturers validate designs and make good decisions earlier before committing to manufacturing, and bring products to market faster.

Probably just as significant is the announcement from US-based Mark Forged, founded by Gregory Mark (a partner in racing car wing manufacturer, Aeromotions), that it has developed the world's first 3D printer to use carbon fibre, fibreglass, nylon or thermoplastic PLA.

The machine maybe small (it measures just 574x360x322 mm), but so were the early 3D printers and if this can be scaled up successfully it could be used for larger carbon fibre structures and be the breakthrough needed if carbon fibre is to become a more widely used material in mass production in the OEM's quest for lighter vehicles.

To date companies have tended to use 3D printing to produce prototype parts, or products for testing much quicker than traditional model making processes. Luxury car maker Bentley is a typical example. It has been employing 3D printing in one form or another since Project 614, better known as the Continental GT, which was launched a decade ago in 2004.

Bentley has an Objet 30 and Connex 500 and has been trialling an Up!Plus+ desktop printer for very accurate interior parts such as knurling on knobs and other switchgear. The Connex is used for a variety of parts from the interior as well as exterior features such as grilles and radiator shells; even though the machine can only make parts to around 500 mm Bentley is able to stitch them together to make a 1.2 m trim parts.

Through its bespoke Mulliner division, Bentley offers clients a wide range of personalised trim and fittings and, whereas in the past these models would be made from rigid foam to give a client an idea of the finished article, it now produces them much more quickly using 3D printers. And, whilst its dealer network, as yet, doesn't have 3D printers in their showrooms it would be entirely feasible for the customer to discuss their requirements with the designer at Crewe and for those parts to be reproduced in the showroom via the 3D printer.

However, the true potential of AM will be realised when it makes the transition from design shop or modelling studio to the factory floor.

Traditional manufacturing employs 'subtractive' techniques that create waste and demand lengthy assembly processes, whereas AM is an additive process that creates minimal waste in addition to enabling complex assemblies to be produced in a single process.

It's a stretch of the imagination but is it possible that vehicle assembly plants as we know them today won't exist? In their place, instead, vast 3D printing and DDM machines will be manufacturing complete vehicles in one hit. That might sound more like 'Star Wars' than 'Car Wars', but NASA has been reported as researching the feasibility of orbiting 3D printer stations and then delivering the base materials to assemble complete spacecraft.

That might be complete blue sky thinking, but already several of the world's biggest manufacturers, like General Electric, EADS and Siemens are leading the 3D march from studio to production line.

Since January, Siemens power generation and maintenance division has been using 3D printing to manufacture spares and other components for its gas turbines; currently it can produce 100 different parts with the result that some repairs can be done in a tenth of the normal time.

"High-temperature turbine parts are probably one of the most challenging applications for 3D printing," Nicolas Vortmeyer, chief technology officer at Siemens' power generation division told the Financial Times. *"It's not the easiest application of 3D printing because in turbo machinery you have some of the highest temperatures and stress and strains."*

Siemens believes 3D printing could be a game-changer in the supply of spare parts which are currently mass produced, stored and distributed as needed. Why not save all the storage space and transport costs, it is argued, by printing the part close to the customer?

According to Wohlers Associates, the automotive sector is the second biggest user of 3D printers after consumer products, but it is lagging the aerospace sector in utilising its potential.

GKN and EADS are developing a 3D printed titanium bracket that takes 40 minutes to print

compared to four hours machining, whilst reducing the bill of materials by 30 per cent.

Even more impressive is GE Aviation's plans to manufacture fuel nozzles for its new Leap engine that will power Boeing's 737 MAX and Airbus A320neo, from 2016, using 3D printers.

Each engine contains 19 nozzles and GE predicts it will make between 30,000 and 35,000 a year by 2020, requiring between 60 and 80 printers.

Currently each nozzle comprises twenty components that have to be cast, machined and assembled. By using 3D printing it can be produced in one piece resulting in a 75 per cent weight saving and with a predicted five times' greater life span.

For some observers 3D printing is little more than a sophisticated toy used to manufacture Iron Man's suit or the giant robot warriors in '*Pacific Rim*' and that it isn't the manufacturing game-changer many predict.

This seems to be borne out by a recent report from Morgan Stanley which says that 73 per cent of manufacturers view it as a prototyping tool and only 23 per cent for production. Among the factors holding back the mass adoption of 3D printing is the cost of the machines and the materials used which, in some cases can be 50 to 100 times that of more traditional materials; although both of those arguments have to be countered by the fact that with increased demand will come reduced costs.

What potential users will really want along with reduced costs, is improved speed.

Machines that are ten times faster than they currently are would make manufacturers sit up and take notice, but it doesn't automatically follow that there would be a total manufacturing revolution overnight or, even, in the long run.

Instead 3D printing, AM, DDM whatever you like to call it, will in the long run become another tool that can be used to design, engineer and manufacture components and intricate assemblies.

Writer: Ian Adcock

△ Just-auto.com

Below: Stratasys Objet 1000 has a large (1,000x800x500 mm) envelope that allows users to produce bigger assemblies, of up to 200 kg, in one piece

David Lindley

Managing Director SMTC UK

Top: David Lindley at SAIC Motor UK Technical Centre

SAIC Motor Technical Centre UK (SMTC UK) works on designing, developing and engineering advanced new vehicle and powertrain products for SAIC Motor, one of the world's largest automotive manufacturers and owner of the MG marque. Dave Leggett caught up with SMTC UK's managing director, David Lindley.

Can you describe the background and history to the UK SAIC Technical Centre's operation?

It started around 2004/05 when SAIC was in discussion with MG Rover about putting together a joint venture.

At that time I was head of 'concept engineering' at MG Rover, so I was getting involved in technical discussions looking at what initial vehicle concepts might emerge out of that joint venture and what the portfolio of products might look like.

Alongside that was the commercial discussion, that I wasn't involved with, but I was building the relationship with the guy put in place to lead the technical centre in Shanghai as part of the new business they were trying to create at SAIC.

When MG Rover collapsed in April 2005, I was contacted by him, on behalf of SAIC, to discuss whether there was any way we could retain the best engineers from MG Rover who had been working on those programmes and also from the powertrain (PTL) area.

The objective at the time was to take some of the best people with a view to continuing the work that we had started. There were a number of options to think about. One was to

start a whole new business.

That was a complicated thing to do quickly at the time. Another option was to see if there was a consultancy that we could set up with and that very quickly narrowed down to one particular consultancy, Ricardo, primarily because they already had a relationship with SAIC. They also had a physical presence near Longbridge, so in terms of geography and trying to retain key staff, that helped. They also had the space and logistics to accommodate our group. It was a very good fit really.

So we set up the initial technical centre business with Ricardo (it was called at that point 'Ricardo 2010'). But there was an option for SAIC to buy it for a small nominal sum. The initial investment to set up the business came from SAIC and it was decided at the outset that the business would be dedicated to working solely for SAIC. From the start, we were working on vehicle, powertrain and styling for SAIC.

We were successful in recruiting a team of engineers from MG Rover and PTL. Within the first two months we had put in place around 70 engineers. Ricardo provided a small group to help us manage the business, particularly the infrastructure that was needed.

SAIC purchased the business, as planned, in 2007, after we had been running for almost two years. In 2008 SAIC acquired Nanjing Auto (NAC), who had bought assets of MG Rover in 2005, including the Longbridge site. Effectively, the SAIC purchase of NAC brought those assets and the engineering side of things all back together. It made sense to consolidate the technical centre back to the Longbridge site where there was office space available and a commitment to manufacture already in place (the MGTF).

So at the end of 2008 we moved from Ricardo's Leamington premises to Longbridge and from that point, SAIC has invested a considerable sum. Turnover in the UK business is over GBP 300m. There has been GBP 8m in capital investment at Longbridge, including a completely new IT system and also a new styling studio and new engine testing facilities.

So the Nanjing acquisition brought a big change in the whole strategy?

Yes. Up until that point, the strategy was based on the Roewe brand and its potential as an international brand. The acquisition of NAC led us into looking at the strategy for MG. MG has since become the international brand for our business with Roewe focused on the Chinese domestic market. So we have built a product strategy and portfolio around those two brands.

Can you give an overview of how the two brands' product portfolios look now?

Nearly all of the current portfolio is new and has been engineered since the start of the Technical centre in 2005.

On the MG side there's the MG3 (B-segment hatch), MG5 (lower priced C-segment hatch), MG6 (higher priced C-segment fastback). There are a couple of other MG products coming to market soon, one is an SUV. On the Roewe side, the product starts with the Roewe 350 (Saloon engineered from the same platform as the MG5), Roewe 550 (Saloon engineered from same platform as the MG6) and the Roewe 950. The 950 is a saloon based on the GM Epsilon 2 platform, a longer wheelbase version of the platform that underpins the Vauxhall Insignia in the UK. It will be using our own powertrain, though it has been launched initially with GM powertrain. Additional to that is an SUV named Roewe W5.

Also in the Roewe range is a small EV, a city car sized pure electric 3 door hatchback vehicle and there is also a plug-in hybrid version of the Roewe 550 using a hybrid transmission that has been engineered internally.

The UK technical centre has played a key role in the design and engineering of the majority of these products as part of the global team.

When the business started, some of the old MG Rover products were on sale, but they have just about finished now.

How did the use of the GM platform come about?

That's down to the long-standing relationship between SAIC and GM. That has allowed us to talk to GM about technology sharing and has led us to be able to use that GM large car architecture in China and has also led to a joint development program for small capacity direct injection petrol engines which will be used in our future vehicles.

That saves cost on the engineering side then?

Yes, but also we are a relatively young business trying to grow rapidly and we only have so much capacity to engineer new products so selectively working with a partner can ease that situation.

How are things organised in the UK?

There are two businesses in the UK, both coming under the banner of SAIC Motor Passenger Vehicles (SMPV). The two UK arms under SMPV are MG UK and SMTC UK. We're both on the same site and work closely together. MG UK concentrates on the UK manufacturing and sales and marketing for MG product. At the moment, that's all for sale into the UK marketplace, but in the future will include sale into mainland Europe. MG UK is currently producing the MG3 and MG6 with final assembly in UK, but the plan is to expand the product range and move into new markets.

