
# proActive

ISSUE 50 - AUTUMN 2013

# BLOODHOUND SSC

*INTERVIEW WITH RICHARD NOBLE AND MARK CHAPMAN*

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


LOTUS
OBS 255
EVORA S

**LOTUSCARS.COM**

6), Combined 28.7 - 31.4 (9.9 - 9.0). $CO_2$ emissions: 229 - 210 g/km. Model shown is Evora S Sports Racer with manual
d Premium Sport Plus interior trim.












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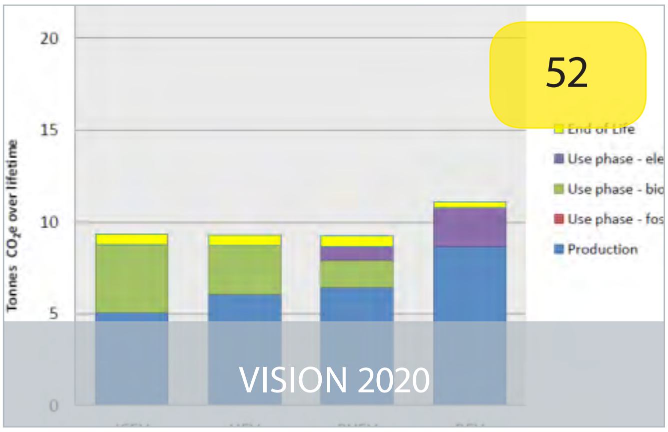
Image front cover (Richard Noble)
credit: Stefan Marjoram and
(Bloodhound SSC) credit: Siemens NX



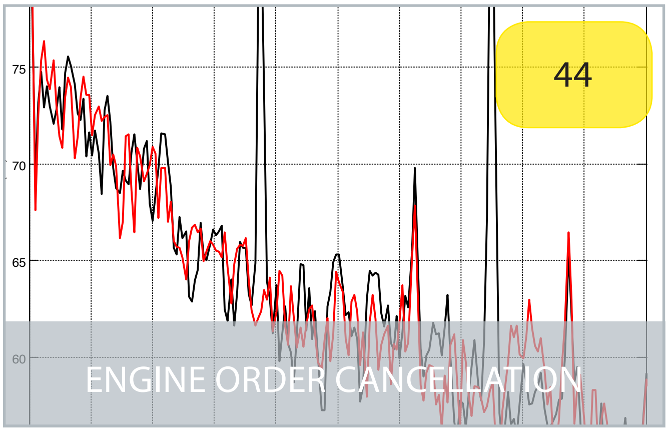










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# Lotus News

## Lotus Cars at Auto Zürich 2013

**Demonstrating Lotus' continued commitment to the exclusive Swiss market, the Lotus range was displayed at Auto Zürich 2013.**

### Elise S Club Racer

The fresh and funky Elise S Club Racer reflects the purity of Lotus design and vehicle dynamics. Evolved from the hugely popular 'Club Racer' variant of Lotus' entry level 1.6 litre Elise, the lighter-weight, enthusiast orientated package is now available on the supercharged 1.8 litre Elise S. The Club Racer concept comprises fun colour schemes, the innovative application of materials and enhanced driving dynamics and performance, all of which make for a compelling purchase for Lotus purists and track day enthusiasts.

The Elise S Club Racer benefits from a maximum 19 kg weight reduction over the standard Elise S and as such rewards the driver with heightened performance. Due to the improved power to weight ratio the Elise S Club Racer delivers 243 PS per 1,000 kg, accelerates to 100 km/h from standing in 4.6 seconds, and reaches a top speed of 233 km/h.

### Exige S Roadster

Appearing alongside the Elise S Club Racer, was the Exige S Roadster. As capable as its coupé counterpart, the Exige S Roadster retains all the intent of a focused sports car but also possesses the poise of a sleek convertible.

Powered by the same 3.5L V6 as the coupé variants and weighing in 10 kg less than the Exige S at 1,166 kg, none of the exhilarating performance of the phenomenal Exige range is compromised, yet the driver is only 'two clicks and a roll' away from cruising in open-top style thanks to the lightweight, factory fitted soft top.


Achieving 0-100 km/h from standing in 4 seconds, delivering 350 PS at 7,000 rpm and 400 Nm of torque at 4,500 rpm, the Roadster matches the coupé's mechanical performance. Style takes an understated approach having shed its rear wing and front splitter to maximise airflow over its sleek silhouette. The Exige S Roadster is the perfect car for a 'joy' ride; what better way is there to enjoy the panoramic views of the world's most beautiful roads than when they are enhanced by the purposeful roar of a V6 soundtrack and to feel the wind in your hair and sun on your skin?

## Exige V6 Cup

Distinctly recognisable as the offspring of the Exige S, the Exige V6 Cup takes performance to the next level. Visually compelling, the Exige V6 Cup comes with bespoke liveries and interior schemes, courtesy of the skilled team at Lotus Design.

Derived from the Exige S and bred specifically for racing, the Exige V6 Cup weighs in at 1,110 kg and is powered by the same 3.5 litre supercharged V6 engine.

## Evora Sports Racer

A visually enhanced and optimised version of the mid-engined 3.5 litre V6 Evora.

Available in both naturally-aspirated and supercharged variants, the Evora Sports Racer proves its value on the pocket, as well as on the road and track.

The main 'Sports Racer' receives a unique exterior colour scheme with an optimised interior to match. Secondly, it comes fully loaded, boasting Lotus' ultimate specification.


# Lotus Motorsport announces new Elise Cup R

**Following the success of the Exige V6 Cup and its hardcore sibling the Exige V6 Cup R, the Lotus Elise S is adorned with the Lotus Motorsport magic to present the track-only Elise S Cup R.**

Evolving from the 1.6 litre Elise platform, this is the first time the supercharged Elise S' mid-mounted, transverse, 1.8 litre 2ZR-FE engine has been used in a Cup variant. Priced at £39,125 + VAT and boasting bespoke livery and aerodynamic body kit, the Elise S Cup R showcases the marriage of form and function perfectly so that performance is optimised yet retains its stylish and iconic aesthetic.

Performance is enhanced over the road-going Elise S thanks to a motorsport specific engine control module (ECM) and a CFD proved aero pack comprising; front splitter, barge boards, winglets, rear diffuser, floor extensions and rear wing. Despite the extra body kit and race-ready additions, Lotus Motorsport manages to maintain the road car's light weight of just 924 kg. These modifications and the clever manipulation of air-flow to create extra downforce, combined with adjustable damper and springs, reduces lap times by 4 seconds on a 5 km lap over the standard Elise S.

The Lotus S Elise Cup R is eligible for entry to the production class in the 2014 Lotus Cup series which operates under the banners Lotus Cup UK, Lotus Cup Europe, Lotus Cup Italia, Lotus Cup USA, Lotus Cup Japan, Lotus Cup Thailand, Lotus Cup China and Lotus Ladies Cup.

## LOTUS ELISE CUP

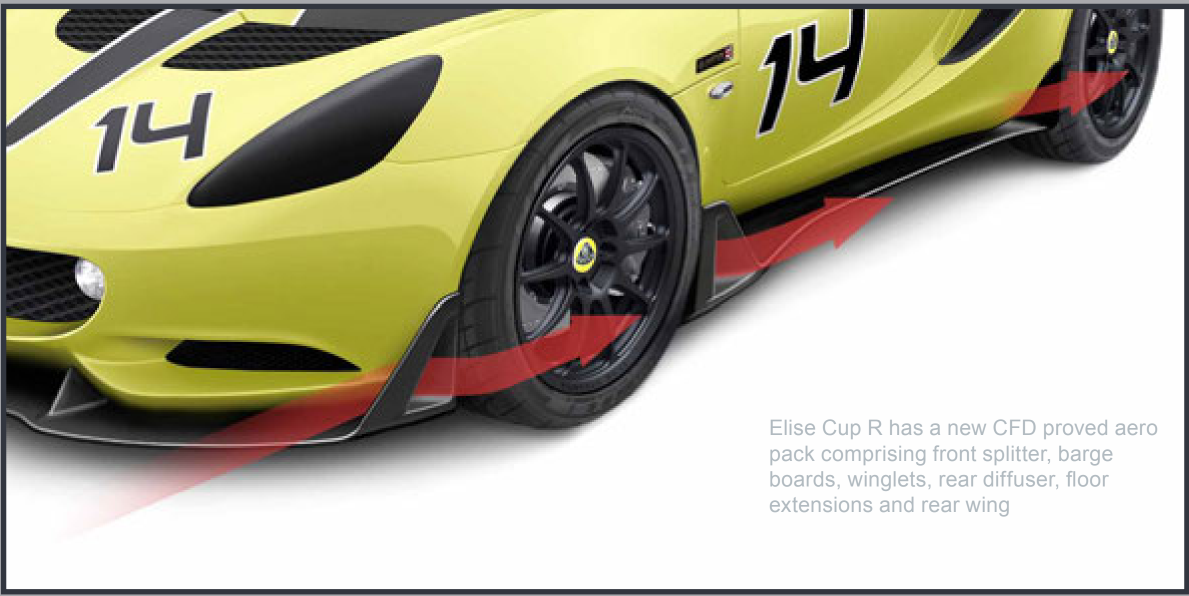
| |
|---|
| Eligible to race in the following series: |
| Lotus Cup Europe |
| Lotus Cup UK |
| Lotus Cup USA |
| Lotus Cup Italy |
| Lotus Cup Thailand |
| Lotus Cup Japan |
| Elise Trophy |

## PERFORMANCE SPECIFICATION

| | |
|---|---|
| Max Power | 1.8S 220 PS @ 6800 rpm* |
| Max Torque | 1.8S 250 Nm @ 4600 rpm |
| Max Engine Revs | 7000 rpm |
| Fuel Rating | 98 RON minimum |
| Engine Position | Transverse mid-mounted |
| Unladen Vehicle Mass | 900 kg** |

## POWERTRAIN SPECIFICATION

| | |
|---|---|
| Engine | All alloy, 1.8 litre DOHC 4 cylinder dual VVT-i and valvematic, 16-valve with Magnusson R900 supercharger utilising Eaton TUS technology |
| Engine Management | Lotus EFI controller |
| Diagnostics | MIL |
| Gearbox | 6 speed manual with sports ratios |
| Gear Shift | H pattern |
| Exhaust System | Sports stainless steel silencer |
| Exhaust Noise | 98 dB (A) at 3/4 max rpm |
| Battery | Lightweight performance battery |




Elise Cup R has a new CFD proved aero pack comprising front splitter, barge boards, winglets, rear diffuser, floor extensions and rear wing

# Lotus F1 Team targets third place in the constructors championship

**Kimi retains third place in the Drivers' Championship on 183 points; 34 behind Fernando Alonso in second. Romain remains in seventh position with 114 points; trailing Nico Rosberg by 45. The team remains fourth in the Constructors' Championship on 297 points from Ferrari's 323, with third spot remaining a firm target heading into the final two races of the season.**

## Kimi takes another P2 at the Hungarian GP

Kimi Räikkönen took second place at the Hungaroring. Kimi used a two-stop strategy for his sixth podium of the season, spurring the advances of Sebastian Vettel in the final laps. Romain Grosjean drove a storming race, withstanding a drive-through penalty and a twenty second addition to his race time to finish in sixth position.

## Team suffers disappointment at Spa in Belgium

Neither Kimi Räikkönen or Romain Grosjean had the best of starts, with both drivers beginning mid-grid in P8 and P7 respectively. Both drivers lost places during the first laps and struggled in regaining them. As Kimi begun his challenge it became clear that he had brake issues. The problem continued to escalate, thwarting his efforts until his race abruptly came to an end on lap 26. Brake failure meant the four-time Spa winner had to retire, bringing to an end Raikkonen's 28 consecutive point-scoring finishes.

## No celebrations at Italian GP

Neither Lotus managed to get through to Q3 in Saturday afternoon qualifying at the Autodromo Nazionale Monza, with both drivers suffering first lap collisions, Kimi with the rear end of Perez' McLaren and Romain rear-ended by Force India's Paul Di Resta. Both drivers did their best to battle back up the grid finishing the race with Kimi in P11 and Romain in the points at P8.

## Kimi takes P3 whilst Romain had a forced retirement at Singapore GP

Kimi Räikkönen drove through the pain barrier to finish in a superb third position, whilst Romain Grosjean felt pain of a different kind after a forced retirement whilst battling for his own potential podium finish in the Singapore Grand Prix.

## Return to a double podium at Korea

Lotus F1 Team scored its third double podium of the season as Kimi Räikkönen took second and Romain Grosjean third in an emphatic team performance at the Korean Grand Prix. Both drivers benefited from strong race pace and drove superbly – including dicing with each other – during a race which saw two safety car periods.

## Grosjean takes third at Japanese GP

Another strong performance for Lotus F1 Team saw Romain Grosjean take a fighting third, whilst team-mate Kimi Räikkönen battled his way to fifth in a tense Japanese Grand Prix at Suzuka. A superb start from Romain saw him lead in the early stages, before fighting hard with both Red Bulls in the latter stages. Kimi endured a tough start, dropping back to P11, before battling in typical fashion to climb up the order.

## Grosjean takes another podium in India despite starting at seventeenth

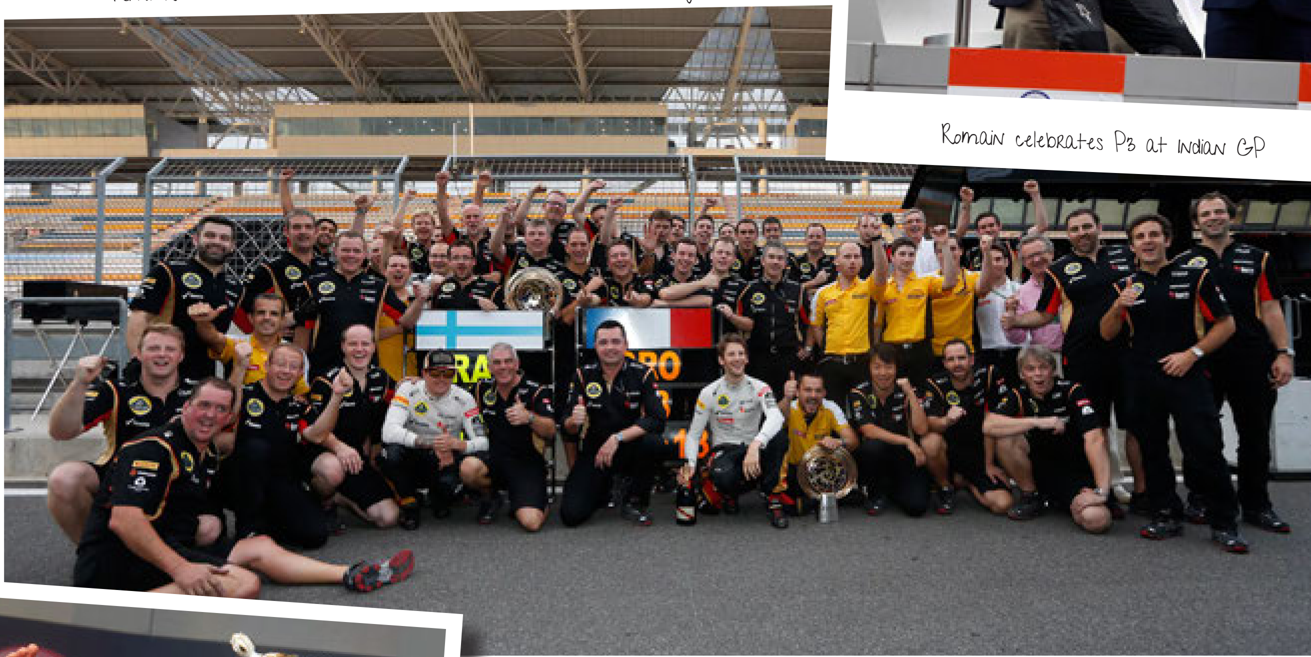
Romain Grosjean drove a perfect race from seventeenth on the Indian Grand Prix grid to third at the chequered flag, despite enduring problems with his engine's pneumatic system, whilst Kimi Räikkönen found the limits of his tyre's performance as the team attempted a one-stop strategy.