SMTC UK is a technical centre focused on engineering and design. We are fully integrated into the global SMPV technical centre activities. There are actually three technical centres as part of that. The headquarters is in Shanghai where there are 2,600 people employed currently and it is growing rapidly. The Longbridge technical centre employs around 300 and there is a further technical centre in Nanjing that has around 200 staff.

At SMTC UK we are working on the full range of SMPV global products, including both MG and Roewe. With that 300 people resource here we have a level of technical capability across the functions needed to deliver a new car. So that includes chassis, body, trim, electrical, vehicle integration, including packaging and safety, testing and validation.

On the powertrain side, we have people on engines and transmissions, and also powertrain integration. And there is also a styling function.

So, how is SMTC UK organised?

The vision for the SMTC UK is to be the most valuable part of the SMPV global technical centre and we have some agreed positioning. At this point in time, that means we focus on four key areas of competence.

1. Advanced engineering. A lot of that is about creating new vehicle architecture with a particular emphasis on second generation products, which we have been focused on for some time now. We're now moving to an architecture approach where we are trying to get greater bandwidth to support products in different market segments and that can be manufactured between different sites, with scale economies and manufacturing flexibility. It's very much along the lines of Volkswagen's MQB kind of approach.
2. The second area is styling, including engineering feasibility support. We have a studio in place in Longbridge which currently houses 4 full size plates, 5 axis milling and a virtual reality facility. One of the reasons for the design element at Longbridge is to tap in to the British element in the MG brand, although we are not only working on the MG brand; we are also doing some Roewe styling at Longbridge. There are 35 people in the UK design team.
3. The third area is engines and engine application. We have taken a global leadership role for the concept, design and engineering of two new engine families for SAIC. One was a fairly conventional small capacity engine family which includes the 1.5 litre 4-cylinder engine that is found in the MG3. The other is a larger capacity more state of the art direct injection engine family which has been developed jointly with a major European consultancy. We are looking to maintain a leadership role and focus on new engines in the future.

4. The fourth area is support for MG UK. That means supporting the introduction of product for Europe, local validation, local target setting, benchmarking and also supporting MG UK manufacturing and aftersales operations, to ensure quality and customer satisfaction.

And how does SMTC UK relate to other parts of the SMPV technical centre?

Since we started the business in 2005, we have become completely integrated as a function. We operate as part of a global function rather than as a separate entity in terms of organisation and operation. It's a single global organisational structure, with clear global leadership and then local leadership in the UK and Nanjing technical centres. We have adopted common policies, methodologies and procedures across the group. We have some level of responsibility for engineers that we put into the China technical centre as expatriates and vice versa. Our key focus is those four key competencies that I have described so that we are supporting global product delivery programmes in vehicle and in powertrain. The China technical centre is the headquarters, so it is leading the strategy in all of these programmes. Our role is to provide very high value engineering skills as a fully integrated part of the process.

And is the work you do in the UK highly integrated with China?

Yes, we are leading in those four areas but we will be working closely with people in China. The advanced engineering work where we can take a lead, will also involve working in an integrated way with other engineers in China. For example, we can take a leading role in the concept layout of a new vehicle architecture, but we would also be working closely with engineers in China who are part of the same team. We will be working closely with Chinese colleagues on a daily basis, rather than, say, handing over our bit of the process when it's finished. It's a highly integrated approach to optimise the use of skill-sets and resources.

And Nanjing's responsibilities?

Nanjing is mainly responsible for manufacturing and aftersales support for the cars that are built there.

Just thinking about the domestic and international brand strategies and the products being developed accordingly, can you pick out differences in what, say, the product strategy for China and for international markets should be? Or is there a convergence in what the markets require these days?

A lot of the movement in the Chinese market has been and is towards international brands and a more premium pricing position. There's almost a two tier pricing structure in Chinese vehicle segments. So one would be, typically, lower cost domestic brands. The other tier is higher priced joint venture product manufactured locally with an international partner and brand, or imported.

There is a desire for European styling, to an extent, but there is also some differentiation. So, for example, there is still a very strong desire for a sedan-type product rather than hatchback and that applies also in small cars.

In terms of design language, it's a more complex situation. Roewe, for example, we are promoting as a Chinese brand and you have to understand the whole environment, culture, history, what inspires Chinese people. Getting a feel for that is vital to understanding what sorts of design cues in a vehicle may appeal.

I would say that, generally, the Chinese market is a more conservative market in terms of how people like to see cars styled.

How is the design work within SMVP organised?

We have design studios in the UK and in China, so that we can get the right balance of influences in the cars that we are designing. The China studio is the headquarters, with 160 staff and that is a pretty big set up. That's led by Tony Williams who used to head up the UK studio, which is now led by Martin Uhlarik, formerly of Nissan's London studio. Both studios work on Roewe and MG designs. In the initial stages, they will typically be in 'friendly

competition' when we are looking at different themes. The UK studio does not work on all products, but on the ones where it is thought we can add most value.

How about communication? Is English mainly used in the technical centre?

Yes, English is the main business language within the technical centre. Obviously if a meeting comprises all Chinese participants, they'll use Chinese, but English is adopted in mixed meetings. We also have live translation at times.

We do travel a fair bit, but we can use things like video conferencing. We also have a single IT infrastructure and have high-speed networks in place to ensure that communications support our high level of integration. We have common equipment policies, common software, systems and licensing arrangements wherever we can and where it is cost-effective.

We also have a proportion of our UK people working as expatriates (around 10% of our workforce) in China and vice versa and that helps build relationships and understanding. There's also a constant level of business travel for engineers shuttling between Shanghai and Longbridge, as well as travel for things like extended periods of training.

How does the whole SMVP technical centre organisation look?

There are 3,000 engineers across the three technical centres. It's organised by technical areas of competence, so there is chassis engineering, group trim, group body, electrical and so on. The other side of that matrix is vehicle line teams, which include engineering programme management and chief engineers for each of our main product lines. Within each function, whether a technical area or a product line function, there is a global director, usually based in China. And there is a vice director who is usually based in UK. Their joint objective is to work together as a team to maximise the value and synergy of the global resources that they have available. They are also jointly tasked with looking at capability building, including recruitment and training in their respective areas. They both have to think about the whole picture, UK and China. And they are both responsible for providing technical direction to their team and the success of that direction.

And your role specifically? What does that involve?

My primary role is managing director for the SMTC UK; that takes up 95% of my time. As part of that I am also a vice-president of the global engineering function's technical committee, which acts as a kind of board for the technical centre.

I take part in regular reviews of the engineering strategy for everything we are doing. So that's looking at things like strategies for capability build, facilities investment. I take part in a weekly meeting specifically as part of that and that can last 3-4 hours.

I am also involved in other global meetings that involve major projects and important parts of our work at SMTC UK.

In addition I have responsibility for developing advanced engineering within our global business, which can mean looking at how we work on things like creating new vehicle architectures.

I have a small level of responsibility for MG UK. I get involved with UK product manufacturing quality.

And in the UK I am also directly involved with managing the whole operation, the facility, how we maintain and develop our capabilities in every sense.

How many ex-Rover people do you have?

Initially, it was high because of how we came into being. It is changing though. We are gradually bringing in more people from other OEMs, Tier 1 suppliers and also more people from mainland Europe. The broadening is a positive thing, helping to bring a bit of a change to the culture we have. We now probably have around 50% of our staff as having worked for MG Rover or PTL.

How do you see the future for SMTC UK?

It's pretty positive on the basis of how we are planning to expand, both into new geographical territories and with more product, which will create increased demand within SAIC

for the work that we can do. The more we sell around the world, the greater is the case for a substantial element of local engineering. So what happens in the European marketplace is obviously key for us.

I think we'll probably be involved in more advanced design work for MG, really looking at its design DNA and how trends are moving in the European marketplace.

We'll be increasingly looking to be creative and 'leap frog' rather than be fast followers of technology. We'll move more heavily into the research side. On powertrain I expect we'll be working on advanced propulsion technologies.

A lot of our philosophy is to do things ourselves, own the technology rather than partner up. We have been through some pain on electric vehicles and hybrids, for example, and that learning on first-gen products puts us in a very good position for the future.

Writer: Dave Leggett

△ just-auto.com

Emissions

EU vehicle legislation

Review of CO_2 legislation and taxes

The United Nations Framework Convention on Climate Change (UNFCCC) is an environmental treaty that looks to prevent man-made changes to the climate system.

Out of this comes the Kyoto Protocol where many nations have agreed legally binding targets for reducing greenhouse gases. This has introduced trading in greenhouse gases, where credits can be purchased to offset reduction targets.

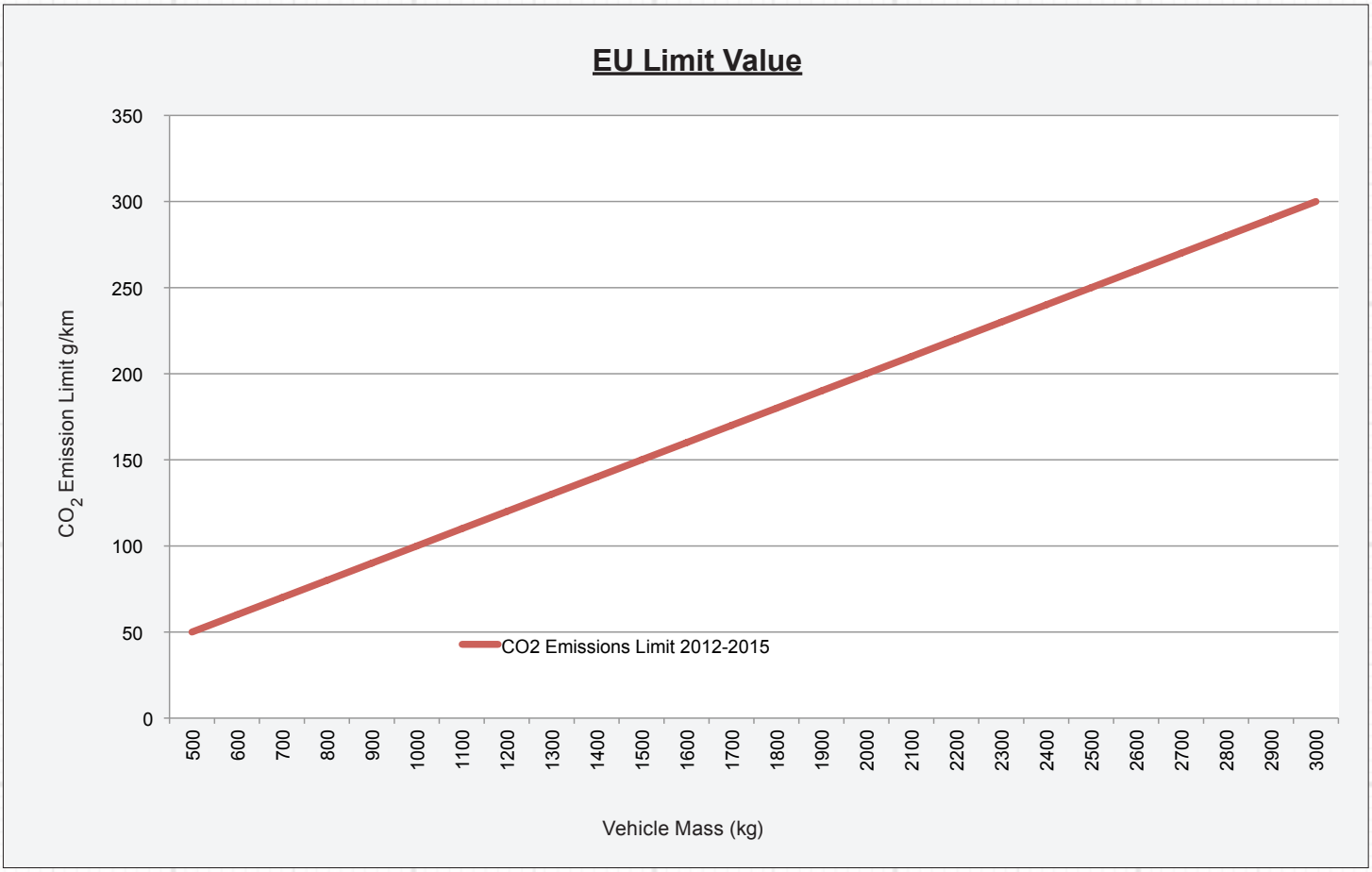
As governments worldwide strive to lower their country's emissions, there are knock-on effects to many industries, including the automotive industry.

These effects have implications on vehicle manufacturers, and implications to customers purchasing the vehicles. One would like to think that these are harmonised across nations but unfortunately, this is not so. It is a complex picture of CO_2 and fuel consumption that, at the end of the day, influences model line-up and vehicle sales. For the larger markets, there are penalties that an OEM would need to pay if their vehicles do not meet emissions or fuel consumption targets.

This article reviews the EU market as an example however, the next edition of proActive will take a look at two other major markets that apply regulatory penalties, namely US and China.

Testing and Certification:

Each vehicle type must undergo emissions testing to certify for fuel consumption, CO_2 and criteria emissions. This sets the 'official' certified figures for each vehicle. In the case of CO_2, the tested value must be within 4% of the certified or manufacturer declared figure.



Penalties for OEMs in the EU

The EU is one of the regions that apply penalties to vehicle manufacturers. From 2012 onwards, legislation has been in force that states a target level of emissions for a given vehicle mass.

The fleet average mass therefore has an associated target of tailpipe emissions of CO_2 in g/km. There is a penalty in Euros (EUR) per gramme of CO_2 that the target is missed by. So if a manufacturer matches or betters their target, no penalty needs to be paid. There is also a staggered approach where the first gramme over target costs EUR 5, the second EUR 15, the third EUR 25 and the fourth and over is EUR 95. From 2019, every gramme over the target will cost EUR 95

Emissions limits are set according to the mass of the vehicle, using a limit value curve (actually, a straight line). The limit value curve is set in such a way that a fleet average of 130 grammes of CO_2 per kilometre is achieved by 2015. The limit value curve means that heavier cars are allowed higher emissions than lighter cars while preserving the overall fleet average. Only the fleet average is regulated, so manufacturers are still able to make vehicles with emissions above the limit value curve provided these are balanced by vehicles below the curve.

The fleet average of 130 g/km will be phased in between 2012 and 2015. In 2012, an average of 65% of each manufacturer's newly registered cars must comply with the limit value curve.

This will rise to 75% in 2013, 80% in 2014 and the full 100% from 2015 onwards. There is a long term target to further reduce the fleet average emissions to 95 g/km for the year 2020 however; this proposal requires approval by the European Parliament and Council to become law.

It is recognised that small volume manufacturers (SVMs) do not have the R&D budgets that large manufacturers have and they are less likely to be able to invest in technologies that will reduce tailpipe CO_2. SVMs are defined as manufacturers that sell less than 10,000 vehicles in the EU and as such, they can apply for a derogation. This derogation effectively sets a higher CO_2 target than the regulation based purely on vehicle weight alone, and is a much more manageable target to meet. The derogation lasts up to five years and can be re-negotiated however; it would not be taken gladly if an SVM is not seen to be making changes to reduce their overall CO_2 emissions.

Many SVMs for example Porsche and Ferrari,

are embracing the latest hybrid technologies and manufacturing sports cars that blend performance with reduced CO_2 levels, albeit on 'halo' products with premium pricing.

Lotus has a current derogation which finishes at the end of 2016 and so to avoid penalties from 2017 onwards, the derogation will be re-negotiated.

There are additional details and clauses in the ruling such as 'super credits' and 'eco-innovations'.

There are more incentives for car manufacturers to produce vehicles with very low emissions (sub 50 g/km) where each low-emitting car counted as 3.5 vehicles in 2012 and 2013, 2.5 vehicles in 2014, 1.5 vehicles in 2015 and then 1 vehicle from 2016 onwards.

Manufacturers that sell pure EVs will therefore have an additional means to reduce their fleet average.

For eco-innovations, certain technologies cannot demonstrate their CO_2 reducing effects under the test procedures used for type-approval.

However, manufacturers can use independently verified data to be granted credits equivalent to up to 7 g/km for their fleet if eco-innovations are in place.

EU customer taxes

The method of applying penalties is harmonised across all member states of the EU however, the taxes a customer pays are not.

This creates a complex and somewhat confusing picture, making it difficult for a vehicle manufacturer to commonise vehicle models to suit all EU tax classifications and levels. Every member state has VAT applicable at point of sale, however, the rate is not common, it varies from around 15% to up to 27%. Per country there are additional taxes that may be one-off or recurrent, based on a number of metrics that differ country to country.

In addition to the requirement to meet fleet average targets, manufacturers also need to be aware of the vehicle tax bands in different markets as the declared CO_2 value can have a significant impact on sales.

The many different methods of taxation within the EU member states create a complex system that is difficult to convey in a short summary. Therefore, what follows are examples of how vehicles are taxed in a few of the major EU markets:

France

There is VAT applicable at a rate of 20%. There is a first registration fee that varies from region to region, based on official government tables of fiscal horsepower. There is an annual tax for keeping a vehicle which is a flat rate of EUR 160 if the tailpipe CO_2 emissions exceed 190 g/km. Below this figure it is EUR 0. The largest tax a customer pays however, is in addition to those already mentioned and is from the 'Bonus-Malus' scheme operating in France. This is a table of fees payable based on the CO_2 value of the car. For the least emitting vehicles, a tax credit is paid to a customer and for zero emitting vehicles this can be as high as EUR 6,500. Credits are paid at varying levels until 90 g/km. Between 90 g and 130 g; there is a band of zero credits or taxes. Above 130 g, the customer starts to have to pay taxes with the first band being EUR 150 and the most expensive, for the most polluting vehicles (200 g and above) at EUR 8,000.

UK

There is VAT applicable at 20% and a first registration fee of GBP 55. Then there is the Vehicle Excise Duty or 'Tax disc'. The rate payable is based on the CO_2 emissions of the vehicle, starting at GBP 0, with bands of increasing values up to GBP 1,065 for the first year. Subsequent annual renewals are generally less expensive but still based on the 13 bands of CO_2 emissions, with the most expensive for vehicles over 255 g/km set at GBP 490. The VED bands and rates are reviewed regularly by the UK Government and changes usually announced as part of the Chancellor's annual budget statement.

Germany:

VAT equivalent at 19%. One annual tax based on engine size. And a second annual tax based on tailpipe CO_2 for vehicles over 95 g/km, this tax is set at EUR 2 for each gramme per kilometre over 95 g.

Italy

VAT at 22%. There are 3 new registration fees, two of them fixed, one that varies based on the power of the car. There are 2 annual road taxes, one based on the EU poisonous emissions level, fuel and power. The second annual tax is a 'supertax' of EUR 20 for every kilowatt of power above 185 kW.

What can be done to lessen the penalties and tax burdens?

It's testament to the development skills of engineers that generally, cars have become heavier, more laden with content, yet with better fuel economy than ever before.

Downsized, pressure-charged direct injection gasoline engines are now commonplace and benchmarking studies show that when compared with 'old' multi-point injection, a typical benefit of 15 to 20 g/km CO_2 can be seen.

Diesel engines continue to be more fuel-efficient and refined. Stop start systems are starting to be considered the norm.

There are still improvements to be had with 'conventional engineering' not just with powertrains but the whole vehicle as well.

Rolling resistance, aerodynamic drag and friction reduction are all being considered, with a possible 30% improvement to be gained as all of these small individual improvements start to add up.

One area where fuel economy and emissions improvements are demonstrated is with models that incorporate hybrid and electric technologies.

Toyota has been the market leader for over a decade, building up their technology from the first Prius in 1997. The development of the Prius continued with each generation of the model, each one improving on the last. It's only (relatively) recently that the hybrid powertrain has been rolled out across their standard range of vehicles and currently Toyota have six models available with hybrid drive.