## Romain takes P4 at Abu Dhabi

Romain Grosjean produced a strong drive to take fourth place in the Abu Dhabi Grand Prix from sixth on the grid, whilst Kimi Räikkönen's race ended in retirement following contact at the first corner.

Kimi Raikkonen leads Paul di Resta and Daniel Ricciardo in Singapore GP


Romain celebrates P3 at Indian GP



Double podium for team at Korean GP

Kimi celebrates P2 at Hungary GP

Grosjean leads into the first corner at the Japanese GP


# Industry News

## TECHNOLOGY: New driver aids from Toyota, Mini and Ford

**Toyota, Mini and Ford have all announced new driver aids that are either available now or under development.**

Toyota will, within a few years, expand its currently available pre-collision system with a new auto steering function to increase the chances of avoiding a pedestrian collision.

Its Automated Highway Driving Assist co-ordinates the new Cooperative Adaptive Cruise Control and Lane Trace Control to keep the car on an optimum driving line and distance from the car in front, within a traffic lane, with least acceleration and deceleration.

Both systems will be available in the next few years, the automaker said.

Toyota's current Pre-Collision System (PCS) uses radar detection to spot pedestrians and other hazards, by day and by night, and initiate alerts and automatic braking to cut the risk of an accident.

Adding automatic steering will help prevent collisions in cases where automatic braking alone is insufficient, for example when the vehicle is moving too fast, or a pedestrian suddenly steps into the car's path.

PCS uses an on-board sensor to detect a pedestrian in the vehicle's path. If it determines there is a collision risk, it triggers a warning light on the dashboard, immediately in front of the driver; if the likelihood of an impact increases, it sounds an alarm to warn the driver to take avoiding action and initiates pre-collision braking force and automatic braking.

If the system detects that a collision cannot be avoided by braking alone, and there is sufficient room for avoidance, it activates steer assist to direct the vehicle away from the pedestrian.

In 2012 Toyota introduced the system with increased pre-collision braking force and automatic braking in the Lexus LS 600h, it aims to make the technology more affordable and more widely available in its model ranges by 2015, prior to outing PCS with Pedestrian-avoidance Steer Assist on sale.

Meanwhile, Automated Highway Driving Assist (AHDA) is designed to support safer highway/motorway driving. The system links two driving technologies to help secure safer driving and reduce the workload on the driver: Cooperative Adaptive Cruise Control, which communicates wirelessly with vehicles ahead to maintain a safe distance; and Lane Trace Control, which helps steer the vehicle on an optimal driving line within a traffic lane.

Toyota insisted the driver would remain in ultimate control of the vehicle and that there is "*no compromise in driving pleasure*". It plans to market AHDA from the mid-2010s together with other systems that can make driving safer and more secure.

Toyota presented its new technology at the Intelligent Transport Systems World Congress in Tokyo and began road trials on Japan's Shuto Expressway from October.

Unlike standard radar cruise control which uses millimetre-wave radar to detect other vehicles, Cooperative Adaptive Cruise Control uses 700 Mhz band vehicle to vehicle ITS communications to acquire acceleration and deceleration data from the vehicle ahead. This allows the speed of the following vehicle to be adjusted accordingly and better maintain an appropriate distance. By reducing unnecessary acceleration and deceleration, it improves fuel efficiency and helps reduce traffic congestion.

Lane Trace Control features new automated driving technologies. It uses high-performance cameras, millimetre-wave radar and control software to keep an optimum, smooth driving line within a traffic lane at all speeds, adjusting the vehicle's steering angle, driving torque and braking force when needed.

To bring its new driving support systems to market as soon as practicable, Toyota is making use of new component technologies and know how gained through road testing using its advanced active safety research vehicle, unveiled last January at the International CES electronics show in Nevada.

Based on a Lexus LS, this vehicle is being used for Toyota's Integrated Safety Management Concept research at the Toyota Research Institute of North America, in Saline, Michigan. Capable of being driven autonomously, it is fitted with forward-facing cameras to detect traffic signals, and front-mounted sensors to detect vehicles, pedestrians and obstacles. These sensors also allow traffic conditions and road layouts in the car's vicinity to be assessed, such as intersections and merging lanes.

Toyota has been researching automated driving technologies since the second half of the 1990s, and has been conducting public road tests in the USA for a number of years. It has also been road testing its next generation Intelligent Driver-support System in Japan for around two years.

Toyota is also taking into account the fact people are living and remaining active for much longer, developing technology that will support older drivers with recognition, decision making and vehicle operation so that they can remain mobile and lead fuller lives. Toyota is also working to create more stable driving environments that will help alleviate congestion, and thus reduce economic losses and carbon emissions.

Mini claims that, since launch, Mini Connected has been market leading in the area of in-car technology, pioneering access to apps and services to both assist and entertain driver and passengers.

In future models the automaker will roll out a number of innovative driver assist systems that also use intelligent networking for the exchange of information between driver and vehicle.

As early as 2007, interface technology for integrating the Apple iPhone with the Mini operating system was introduced. Since 2011, additional online-based functions can be integrated in the Mini Connected package with the help of apps.

The head-up display helps the driver concentrate on what is happening on the road by displaying relevant information right in the driver's line of vision. This can be seen quickly and conveniently without having to take your eyes off the road. The collision warning and pedestrian warning systems, including city braking function make it easier to avoid dangerous situations, particularly in city traffic. The parking assist feature offers maximum comfort in searching for and using parking spaces, while the reversing camera gives drivers a better view when manoeuvring.

Other innovations in the driver assist systems include the video-based speed and distance control which automatically keep a safe distance from the vehicle in front, and the speed limit information system, which detects and displays speed limits as they apply to the current section of road. This system is supplemented by the no passing display and traffic sign memory functions. The digital headlight assist function contributes to optimum visual conditions when driving at night. This system helps the driver use the full range of headlight functions. Oncoming traffic and preceding vehicles are registered by a camera, while automatic switching to dimmed headlights avoids causing a nuisance for other drivers.

Not to be outdone, Ford has revealed prototypes with Fully Assisted Parking and Obstacle Avoidance technologies.

The automaker is also developing its Fully Assisted Parking Aid to enable drivers to park at the touch of a button from inside or outside their car.

Obstacle Avoidance uses automatic steering and braking to avoid collisions.

## BELGIUM: Lexus add built in wi-fi hotspots to most models

**Lexus Europe has introduced 'Hotspot' on most of its models offering independent, high speed wi-fi connectivity for every vehicle occupant.**

Always available and immediately activated when the car is switched on, the system allows for the simultaneous use of up to five wi-fi devices on board. It also enables in–car interaction between them for both business and gaming purposes.

Wi-fi alliance certified, Hotspot operates via two 3G diversity antennas which guarantee optimum connectivity even at high vehicle speeds. 3G and 2G mobile communications technology supported and capable of over the air software updating, it is open to any GSM operator via the customer's SIM card.

Lexus said the dual antenna format gives superior performance to that of a smartphone enabled hotspot but also eliminates the excessive battery drainage and other limitations which typify smartphone wi-fi connectivity.

The system is hard wired into the car battery to provide a constant power source and will operate in all weather conditions and temperatures between -20 and 65 degrees C.

"*Improving in-car signal strength, operability and user flexibility, Lexus Hotspot offers drivers, those working from their cars, taxi- and chauffeur-driven business users and even entire families the ultimate in affordable wi-fi connectivity,*" the automaker said.

Hotspot is also available in IS, GS, CT and RX models.

## USA: Nissan targets autonomous drive to market by 2020

**Nissan says it will be ready with multiple, commercially-viable autonomous drive vehicles by 2020.**

Work is already underway in Japan to build a dedicated autonomous driving proving ground, to be completed by the end of fiscal year 2014. Featuring real townscapes (masonry not mock-ups) it will be used to push vehicle testing beyond the limits possible on public roads to ensure the technology is safe, the company says.

The company also says that it will deliver autonomous driving *"at realistic prices for consumers"*. The stated goal is *"availability across the model range within two vehicle generations"*.

"*Nissan Motor Company's willingness to question conventional thinking and to drive progress - is what sets us apart,*" said CEO Carlos Ghosn. "*In 2007 I pledged that by 2010 Nissan would mass market a zero-emission vehicle. Today, the Nissan Leaf is the best-selling electric vehicle in history. Now I am committing to be ready to introduce a new ground-breaking technology, Autonomous Drive, by 2020, and we are on track to realise it.*"

Nissan is demonstrating the breadth of the capability of its autonomous drive technology for the first time at Nissan 360, a huge test drive and stakeholder interaction event being held in Southern California. Laser scanners, Around View Monitor cameras, as well as advanced artificial intelligence and actuators, have been installed in Nissan Leafs to enable them to negotiate complex real-world driving scenarios.

Nissan says its autonomous driving technology is an extension of its 'Safety Shield' advanced driver assistance systems, which monitor a 360-degree view around a vehicle for risks, offers warnings to the driver and takes action if necessary.

# UK: Jaguar Land Rover unveils plans for new technology centre

**Jaguar Land Rover (JLR) has revealed details of the near GBP 100m National Automotive Innovation Campus (NAIC) at the UK University of Warwick, scheduled to open in 2016 to provide advanced technology and research.**

The Tata-owned automaker is to provide GBP 50 million of NAIC's funding, with around GBP 15 million originating from the UK government, while further partners include Tata Motors European Technical Centre and Warwick Manufacturing Group (WMG).

"*It [NAIC] is to attract great brains from around the world and the UK,*" JLR director of research and technology, Wolfgang Epple, told a media briefing today (24 September) at Warwick University.

"*We have got a lot of attention from suppliers, which indicates to us this will be a world class centre of excellence. There is a huge challenge in the UK, which is skills.*

"*We need to find and inspire some fire into these [automotive] brains - that young people get interested into engineering...and make a decision to spend their entire life and energy in engineering. That is an additional target for NAIC - to inspire young people.*"

Construction of the NAIC building will start shortly, with around 1,000 academics, researchers, technologists and engineers working at the facility, which will feature workshops and laboratories, as well as powertrain, design and visualisation elements.

Around 200 JLR researchers and engineers are currently based at WMG, with the automaker noting by the time NAIC opens in 2016, some 500 staff will work in the advanced research team.

Project details have not yet been unveiled, but JLR head of research, Antony Harper, said: "*We will announce the details of the specific research projects in due course, but these will be long-term, multi-disciplinary challenges, such as electrification, smart and connected cars and human machine interface.*"

Wolfgang Epple will coordinate development of the new facility, which will complement JLR's product creation centres in Gaydon and Whitley. The research director has also been appointed Honorary Fellow at Warwick Manufacturing Group.


## JAPAN: Toyota details future hybrids

**Toyota has said its next generation Prius will begin a new era in hybrid technology with further gains in fuel economy and reduced emissions, with cable-free inductive charging for the plug-in version.**

The new Prius will be the first in a broad range of Toyota and Lexus vehicles that will make use of a substantially improved family of hybrid powertrains.

These will deliver significant improvements in fuel economy from a more compact package that is lighter in weight and lower in cost.

Their performance will reflect the significant advances the automaker is making in battery, electric motor and petrol engine development in its wider strategy to deliver electric vehicle power through hybrid, battery electric and fuel cell technologies.

In each of its three generations, Prius has delivered an average reduction of 10% in its $CO_2$ emissions. Toyota's challenge is to continue to improve at this rate.

The next Prius will feature improved batteries with higher energy density, which means greater energy storage capacity within a smaller unit. Toyota, already a leader in advanced battery technology, has stepped up its research, development and production capacity for both nickel metal hydride and lithium ion, and will use each technology where appropriate in its expanding focus on vehicle electrification.

It has also ramped up development of new battery technologies such as solid state and lithium air, and devoted resources to chemistries beyond lithium, such as magnesium and other low valence materials.

The next Prius will use smaller electric motors but with a higher power density. The motors in the current model have four times the power density of those used by the original Prius back in 1999, and the improvement will be higher still in the next generation car.

The thermal efficiency of the petrol engine will improve, too, from 38.5% currently to a claimed world best of more than 40%.

The next Prius will be constructed using Toyota's New Global Architecture, bringing a lower centre of gravity and greater structural rigidity, contributing to greatly improved driving dynamics.

A focus on raising aerodynamic performance will bring new exterior styling with a larger interior and refinements in design, layout and ease of use.

The next generation Prius plug-in is being developed in parallel with the standard model. Toyota has learned from current customers they would like a greater all-electric driving range and more convenient charging. In response, Toyota is working on a new wireless inductive charging system that produces resonance between a floor coil and vehicle coil to transmit power to the battery without a connecting cable.

Verification work on this system will be carried out in Japan, the US and Europe during 2014.

ENGINEERING

**WHOLE VEHICLE TESTING**

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Lotus has a dedicated testing facility at Ann Arbor in Michigan and Hethel in the UK. Lotus Engineering is dedicated to meeting our clients' programme objectives on time, every time.

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# Aluminium Anodising

*Lotus Lightweight Structure's anodising facility in Wellingborough*


Whilst it is well known that Lotus manufactures its own chassis at Lotus Lightweight Structures in Worcester, it is little known that Lotus also has its own anodising facility in Wellingborough, which is the world's largest producer of structural chassis aluminium anodising. The plant can currently produce in excess of 0.5 million square metres per annum and has processed over 10 million automotive components.

Andy Wilson, Head of Lotus' anodising facility explains the process, and history of this world class facility.

Previous to the Lotus Lightweight Structures acquisition in September 2009, the Wellingborough facility specialised in luggage carrier systems, as a Tier I supplier for Vauxhall/Opel providing aluminium powder coated roof rail assemblies.

In 2003 we developed a chromate pre treatment process and fully extruded aluminium component service for a bonded aluminium space frame which served the Gibbs Aquada amphibious vehicle capable of a land speed greater than 100 mph and a water speed upwards of 30 mph.

Over the next 12 months we became renowned in the UK automotive market as an extruded aluminium finishing SME with an expanding portfolio supplying welded aluminium sumpguards for the Freelander and

also as a Tier I supplier for Lotus Cars.

By the Summer of 2004, there were plans to construct an anodising plant after a nomination from Aston Martin for their next generation lightweight aluminium chassis. The Wellingborough facility with the ability of converting extruded aluminium into an anodised component under 'one roof', and less than one hour's travel from the Aston Martin production facility at Gaydon excited both parties.

Later that year we were awarded the contract to provide both aluminium components and provide a Tier I service for all chassis component anodising services. The plant entered service for pre-production build by February 2005.

The anodising plant itself is unique in that it is an amalgamation of a electropaint system and advanced state of the art hardware. The electropaint conveyor system, a series of dip tanks, lip extraction fans, the transporter system and load/unload shuttles were upgraded and utilised. In parallel, plant equipment was sourced Europe wide. State of the art pulsed current control rectifiers and a ion exchange sulphuric acid recovery system were sourced from Italtecno in Italy.