There is room in the market for many solutions and derivatives. There are examples where manufacturers choose to hybridise or electrify their combustion counterpart, usually by integrating off the shelf hybridised transmissions from 'traditional' gearbox manufacturers, such as ZF. There are also examples such as the BMW i3 and i8 where an entirely new sub-brand has been created as a platform for hybrid and electric powertrains.

Closing remarks

For the EU, the CO_2 regulation is well understood and harmonised for all member states.

On the other hand, the customer taxes are not harmonised at all. This makes it difficult, if not impossible, for a manufacturer to optimise a vehicle model that would suit all member states. The situation forces manufacturers to have diverse model range and vehicle specifications.

The clever bit is to be able to offer this diversity and still have the economies of scale that commonised components and systems will provide.

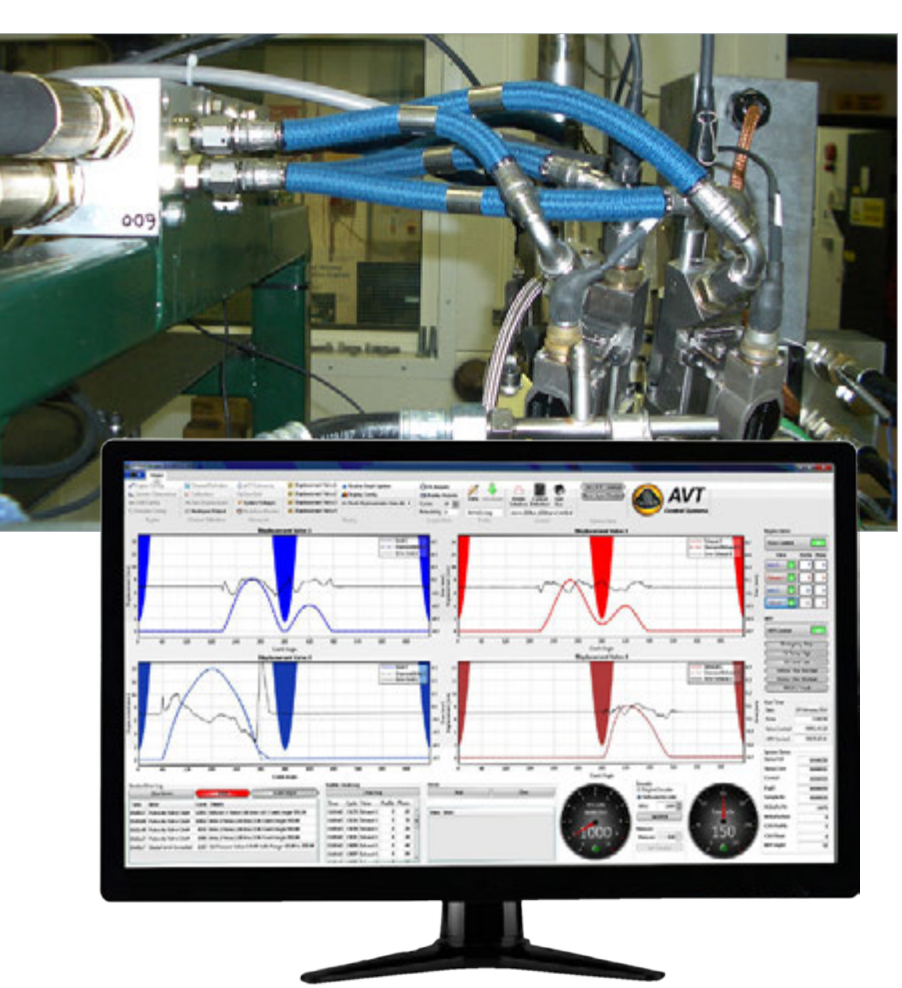
It can be seen with large OEMs, that they are creating additional models that further segment the vehicle classes, for example, Audi now have a model range consisting of many more models compared with their line-up just 10 years ago. A similar message is given out by BMW when their current model line-up is compared to 10 years ago.

Additionally, in-depth knowledge of current and future legislation and taxes needs to dovetail into product planning strategy so that the vehicle specifications, model line-up and marketing will all be factors in minimising the penalties for the OEMs and the tax burdens for the customers.

The next edition of proActive will review the situation in China and the US, taking a look at how the fuel consumption and tailpipe CO_2 regulations are structured and how the penalties are applied. Additionally, the customer taxation will be reviewed for these markets and will bring up some interesting information, particularly in China regarding sales price points.

Writer: Phil Barker

△ Chief Engineer for Hybrid and Electric Vehicles, Lotus Engineering



Active Valve Train

Expanding Combustion Knowledge

Our background, education, work experience and exposure to technologies often results in us being trained to a way of thinking so thoroughly, that we're sometimes unable to think differently to give us the cutting edge we need. It's that *'thinking outside the box'* phrase we've come to hear and loath. Breaking out of that proverbial box requires courage, innovation and investment.

In the engine design world, it's a paradigm shift in thinking which leads the exploring engineer into engine combustion strategies which are possible with the use of a variable valve train system, in particular, our Lotus Active Vallve Train (AVT) system.

But, it's not just about seeing data from a different angle. It's about access to new and previously unavailable data, this is what makes the difference. It's a dream world of a valve control system operating in real time and adjusting individual valves according to the demands of the ECU.

A world where the physical link between the crankshaft and the valves is completely decoupled, thus enabling the opening of valves at every stroke to run as a two-stroke or as a conventional four-stroke operation, and even to venture into six-stroke and eight-stroke combustion.

Multiple exhaust valve events become a reality and a whole spectrum of new combustion strategies becomes possible.

With over 30 Lotus AVT systems now sold worldwide, it's important that we take note of global market trends and client feedback as we forge ahead into a strong legislatively-driven world of emissions control and fuel economy. The research departments of major OEMs, research institutes and universities

> *"Before we received the Lotus AVT system I thought that we will get an extremely complicated system on board which might cause several issues in daily operation and in case of something going wrong the result would be a catastrophe. Now, after the first year of operation I learned that this system is the most reliable system we do have in our testing environment. No day, even no hour of dyno downtime was caused by the Lotus system. It simply worked perfectly without attracting attention"*
>
> **Manager, German OEM**

around the world benefit from the ability to control each valve independently with the potential for cycle to cycle variation and high operating speeds up to 8,000 revolutions per minute using the latest AVT system.

So, what is AVT?

The Lotus Active Valve Train (AVT) is an electro-hydraulic product which is used for engine research and incorporates the independent and flexible control of engine valves on adapted client engines, meaning any number of engine valves can be operated at any one time using any available lift profile. It is a sophisticated research tool, for use in engine test cells and incorporates many engineering disciplines: mechanical and hydraulic, electrical and electronic, software and control. It is used in a variety of investigative spheres: performance and combustion strategies, engine and fuel design, emissions control and efficiency.

Instead of the conventional camshaft and return springs which control engine valve movement in a fixed relationship, AVT gives true fully flexible and variable engine valve movement without any need for a camshaft. It is camless valve operation with no return springs. The opening and closing of engine valves is controlled electronically, and operated hydraulically, which gives full control of individual engine valve lift profiles for client engines. It provides a tool for faster in-depth research into advanced combustion strategies, performance and fuel economy and is the enabler for advanced low temperature combustion techniques such as HCCI/CAI.

A hydraulic power pack supplies pressurised hydraulic fluid to the electro-hydraulic servo valves which control the flow of hydraulic fluid proportionally to either the top or bottom of each double-acting actuator piston which connects to an engine valve. This enables control of the velocity, timing and lift displacement of the engine valves for each individual crankshaft degree of rotation. It is possible to vary the opening and closing points of fully definable profiles individually in one-degree increments while lift is adjustable to any valid figure between 0.01 mm and the maximum travel of the actuator (around 15 or 16 mm).

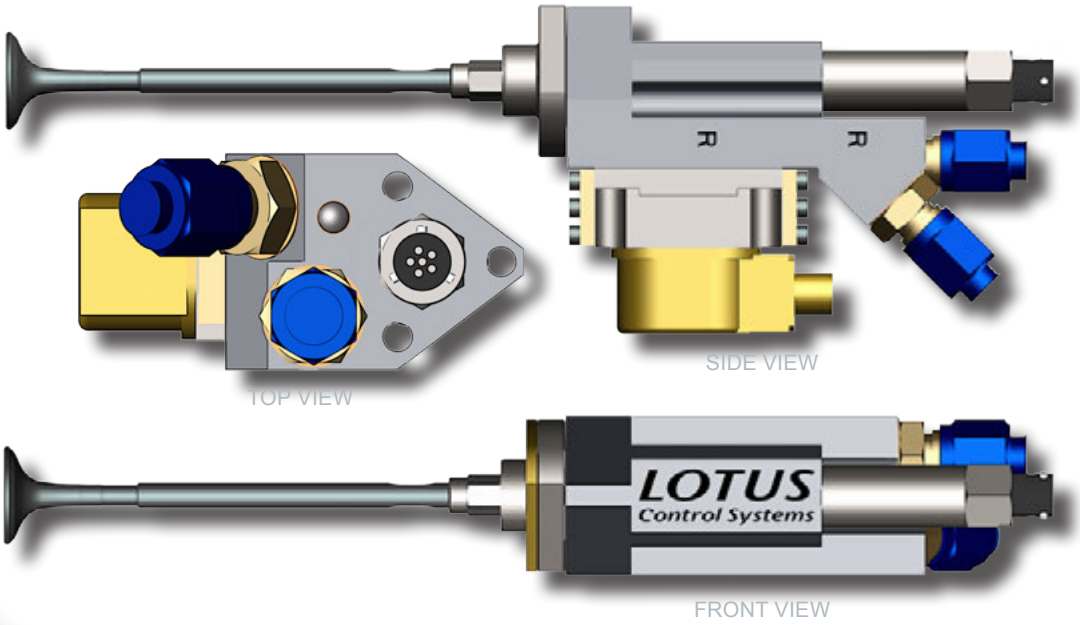
The system employs a closed-loop control algorithm with displacement feedback to detect and correct the actual measured displacement towards achieving the desired displacement (it's a phase-advanced PID control algorithm). Further optimisation of the profile is achieved by adjusting the algorithm tuning parameters manually. The effects of this manual tuning can be observed immediately and gives a visual check on the quality of fit between the demanded and achieved profiles. With a sampling rate of 40 kHz, the system status is monitored to identify potential malfunctions triggered by alarms, hydraulic pressure loss or valve to piston clash scenarios, etc.