The tank burner control systems were purchased from Lanemark International, chillers capable of providing hard anodising as well as soft from ICS. The plant control architecture was designed and installed by MPS.

Every aspect of the development was managed in-house including the installation of new mains gas and towns water supplies to the design and manufacture of flight bars, carriers and racking systems.

# The anodising process

Anodising is an electrochemical process for producing stable oxide films on the surface of metals and has rapidly developed since it's early industrial use in the 1920s. However, it is still the most recently developed of the commonly used 'wet' metal finishing processes (one carried out in an aqueous solution).

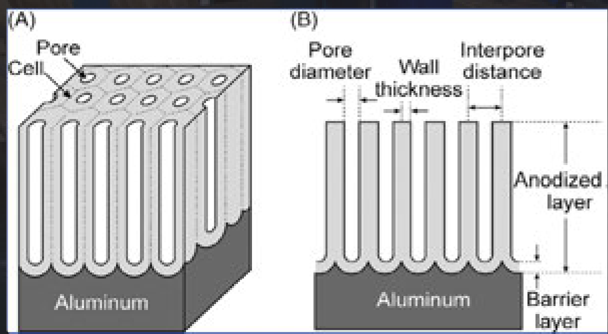
The process derives its name from the fact that the metal part to be treated becomes the anode in an electrolytic cell. It is ideal for producing stable oxide 'barrier' films on the surface of metals to enhance corrosion/chemical resistance or creating physical surface properties to increase abrasion resistance and hardness as well as preparing surfaces with increased bonding strength. Anodising aluminium can be achieved in a wide variety of electrolytes, employing varying operating conditions including concentration and composition of the electrolyte, presence of any additives, temperature and electrical parameters. There are three main phases to the process.

## Surface preparation

In which a chemically clean surface (free from lubricants/oils/corrosion products and the naturally occurring aluminium oxide) must be achieved. This involves an alkaline soak cleaner maintained at a temperature of between 65-75 °C in which the free alkaline saponifies these compounds and thus makes them water soluble. Additions of surfactants reduces surface tension and thus enhances the degreasing effect by promoting 'wetting'. After this cleaning stage an alkali etch is performed in a caustic solution at temperatures between 60-67.5 °C to further saponify the lubricants whilst dissolving a small amount of the naturally occurring aluminium oxide from the substrate surface. The final preparatory stage is a hydrofluoric/nitric acid dip to remove the smut formed by the alloying elements of the aluminium. All alkali and acid process stages are interspersed with a series of cascading/recycling towns water rinses.

## Anodising

The aluminium substrates are now ready for the anodising process. Each part is already mechanically fixed and electrically connected to the carrying flight bar and is immersed in a solution of Sulphuric acid at a temperature between 17-19 °C. The flight bar is then automatically connected to the positive terminal of a 5,000 A DC rectifier which then surveys the electrical conductivity between the anode (parts) and the static cathodes. By presetting the anodising current density and requested number of microns (thickness of the oxide film), the rectifier delivers a constant current over a constant time. As a current is passed through the electrolyte, the negatively charged ions migrate to the anode where one or more electrons are discharged creating a build up of aluminium oxide at the surface. Hydrogen is subsequently released at the cathode which is then removed from the liquid surface by a lip extraction system. The anodic film is duplex as it consists of two layers and during anodising the non-porous barrier layer (insulator) is formed first adjacent to the aluminium substrate. This conducts current only due to it's low thickness. The second porous layer is then formed due to the dialectic breakdown which occurs resulting in the formation of small pits. The electrolyte then penetrates into these pits and further oxide growth occurs with the oxide expanding to form a porous structure. The pores are typically 10-20 nm in diameter and the control limit thicknesses for structural anodising is 2-10 μm (typical width of a human hair is 50 μm).




## Sealing

After anodising, the parts are then thoroughly cleaned by a succession of three deionised water rinses before entering the sealing stage. This is performed in boiling deionised water with the addition of complex organic based additives. This partially converts the as-anodised alumina of the anodic coating to an aluminium monohydroxide known as boehmite


FIRE EXIT
Tank 16

## Plant quality systems

Every load is quality assured at several stages. This includes full traceability of the parts from material receipt to ship.

The parts to be loaded onto the system are scanned and given a unique works order. The part information is subsequently scanned onto the LLS manufacturing resource planning (MRP) system and also into the plant process operating system which hard codes the relevant anodise program and designates a unique flight bar number.

All stage timings, temperatures, anodising profiles and water quality are data logged and recorded.

Each flightbar also contains a number of extruded test samples for adhesive bonding certification. The anodised coupons are adhesively bonded and tensile tested using an in-house Instron tensile test machine. Each bond durability test consists of a ultimate failure load and the energy released at peak load. Off line chemistry certifications are performed daily in our plant laboratory and we also have a highly accurate Hach Lange DR2800 spectrophotometer to measure the concentration of the additive, the total suspended solids and turbidity of the seal.

All chemistry values are electronically recorded and SPC charts are produced daily to track progress and identify long term drift.

Although sulphuric acid anodising technology is almost 100 years old and many anodising companies use this technology to Qualanod standards for architectural applications, there are only a handful of companies in the world capable of producing to the high specification that structural bonding applications require.

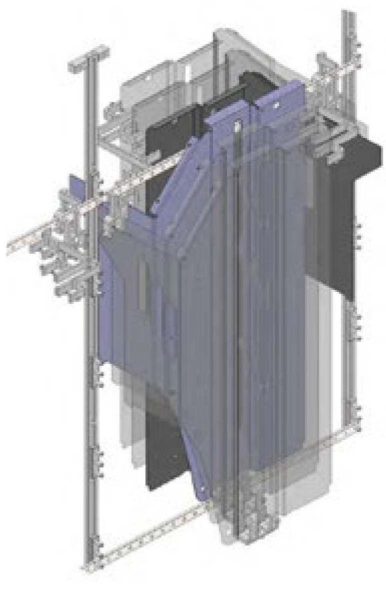
Most anodising specifications suggest the required quality systems only, however, the LLS anodising specification details all chemistry, time and temperature controls. If we take one process stage alone (e.g. hot seal), we have seven controlled/measured variables; minimum solution temperature and turbidity, maximum

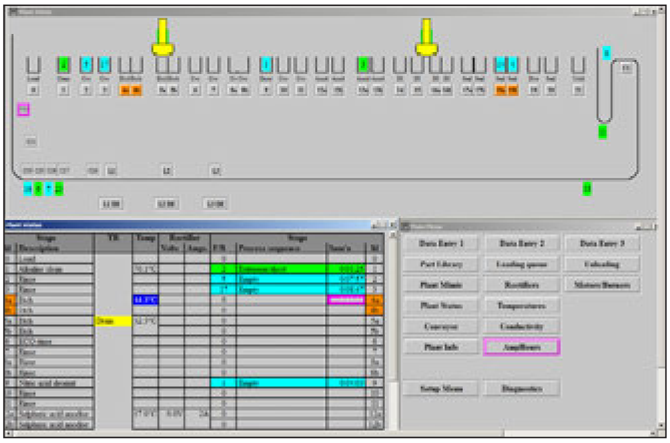
conductivity and total suspended solids minimum/ maximum immersion times, seal additive concentrations and pH.

We currently anodise over 500 unique part geometries manufactured from four alloy types, Al6060/3 extrusions, Al5074 sheet, Al5083 superform and Al356 castings for which we have approximately 30 flight bar jigging arrangements some of which are bespoke to unique geometries.

The jigging is not to be an overlooked part of the overall process. They must mechanically attach and at the same time provide individual electrical paths to each part.

All LLS jigging solutions are designed in-house and predominantly manufactured from Grade 2 wrought titanium. Again many traditional anodisers use aluminium jigging although it is less expensive and has greater electrical conductivity than titanium, it is chemically attacked by the anodising process and needs constant chemical or mechanical stripping to remove the electrical insulating aluminium oxide. Like the aluminium part, the jig also becomes anodised from the process. However titanium does not have the same passivation rate as aluminium to form an oxide so stripping is not required between cycles.