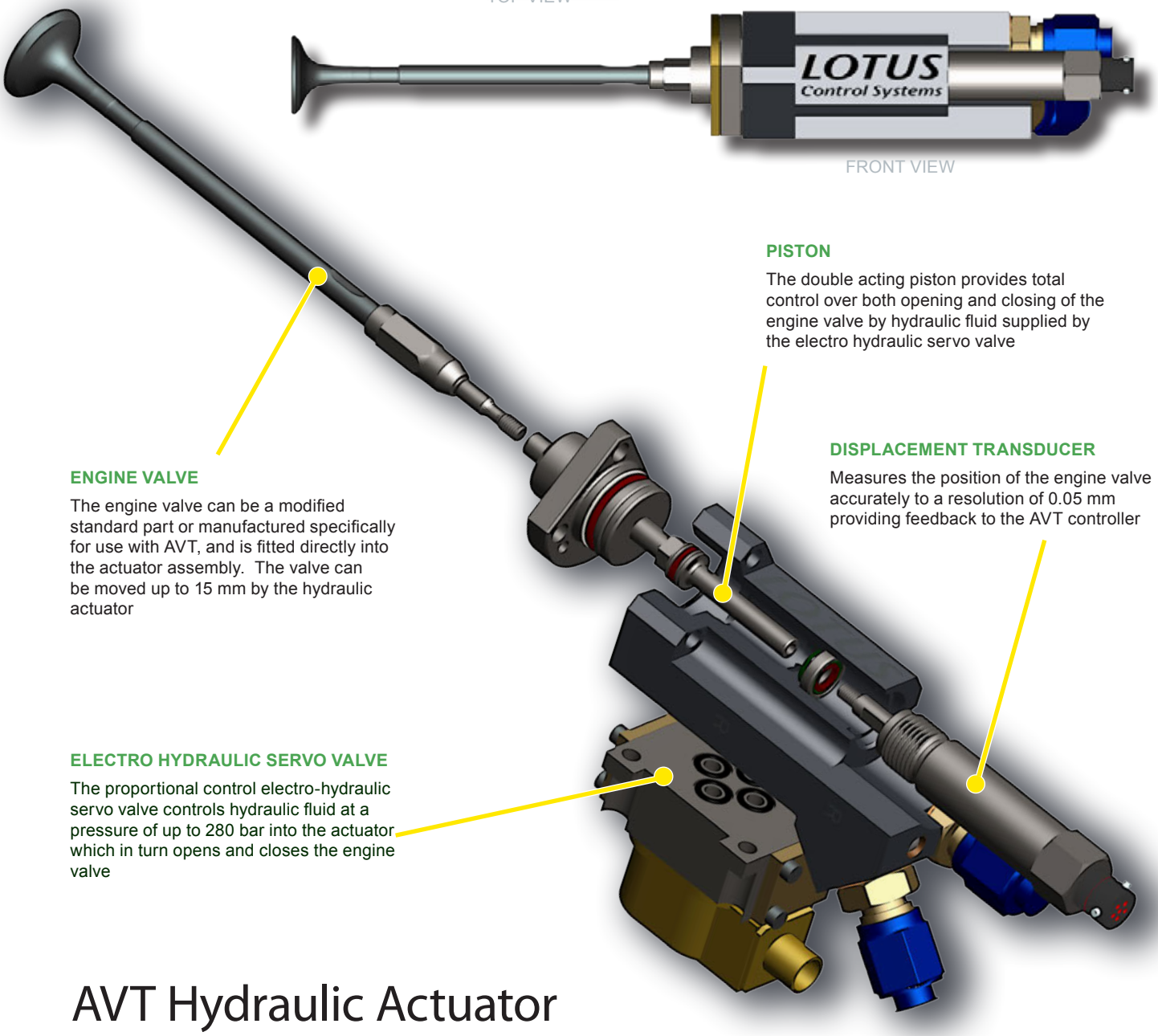
The Lotus designed multi-layer IOI (Input-Output Interface) PCB and electronics make for convenient connection to client facilities and safety interlocks, thus ensuring compatibility and the protection of personnel and equipment in what is a high-stressed control environment. The processing power of the PC is harnessed by the Lotus IOI plug-in board thus enabling us to concentrate on the control process while leaving processing speed and power to the PC manufacturer.

The PC-based user interface will be familiar to modern software users. The Microsoft interface provides an ease of use which is clear, configurable and intuitive. The monitoring of engine speed and system pressure takes place alongside profile switching and control of valve actuation and parameter tuning, to name but a few.

The ability to switch profiles is one of the significant advantages of using the AVT system. During an engine test session, it is possible to select any valve profile from a library of 128 lift profiles for each engine valve.

Each of the profiles can also be phase advanced or retarded by 128 degrees. If required, whilst the engine is running, a lift profile can be switched in real





ENGINE VALVE

The engine valve can be a modified standard part or manufactured specifically for use with AVT, and is fitted directly into the actuator assembly. The valve can be moved up to 15 mm by the hydraulic actuator

PISTON

The double acting piston provides total control over both opening and closing of the engine valve by hydraulic fluid supplied by the electro hydraulic servo valve

DISPLACEMENT TRANSDUCER

Measures the position of the engine valve accurately to a resolution of 0.05 mm providing feedback to the AVT controller

ELECTRO HYDRAULIC SERVO VALVE

The proportional control electro-hydraulic servo valve controls hydraulic fluid at a pressure of up to 280 bar into the actuator which in turn opens and closes the engine valve

AVT Hydraulic Actuator

time. The profile itself can contain as many lift events as are physically possible to implement. For example an engine can be configured to switch between two and four stroke combustion. Recognising that this cannot be performed manually for any length of time, the instructions for such operations can be linked to the client ECU via the CAN bus. This allows the programmatic introduction of a different profile based on the decision-making assigned to the ECU software and could relate to any optimal engine condition during the test, for example, exhaust emissions or engine performance.

Even though there is a limitation to using only one profile library (of 128 profiles) at a time, the discerning engineer will have any number of libraries available at their disposal so that these can be used as required.

The build-up of profile libraries becomes the knowledge base of the engineer and libraries of many thousands of lift profiles can be specified for use in their engine test programs.

In addition to supplying the AVT system, we offer installation, commissioning, training and support.

This is vital because clients who have made significant investments in the technology like to know that they are supported.

Customer relationships have always been considered to be crucial to our work and this has proved itself over many years. The steps from sales to project management to technical knowledge is an ongoing relationship where first names, open dialogue and confidentiality have become part and parcel of our delivery.

The results, especially in recent years, have led to clients having multiple AVT systems along with our ongoing support.

Lotus AVT in its current configuration is not a production system which is ready for OEM use in vehicles. AVT sits firmly in the test cells of the research community and this is what is often misunderstood.

We're not trying to compete with Fiat's MultiAir, Honda's VTEC or BMW's Valvetronic production systems. These are solutions for road vehicles and are optimised in operation so that they don't require the total flexibility offered by a fully variable system used for research. These are different arenas and both are very much relevant to production and to research engineers.

Where do we go from here? It's a question asked often.

On at least 30 occasions to date, the Lotus AVT system was chosen to assist engineers with their combustion research work. In many cases we believe wins against other competitor systems were because we offer significant advantage and benefits in research which cannot be easily matched.

At the time of writing (March 2014), we're communicating with ten different (mainly) existing clients across the globe including seven major OEMs: three in the USA, three in mainland Europe and one in Japan. Discussions for assistance range from spares and support contacts in the USA and the Middle East to feasibility studies and new systems in Europe and the Far East. Interest and potential applications are high and encouraging, as engineers strive to achieve more efficient combustion systems.

We recognise that AVT needs to move beyond single cylinder application into the more demanding multi-cylinder application. We recognise too that universities are an important investment into the future and they would welcome a more targeted product.

Writer: Steve Louis

△ Control Systems, Lotus Engineering

Russell Curtis

Group Chief Engineer, Design Engineering

What are you busy with right now and can you describe your role?

My role is to coordinate the delivery from my direct reports in support of activities for our customers, and to formulate the capability development plans for the approval of the Lotus management team. Obviously our key objective is to deliver our current programmes to the satisfaction of our customers. This is a key part of my role.

We are also constantly looking to develop new business opportunities, improve our own capabilities and improve our delivery methodologies.

In addition, we are currently recruiting within the vehicle design group which should also bring in new ideas, capabilities and backgrounds so as ever this is an interesting period at Lotus.

How varied is the work? Can you give an indication of the types of design brief you get?

Very varied, we are currently supporting a full vehicle programme concept design study, a renewable energy programme with our Hybrid and Electric vehicles team and proposals with two separate OEM customers for full engine family programmes following the successful completion of concept study programmes delivered and coordinated from Hethel.

And what sort of companies commission Lotus in this area? (OEMs mainly, I presume?)

Yes, mostly large OEM customers from UK, Europe and Asia. In addition to these activities we provide support for Lotus Cars and Proton Cars. We also support smaller OEM companies and start-ups who are interested in our whole vehicle engineering experience.

Why would a third party engage Lotus for design engineering work (eg is it because Lotus offers skills/ something they typically don't have, or for capacity/cost reasons)?

Certainly cost is often a key consideration for customers, we operate in a very competitive arena.

Having said that, Lotus does have key powertrain and chassis design capabilities which are of great interest to our customers with these skills not being readily available in the marketplace.

How is the design engineering activity organised and how long do jobs normally run for? Is calibrating the right level of resource to jobs a challenge?

We have two parallel design groups: Vehicle Design and Powertrain Design. The engineers in these groups specialise in their respective fields, but can also operate within the other group if required, so giving us a very flexible resource.

Each area has technical lead engineers specialising in particular functions. These technical leads manage the design teams within the projects as well as liaising with the OEM engineering groups and the component suppliers. They also act as liaison with other functions such as CAE, development and manufacturing. In this way we have close control of our design teams and we also supplement these resources with temporary contract staff as demand dictates.

To what extent do your teams work closely with clients? Are teams working for long periods off site, with the clients?

A model which we have successfully run on recent projects is to locate a senior designer or technical lead engineer with the client for a few weeks at the start of the project to coordinate data acquisition and to develop relationship with the client's team.

This engineer then returns to Hethel as the programme develops, to coordinate the team at Hethel and to liaise with the client's engineering groups.

In this way we ensure close relationships with our client's engineering groups from an early stage.

How many engineers are there and are they all based at Hethel?

We have a relatively small team of 20 engineers within the design engineering group at present, which we supplement with contract resources as required. We can also call on our facility in Michigan, USA for additional support if needed.

Do you find there are issues with obtaining/recruiting for particular skill sets?

Certainly Powertrain and Chassis design skills are in great demand within the industry at this time so it does prove challenging to attract these skills. We are lucky at Lotus however, as engineers we talk to often recognise the

variety of programmes that they will be asked to support at Lotus and so are interested to discuss potential roles.

Even so we are currently finding that we have to recruit from outside the UK for some of these skills.

How do you market your capabilities to the industry?

Mostly our customers are very aware of our outstanding history of automotive design engineering over the years. What we do need to ensure is that our customers understand how we are developing our offerings around current technologies, such as hybrid and electric vehicles for example.

We find that a regular presence at technical conferences and automotive shows around the world, goes a long way to reminding customers of our capabilities.

Our customer base remains UK and Asia biased and we would love to develop a technical delivery capability in Europe as the demand increases.

How do you maintain client confidentiality and reassure clients about that?

All of our programmes are stored within separate vaults on the IT filer to ensure that no client data is at risk. Also, only those engineers signed-off to the project are given access to a project folder.

Similarly, all the engineering programmes are operated from separate swipe-card controlled offices. Again, only personnel approved to work on the project will be given swipe-access to these offices.

As engineers move between projects, they are allocated logins and swipe-card access to the new project.

To what extent does your team feed into Lotus Cars work?

We have always been an engineering provider to Lotus Cars programmes and have several engineers currently supporting design roles in Lotus Cars projects.

We have also taken on bespoke work packages where Lotus Cars has capacity or skills shortages.

This can be seen as an advantage for our customers in as much as our engineers are directly involved with our own Lotus Cars products, which is valuable experience that they can bring to our customer programmes.

What gives you satisfaction in your job?

As a design group, our primary role is to deliver the design programme on time, within cost and to the specification required by the customer. When we achieve this and receive a message of thanks from a happy customer, it is extremely satisfying.

It is also exciting when you see the first components coming in for the start of the powertrain or vehicle build and test phases. This is where you see the designs that you have developed in the virtual CAD and CAE environment take physical shape in a working powertrain or vehicle. It is great to see the teams gather for a first engine or first vehicle run.

Titanium Rear Subframe

Bonded titanium structures

Lotus Engineering has recently completed an exciting new project which pushed the boundaries of materials, joining and manufacturing technologies, resulting in a lightweight titanium rear subframe for the Lotus Exige S.

The adhesively bonded titanium frame is 36% (18 kg) lighter than the current high strength steel assembly. The mass reduction has been achieved whilst increasing first torsion mode by 19%, with comparable torsional stiffness, point stiffness and crash performance. This is a major achievement given the subframes' tight package and the fact the Exige S is already a lightweight sports car.

The six month collaborative project between Lotus and its partners Caged Laser Engineering and S&D Speciality Metals was funded by the Niche Vehicle Network (NVN). The objective of the project was to design and develop a rear subframe for the Lotus Exige S with a 30% mass reduction whilst attaining the same structural performance as the current steel frame.

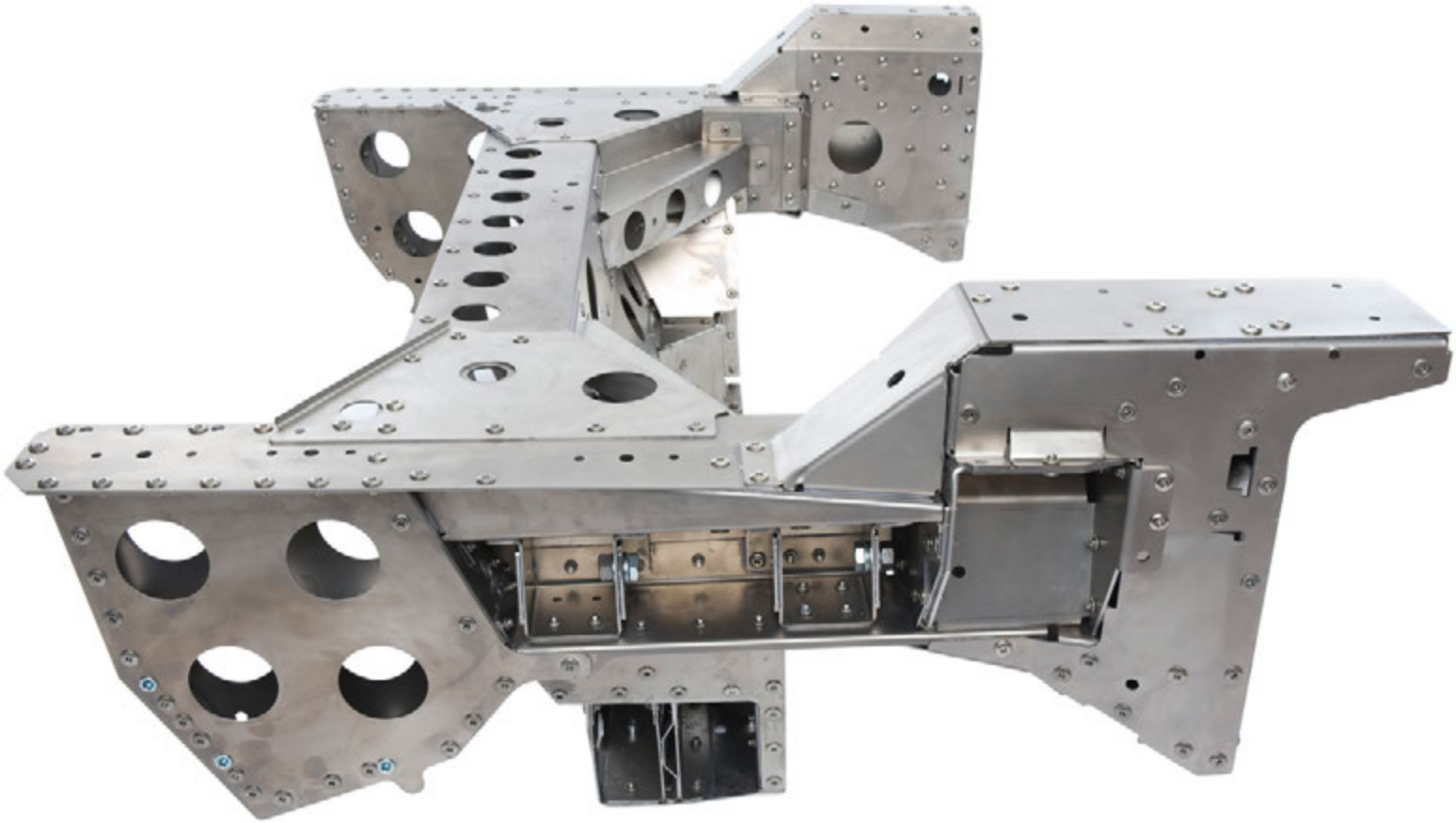
Key to the success of the project was the assessment and selection of a suitable structural adhesive and associated pre-treatment to achieve strong and durable bonded titanium joints. This included testing and evaluation of the laser ablation pre-treatment process.

Titanium is a lightweight metal which is as strong as steel, but with almost half the weight. It's also highly resistant to corrosion due to the formation of a passive oxide layer which protects the metal and requires no further corrosion protection.

Titanium is also a poor conductor of heat, which can be advantageous if a structure is required to minimise the transfer of heat, such as a subframe surrounded by an engine and exhaust system. These factors make titanium an attractive material for certain lightweight automotive parts, especially in combination with structural adhesives which are known to improve joint and overall assembly stiffness.

Project Activity Summary

The research project incorporated five main phases of work. The first phase focused on the testing and selection of a suitable adhesive and associated pre-treatment, in order to enable prototype frame build. The second phase covered the design and computer aided engineering (CAE) simulation of the frame, which included two iterative loops.



During this phase, package information was supplied to Caged Laser who led the design process with support from Lotus who conducted CAE analysis. The third phase of work involved the manufacture of a number of prototype frames to be used for various purposes including a frame destined for vehicle assessment.

Next, free modal testing was carried out on a fully assembled frame. In addition, a number of full sized test samples were produced to represent the titanium and steel (baseline) frame suspension pick up points. These samples were tested to failure using cyclic loading. The final phase is to assemble a titanium frame into a Lotus Exige S for assessment.

Overview of Exige S Rear Subframe

The rear subframe for the mid-engined Exige S is a highly loaded structural assembly which holds the 3.5 litre supercharged V6 engine. The current frame is a welded structure manufactured from high strength low alloy (HSLA) steel, which is then zinc hot dip galvanised to provide excellent corrosion protection. The frame is also designed to manage rear crash loads.