## Data management system

A key element in making all the aforementioned happen is our bespoke data management system (DMS). It is a modular package for process control, data monitoring, process alarming and plant fault diagnostics, which has also been extended to provide advanced features such as work history logs, production reports and maintenance schedules.

Networking also allows the DMS to provide multiple terminals for access to live and historical information, both locally and remotely. The plant graphics show status, mode and movements of transporters and loads, together with tank process information which allows the operator to obtain a quick and clear view of the current status of the plant.

When work enters the plant, the processing information must be selected, and by using an integrated part library system the operator is only required to enter the component part number, batch number and quantity which is all achieved by barcode scanning, thereby eliminating any keying errors.

Multiple part types may be jigged together with the system automatically checking for compatibility between them. The unique anodising profiles are then automatically obtained when the part number is entered. An overview of the plant and processing parameters are provided in real time and the work that is in each stage is dynamically displayed, together with the transporter current motion and positions, including processing parameters, associated alarm limits and set points. The plant transducers monitor, control and display all process parameters and this data is collected by the front end control system via digital and analogue inputs and then passed on to the DMS.

The DMS continuously records information about the activity of the plant, which can then be displayed in various reports allowing selections of time periods to view based on shifts, weeks or for a user defined period.

## Summary

The Lotus Lightweight anodising facility is one of the most advanced of its type globally and provides a level of quality, control and data recording that is beyond that demanded by most OEMs. The staff operating the plant are highly dedicated and have a full understanding of the demands of the automotive sector. LLS is already expanding its offerings to other sectors, as well as taking on new projects from automotive OEMs.

Writer: Andy Wilson PhD
△ Head of LLS Anodising

For more information on anodising and other services from Lotus Lightweight Structures

Contact: proactive@lotuscars.com

# Bloodhound SSC

*Interview with Richard Noble and Mark Chapman*

The Bloodhound SSC team is planning to take its purpose-built car over 1,000 mph and to a new land speed record at a site in South Africa in 2016. Richard Noble, who held the land speed record himself between 1983 and 1997, is directing the project. Mark Chapman is taking care of the engineering side. Dave Leggett talked to both of them about getting to their ambitious goal.

### DL: Richard, can I start by asking you about your role and main responsibilities on the project?

RN: I am the director of the company so I am totally responsible for all activities of the company.

### DL: Can you describe a typical day?

RN: Well, it starts early, at 5:00 am. You never know quite what's coming next but I like to keep a handle on the accounts and I have all the running balances in front of me. And I deal with the invoices and with paying the bills. There are also sponsorship deals going on, five or six major ones at any one time, and there is also the education team. There have been some changes in the education team which has meant some recruitments, so all that's going on also.

We have a major digital programme in development now, so there's a lot going on with that, too, with various deals.

It's a huge myriad of activities, inspiring and exciting.

### DL: What are the educational team involved with and how did that come about?

RN: Well, we set up to develop and build and produce a Mach 1.4 car. We decided that we would produce the most advanced car possible and the key to that is the Eurojet EJ200 jet engine, a highly sophisticated military turbofan normally found in the engine bay of a Eurofighter Typhoon. It is very light, very fuel efficient and it's got a small cross-sectional area.

Andy Green and myself were fortunate enough to have a meeting with Lord Drayson, the then minister for defence, equipment and support in the last government. We wanted an engine and he wasn't about to let us have that...

He noted, however, that the Ministry of Defence was having trouble recruiting engineers and that there was a need to generate interest in engineering among young


Image credit Stefan Marjoram

people that was formerly served by the military technological activity associated with the Cold War, the aerospace industry's products, like the supersonic Lightning, Harrier, Vulcan aircraft and so on. He went on to say that these aircraft were constantly being seen by kids...

But once the Cold War was over, that stimulation was turned off, which is where Bloodhound comes in and taking our project out to schools, to inspire children, that was Lord Drayson's idea.

We have now got 5,452 schools on the Bloodhound educational project.

It works very well because basically almost every family has got a car. The kids know what a car is, so they can identify with what we are striving to achieve. On top of the schools in the US, we also now have 300 schools in South Africa and the project is now being followed in 220 countries, in fact, every country in the world with the exception of North Korea and the Vatican City.

**DL: This educational aspect to your activities sounds pretty important...**

RN: Yes, it is. Another point is that it also helps our sponsors with their corporate social responsibility requirements. So that's an added bonus to the Bloodhound sponsorship proposition. We're obviously grateful to Lord Drayson who came up with the original idea and it's at the centre of what we are about; it's absolutely terrific and we couldn't do without the education, put it that way.

**DL: So, how does it work?**

RN: There's a dedicated team of twelve, who are full-time. We have a show car, which is a full-scale model and that visits exhibitions and schools and does between 50,000 and 60,000 miles every year. The key focus is primary schools, because that's when you have got to get the kids really interested in science and engineering. So, to give you an idea, we have made about 60,000 balloon cars – they make balloon cars and then race them. They also build rocket cars. The playground rocket land speed record was originally 88 mph and it is now 204 mph, so they're really pushing hard...there is quite a battle between the South Africans and the Brits there...

What we are starting to see is a completely new culture. With the 5,000+ schools we're talking about 1.5 million school kids and we're going to get quite a few engineers out of that, so it's going to deliver big time.

**DL: How many people do you have in the whole team?**

RN: It's sixty full-time people, in total, at the moment. It's a small team to do a project on this sort of scale. To describe the resourcing more generally, in terms of overall costs, around 75% goes into engineering, research, design and build, and 25% is support work, non-educational.

**DL: It's obviously a complex proposition, from an engineering point of view?**

RN: Oh yes, make no mistake about that. This car is as complex as a modern jet fighter and built to a very high standard indeed. We're building down at Avonmouth with a 25,000 sq ft facility. It is absolutely fascinating; I get down there about once a week and you see the quality of this thing; it is very, very special indeed.

**DL: Assuming that you are successful with the mission objective, reaching the target land speed record, what happens then? What's next?**

RN: The lead then passes to our main sponsors and we say 'guys what do you want to do with it now?'.

Something to bear in mind is that the key to the whole project is 'open data'. The teachers we engaged with early on said 'we don't want this treated in the traditional British way, photos and press releases and so on. We want real data!' Our initial reaction was that we couldn't possibly do that, but then we thought about it we realised that we were in a unique position. The FIA rules for land speed records just stipulate that you must have a driver and a vehicle with four wheels. It deliberately is non-specific to allow for maximum innovation. That being the case, the competitive vehicles in this area are all very, very different, so our technology simply does not transfer. We then realised that this was the magic key to the whole thing, that we could make all of our data available and that this would help our educational side and sponsorships and would


not help the competition.

If you think about it, the defence sector can't do this and neither can highly competitive areas of motorsport such as F1 where there has to be secrecy on data.

Every time the car runs we are going to download, from the car live, 300 data channels and three video channels. It's quite an undertaking because when we are in South Africa we will be running from a remote desert; the radio masts (five of them, each 60 metres high, concrete footings the size of a bungalow) are going up at the moment. The data channels will involve pressures, loads, temperatures and so on.

The idea is that all over the world, kids will be able to study this and understand exactly what is happening as it happens.

Image copyright Stefan Marjoram

**DL: So what's the timeline for the project?**

RN: We have got it under control now. We hoped to get it together in 2014, but we're not going to do that. We're now going to get the car in quarter two of 2015, so that's an extra year's worth of work and funding but we have had to just bite that and get on with it.