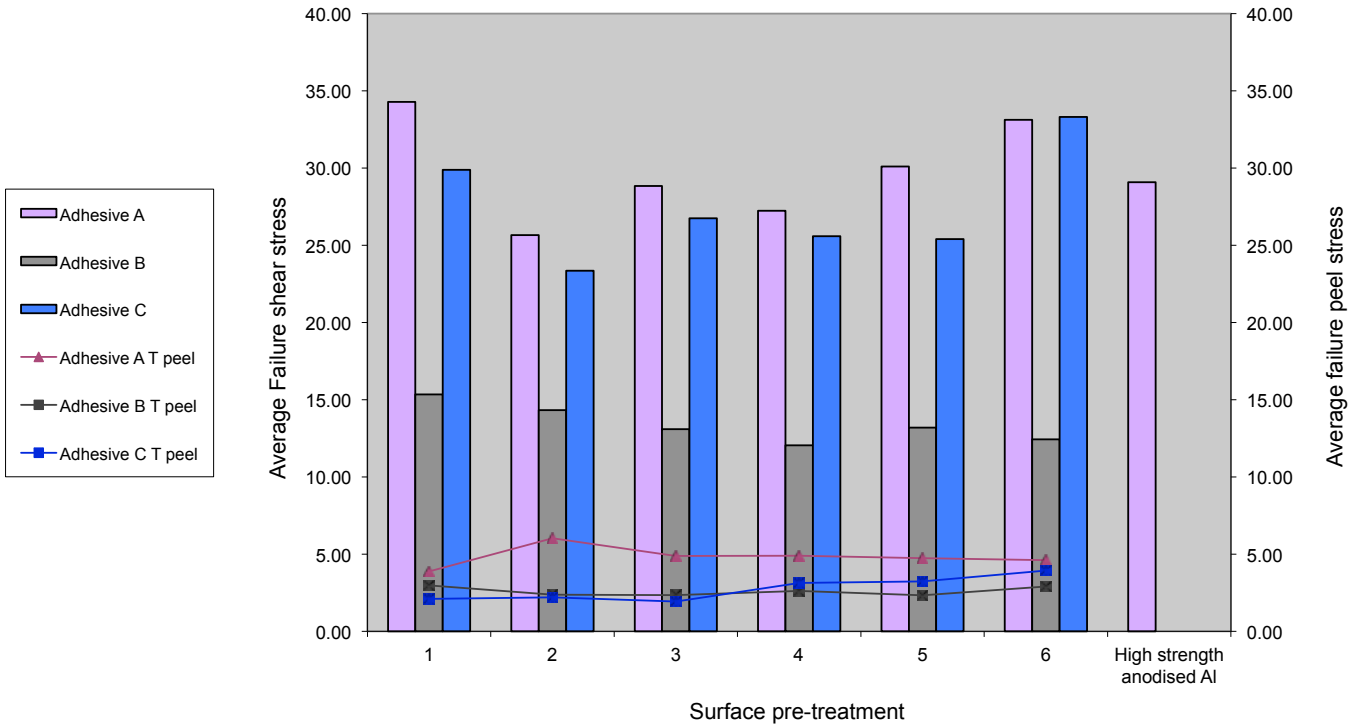
Joining Test Programme

Key to the success of the project was the joining test programme, required to assess and select the optimum adhesive and associated pre-treatment. Three separate adhesives were tested in combination with several surface pre-treatments.

The primary pre-treatment process for assessment was ablation, which is a method for the removal of material from the surface of an object by vaporisation, chipping, or other erosive processes. Ablation was carried out using an industrial laser, which imparted topographical changes to the surface of the titanium and provided a consistent contaminate free surface on which to bond.

Testing carried out by the aerospace industry has shown some promising results in terms of bond strength and durability performance for laser ablated pre-treated samples.

The joining programme was split into three separate phases and involved several tests including lap shear, sea water acetic acid (SWAAT), elevated temperature and dynamic testing.



Top: Adhesively bonded titanium average failure stress results at ambient temperature

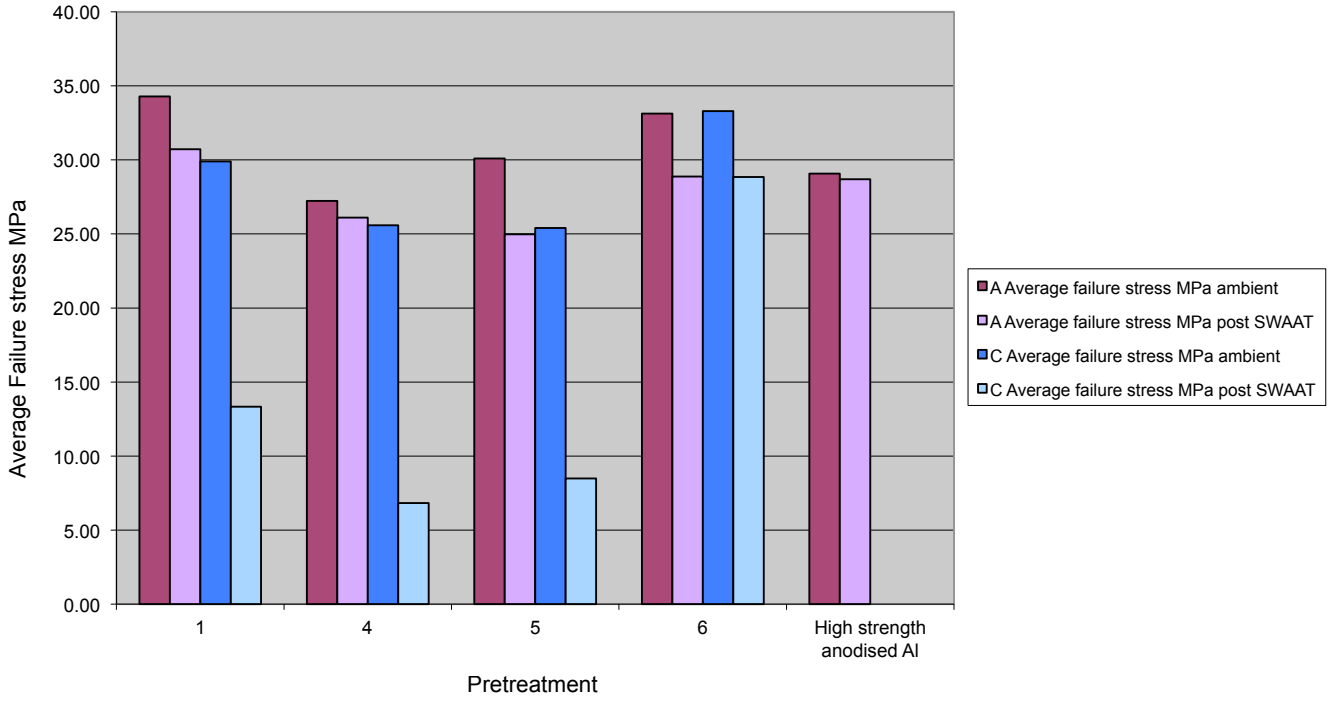
Joining Test Results

Target benchmark performance was assessed against a high strength aluminium sheet material, bonded using structural adhesive with an anodised pre-treatment supplied by Lotus Lightweight Structures. It is clear from the tests carried out that adhesive **A** performed well versus the benchmark in terms of load to failure across all pre-treatments. Adhesive **B** however, showed consistently lower results and in most cases adhesive failure. Adhesive **C** also performed well versus the benchmark. Both adhesives **A** and **C** showed cohesive failure, which accounted for the high failure loads and showed at a relatively early stage in the project that it was possible to produce a structural adhesive joint for titanium. Adhesives **A** and **C** were therefore carried forward into the next phase for further testing.

The second phase of the joining programme included the lap shear testing of bonded titanium samples after SWAAT testing, which is an extremely aggressive cyclic corrosion test used to assess bond durability. SWAAT testing of bonded joints was carried out for 1,000 hours, after which the lap shear samples were tested and compared against samples from phase 1 to indicate any potential drop off in performance. From the results it is clear that adhesive **A** performed well across all pre-treatments and showed a relatively small reduction in load to failure post SWAAT. Adhesive **C** however, gave a reduction in performance post SWAAT for three out of the four pre-treatments tested.

On further investigation it was clear that certain laser ablated samples from the batch used for SWAAT testing showed relatively minor levels of distortion or curvature due to heat input from the ablation process. Consequently, adhesive **C** was unable to fully wet the surfaces leading to lower than expected failure loads, which showed that joint performance of this particular adhesive is critically dependant on minimisation of the bond gap.

Phase 2 of the joining programme also incorporated elevated temperature testing of the adhesives to determine the influence of temperature on joint performance. Temperature measurement of the existing steel subframe was carried out early in the project and was found that local areas of the structure reached temperatures of above 200 °C after



Top: Adhesively bonded titanium average failure stress results post 1,000 hours SWAAT

extended track use, adjacent to the exhaust at its closest point to the surface of the subframe. The majority of the frame however was found to operate below 70 °C. This data was fed into the design loops in order to manage and reduce the service temperature of the titanium structure.

Elevated temperature testing of adhesives **A** and **C** showed a decline in performance with a sharper reduction in failure loads above 100 °C. This supported previous elevated temperature testing carried out by Lotus.