So, second quarter of 2015 is the rollout of the car here. Then we have to do UK trials to get it sorted out, make sure that everything works all right, that should be around two months. We have the use of a runway to enable us to run up to about 200 mph, light the afterburner and that's about it. We will then fly straight out to South Africa. We'll probably be on the desert there for about three months, the great thing there is that the desert has an eight month weather window, in America with the Thrust Projects we only had a six week weather window, which made everything


absolutely frantic.

It's great that we can be operational for up to three months in South Africa.

The objective in 2015 is to get the car supersonic. Once we have done that, we'll bring the car back home for a re-work and modifications to get back to South Africa and finish the job in 2016. That's the plan.

**DL: Mark, can you explain the main engineering challenges of the Bloodhound project?**

MC: The main challenge, with something like the land speed record is that there is no rule book or reference base. It really is a clean sheet of paper. The fixed things are the propulsion system, the engines, and then you have to put it all together in a shape that will go very fast. It's not like an aircraft or an F1 car, where you have some clues from past work. Also, you might be able to look across the paddock to competitors. There are very many land speed cars but they are all very different vehicles. The starting point is the propulsion system. Once you have that, then you have to work around it to produce a vehicle that is stable, with low drag and keeps the driver safe.

We're doing it all for the first time and in a unique way.

**DL: I'm curious about the gestation of the project. When was the car designed?**

MC: Somewhere around 2006 work started and to begin with it was a pure rocket car, but the drawback with them is that they are hard to drive slowly, so it's difficult to build up your speed gradually in a safe way. They tend to be either on or off. So fairly early on it was then decided that we wanted a jet car with a rocket for the additional power. The main issue with the jet engine is the intake and achieving a smooth flow where the engine face is. Initially we had two intakes, but eventually we changed the design to a single intake. The early car had the jet engine below and an 's'-shaped intake duct. We did a lot of work to straighten that out and drop Andy as low as possible in the car. The job after deciding on the design of the propulsion system is to work on all the packaging, the nuts and bolts, to make the whole thing work.

**DL: Is there a point at which the car design is 'signed off' and fixed?**

MC: No, it doesn't really work like that, it is constantly being changed and tweaked, adjusted – a very iterative process as we proceed. It will be finished when the car runs in South Africa. There are certain windows we have to hit, for manufacturing say. But even now we are not at a stage where we have a complete scheme of a car. Some areas of the car are finished, but others are not. Maybe a third of the car's structure is done, but there are still areas of the car where we are designing concepts, and that has to fit with what is already coming together

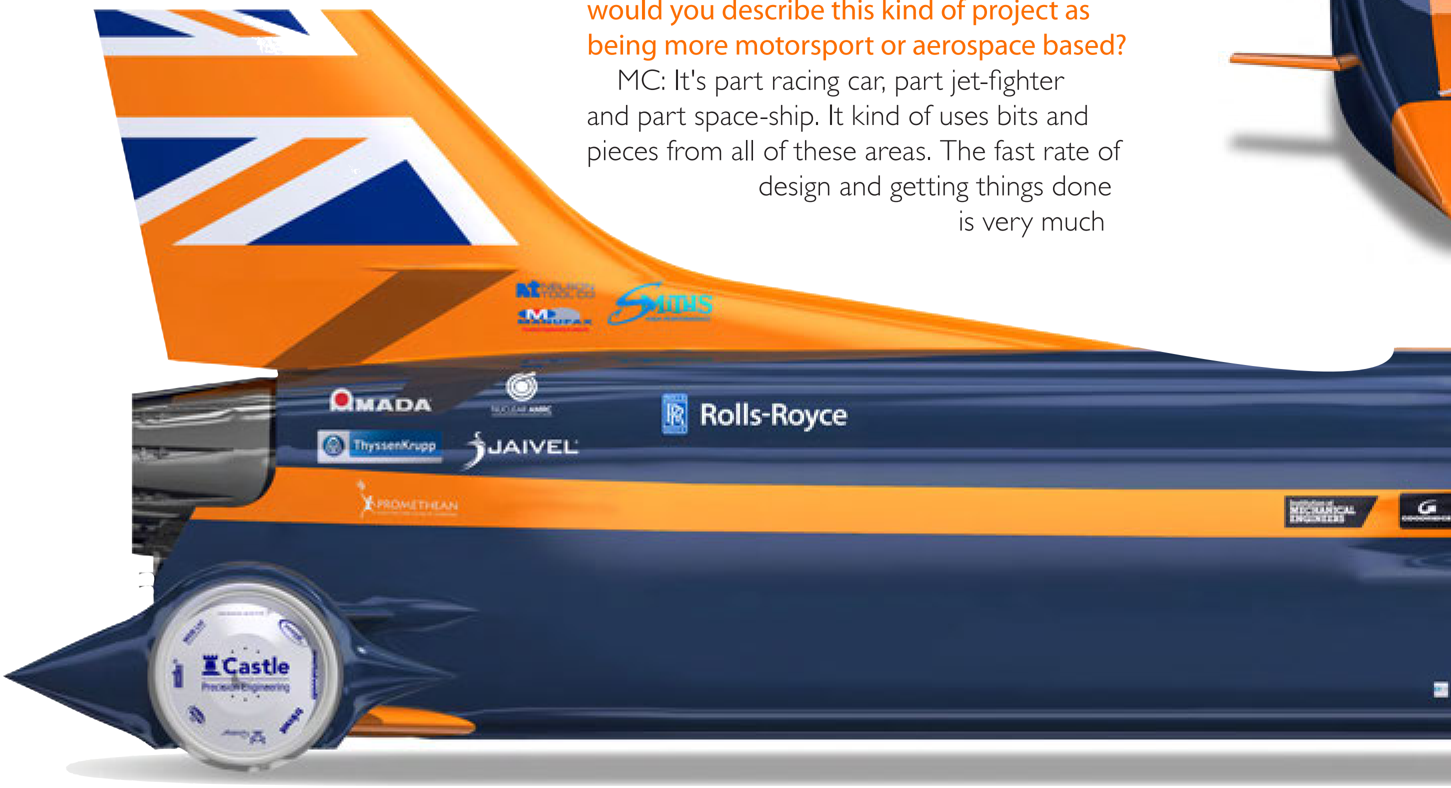
It's a small team and we don't have the luxury of doing a complete scheme and employing a vast team to make a signed off design work. It's constantly iterating, with blocks of the car getting done and released, completed, while other things are still being worked on or even designed around what's already been done.

**DL: How much is done in-house and how much is outsourced?**

MC: The iterative process I have described can make it difficult for traditional outsourcing ways of working. Design is best handled in-house as far as possible. In general, motorsports engineers are used to turning things around quickly, but the timescales (product lifecycles in aerospace), where we are here in Bristol, tend to be much longer.

**DL: In terms of engineering fundamentals, would you describe this kind of project as being more motorsport or aerospace based?**

MC: It's part racing car, part jet-fighter and part space-ship. It kind of uses bits and pieces from all of these areas. The fast rate of design and getting things done is very much



motorsport end of the market. Aerospace is more about precise things such as load case, well known regulations and requirements, plenty of history. So, for example, there's the old A320 and you're doing the 'new' A320. It's an evolution with a rigid set of rules for, say, bolt pitch or rivet pitch, materials used.

We do take a lot of input from aerospace side – fatigue, margins, safety aspects. We are not doing a prototype racing car or something to test; the one car is the end-product. We are only building one car, so it has to be successful in all aspects of performance. But obviously, unlike an airliner, if a bit breaks the car rolls to a halt, Andy gets out and we can fix the failed part, so in that development sense it's maybe a bit like a racing car.

The duty cycle for the Rolls-Royce engine on Bloodhound is 2 minutes. It's not doing a two-hour sortie. In its whole life it is only going to run for about an hour or two. Losing power is not catastrophic the way it could be in an aircraft, so that creates a different set of parameters to work to.