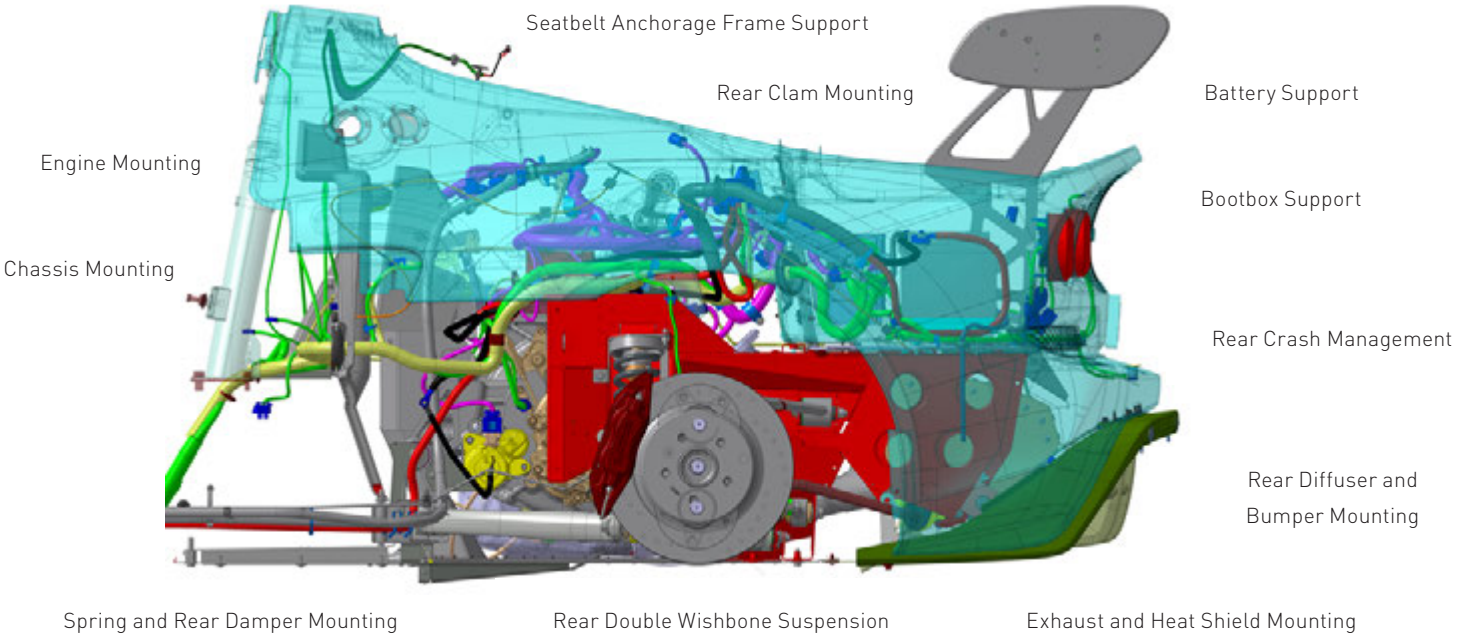
The objective of Phase 3 of the joining test programme was to assess titanium adhesive joint performance with dynamic lap shear and T-peel tests, using a Lotus designed drop rig. Results from the testing were used principally for CAE analysis in order to achieve accurate analysis for rear crash simulation. A high-speed camera was also utilised to record the failure event for subsequent evaluation.

On completion of the joining test programme, adhesive **A** was selected in combination with laser ablation pre-treatment for the joining system used to manufacture the prototype frames. Results from the tests carried out showed that titanium could be joined using structural adhesive with comparable failure loads, versus the target baseline, characterised by cohesive failure of the adhesive. In addition, the tests showed that bonded titanium joints with adhesive **A** could survive the aggressive cyclic corrosion SWAAT test, with relatively small reductions in load to failure which proved that durable joints could also be produced with the proposed joining system.

Subframe Design

Caged Laser and Lotus were extremely focussed on designing the frame to minimise mass whilst achieving the same level of performance as the steel benchmark assembly. Regular design reviews were held and the mass of the frame was tracked on a daily basis. If mass was added in a certain area of the frame to meet a stiffness target for example, then the same or ideally more mass was removed elsewhere. This approach ensured that titanium frame weight was minimised throughout the design phase and kept on target during the project.

The primary joining process for the titanium assembly was the use of structural adhesive.



However, mechanical fixings were also used in combination with the adhesive to ensure the bond flanges maintained contact during the adhesive cure cycle. In addition, fixings were used to fixture the assembly and to minimise the need for investment in assembly jigs. Mechanical fixings were also added to prevent adhesive peel in the event of a rear impact, which made a significant improvement to the crash performance of the frame based on CAE analysis.

In order to manage the elevated service temperatures of the titanium frame, additional clearance to the exhaust was added by enlarging the opening in the frame through which the exhaust is routed. This strategy was carried out in combination with the design of a lightweight aluminium heat shield to protect the most vulnerable joints from excessive temperatures. The heat shield was designed with an air gap on both sides to maximise its effectiveness.

Were possible, in conjunction with CAE, lightening holes were added to the frame to further reduce mass and offset the addition of flanges required for adhesive bonding.

CAE Analysis

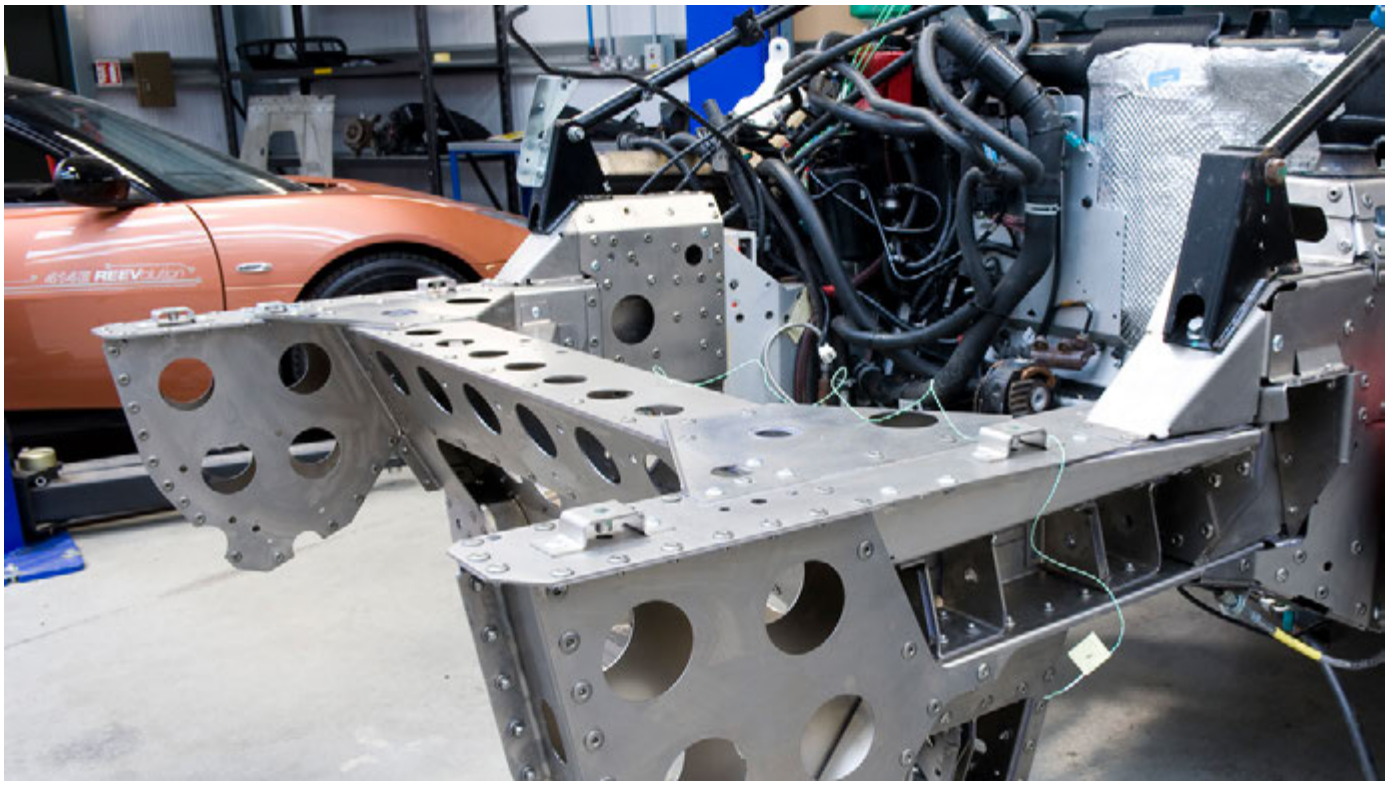
Finite element analysis (FEA) was carried out throughout the design process.

Analysis covered structural normal modes, full vehicle torsional stiffness, point stiffness, proof load evaluation and rear crash protection. At the preliminary stage of the programme, optimisation techniques were used to determine the required panel thickness of the titanium subframe to achieve comparable modal performance versus the current steel frame. Subsequently, FEA was used extensively to assess and maintain the structural performance of the titanium frame whilst reducing mass.

Data generated during the adhesive test programme was used to improve the material modelling of the adhesive for dynamic impact analysis.

Subframe Prototype Manufacture

The prototype frames were manufactured at Caged Laser Engineering's facilities in Somerset. Caged Laser and Lotus focused on ensuring the frame was designed for manufacture, especially with respect to assembly of the bonded joints. The individual titanium blanks were cut to size and pre-treated by the laser. Subsequently,



the blanks were folded to shape using standard tooling for minimal investment. Adhesive was applied to all matching faces, and structural rivets were added to pre-cut holes produced by the laser to locate each individual part. Only a single low cost fixture was required to brace the final assembly during the adhesive cure cycle, in order to prevent distortion of the subframe in the oven.

Subframe Prototype Testing

Several test samples were designed and manufactured to accurately represent the wishbone mounting hard points of the titanium bonded and current steel subframe. Both the titanium and steel samples were subjected to cyclic load rig testing at Lotus. In addition, a free modal test was conducted on a finished frame to determine torsion frequency and compared against the CAE analysis results.

Project Outcome

The final weight of the titanium frame is 32 kg, which equates to an 36% reduction versus the current steel frame, exceeding the original project target of 30% .

In addition, the titanium bonded frame showed comparable torsional stiffness for full body, with a 19% increase in first torsion mode, as the adhesive joints improved load bearing capacity, compared to the steel spot welded frame.

This factor also accounted for improvements in peak stress levels for various load cases. Rear crash analysis showed that buckling behaviour was comparable to the steel benchmark, with no leakage of the fuel tank after rear impact.

At the time of print, the titanium subframe is now assembled into an Exige S development car and will undergo assessment over the next few weeks.

The six month project has shown how integration of lightweight materials and state of the art joining technologies can significantly reduce the mass of an already lightweight sports car.

Lotus will continue in its pursuit of reducing vehicle weight by research and development of new materials and process technologies. This approach will ensure Lotus cars remain the lightest in their class.

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ENGINEERING

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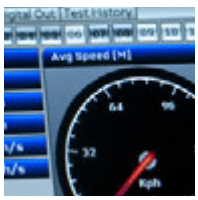


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