**DL: Managing the vehicle system 'blocks', the process of engineering and manufacturing – does it all happen more or less simultaneously?**

MC: Doing everything at the same time, developing the car at the same pace across the board would take forever. We have to focus on sections. So, we have a scheme concept level at which we know everything works. Now, we are concentrated on finishing modules. We have finished the lower structure of the car, it has been designed, released, manufactured and built. That's a complete module done. We are just about to release the front suspension for manufacture. That's a nice, tidy module that will come into the workshop and be built up. Once we have those big primary structure building blocks, the suspension, infrastructure of the comfort area and big chassis components done, then the focus moves to the internal stuff.

We have the scheme concept on CAD and the inside of the car, on a one-off like this tooling is a bit of a luxury, we'll end up using the car as a tool. We've only got one monocoque, so we can use soft tooling, we can fettle for exact fit to the structure we have rather than have a lot of production jigs for manufacturing identical parts. We just have the one vehicle that a part has to be right for. We can use the actual car as a tool when it comes to internal things like looms, tanks and pipework.

**DL: How does the remaining schedule look in terms of workload on the engineering and manufacturing side?**

MC: Well, there's quite a bit left. The final components for assembly will be forward structure parts in the spring of 2015. From a design perspective, I am currently recruiting and trying to increase the design resource to spit drawings out as quickly as possible. There's one area of design effort that needs to happen that will be ongoing for the next 6-9 months. After that, all of the major design work is completed and we're into working on manufacturing. The team we have at the moment will be flat out for the next 18 months and as we get to the early part of 2015, the amount of design effort on the car will reduce, but by then we'll have ramped up the effort for the support and turnaround equipment. So, as we get the car sorted out, the workload gradually shifts to the ground support and turnaround equipment that we will need.


Images credit Siemens NX


Image credit Siemens NX

**DL: Are there technology development spin-offs from the work in developing an exceptionally high-speed vehicle such as Bloodhound?**

MC: We try hard not to develop any new technology. We don't have the time, budget and resource to do that. However, what we do, is look at a very broad range of industries and see if anyone has had to solve problems similar to the ones we face and then see if we can apply that to our car. So we are quite good at demonstrating well-known technologies outside of their normal field of use. We can showcase a raft of technologies to people who would not normally see them. For example, we have recently taken some of our motorsport supply chain to a defence show. They got to see some defence stuff and the defence people got to see us; aerospace events offer a similar opportunity to promote the broad range of skills and technologies used on the car.

We also work differently from other sectors and approach problem-solving in a different way. For example, on the body shape we had a huge issue finding a body shape that was stable at high speed. We could have gathered a lot of aerodynamic data and analysed that, but we thought it would take forever because there just isn't the knowledge out there about land-based supersonic vehicles and ground effects. So we ended up designing an experiment that would get us to where we wanted to be in three months. That took us from a process of 18 months that involved 13 configurations that were unsuccessful, to three months on 43 configurations (by changing how we did the modelling and computational analysis). On the final set of runs we were doing eight a day and over a period of three weeks we were converging on an optimised solution. It was all about how we use mathematical models and optimisation tools to short-cut what might be a more conventional way of doing things.

We have to operate a little differently because of our resource base and the nature of our project. If we find ourselves running into a brick wall we do not ask: how much more resource do we need to solve the problem, we ask the question: are we trying to solve the correct problem, what can we do to change the problem so that it becomes one that we can solve.

**DL: And it's a highly collaborative relationship with your suppliers?**

MC: Very much so. When we design components, the supplier will often be involved very early in the design process. We are trying to do this on best cost, so there's no point in working with sponsors or suppliers and giving them a design that leads to them saying 'that's not how we usually do this and it has big cost implications'. We want to match the capability of manufacturing to the way the part is designed in the first place. Having their input early on is key to achieving a process that everyone is happy with.

**DL: Can you give me an idea of how complex a vehicle like this really is?**

MC: It's about 10,000 drawings. But the structure is as simple as we could possibly design it. We don't know exactly what the loads are going to be on this car as it runs across the desert. We can predict and estimate them, but we need a design that has a certain amount of flexibility. If we find that the loads are higher than we thought, there's some capacity in the design to stiffen or strengthen in places. That's why the rear-end of the car is a metallic structure, so that we can revise that and adjust it as we get more data and information. A lot of thought has gone into making this design as 'robust' as possible. As we get more information on how it runs in the first year, we really do not want to throw it all away and effectively do a new car.

**DL: And Richard, final question, what's it like to hurtle along at over 600 mph? What goes through your mind?**

RN: Let's put it this way, it's a very mature thing. With the Thrust 2 Project, I started at 30 mph and then gradually built up to 650 mph and you're developing both the driver and the car. The driver is very much a part of the team and it's very much a cold-blooded exercise: there is no room for emotion. One thing we do not want is emotional drivers. Once the hatch is shut and the car is off, the rest of the team has no control over what happens next, so the temperament of the driver is vital. The driver has to be completely integrated to the team and focused on the tasks, driving exactly according to the requirements of the engineers. The engineers work out the run profile and the driver has to deliver that.

So, basically, there is no room for getting excited. It's a very tough job, very much like a test pilot. With Bloodhound, Andy Green has been involved in the design from the beginning so he knows the car the whole way through. When I was driving, you'd go out every morning and do a 600 mph drive. After a bit it became the norm, like driving a taxi!

It's about developing the car and the driver and eventually you get to a stage where both together are highly competitive, everything repeatable.

**DL: Is it exhausting?**

RN: Not physically, but mentally yes. What I found towards the end of the programme, driving at very high speeds, was that everything seemed to be happening in slow motion. Your mental processes are working at maximum speed and therefore everything seems to be happening in slow motion. For instance, you start to see the details in the track coming up at 650 mph.

And then there's the very savage deceleration and in my car [Thrust 2] the parachute was quite big for the job. We would go through extraordinary 6G deceleration losing 130 mph a second. That creates an effect called somatogravic illusion, which upsets your inner ear, your balance and makes you think you are driving vertically down towards the centre of the Earth.

**DL: Do you drive fast generally, when off the track?**

RN: I like to be very careful on public roads! I generally drive a VW Golf, though I do also have a Lotus Elan (1995) which I love dearly!

Writer: Dave Leggett

△ just-auto.com


# Lightweight Cycles

*Mass and inertia in the world of cycle racing*

In the efficiency focused automotive world, we all know that mass matters, but how much thought do we give to where that mass is located?

Vehicle dynamics, of course, keeps a close eye on the issues of centre of gravity position, and unsprung mass is generally considered less desirable than sprung mass, but there is another aspect of the mass location within the vehicle that receives rather less attention.

Of course, the automotive industry is not unique in its interest in engineering efficiency, the world of cycling has long pursued the most minute of gains, with aluminium technology now being widely replaced by carbon fibre not just for the professional racers of the Tour du France and Olympics, but increasingly filtering into the volume production market aimed at the enthusiastic amateur and club racer.

This drive for lightweight has led to a heated debate about just where that weight should most effectively be shaved off in order to maximise performance. Central to this debate are the wheel and frame manufacturers. With both components now making extensive use of high tech and high cost materials, the answer to the question of where best to spend considerable sums of money to achieve the greatest performance gain is key to securing sales for the respective manufacturers.

Looking impartially from outside the cycle industry (though many may remember the Lotus' bike which famously carried Chris Boardman to a world record and gold medal in the 1992 Olympics) at some of the questions the debate has raised, an examination of the science might put the claims and counter claims into context.

Firstly, why does the weight of a wheel play a more significant factor in performance than the weight of other parts of a vehicle?

The weight (or mass) of a wheel isn't more significant, but the inertia of a wheel is. If the weight of the wheel changes, then typically the inertia changes too. Inertia is the result of a mass at a distance from the axis about which it is being rotated, in the case of a wheel it is the distance of the mass from the spindle axis.

### How is the force required to make something rotate different from the force that makes something move generally?

The force required to move (translate) a mass faster (i.e. to accelerate it) is defined by Newton's Second Law, from this can be derived calculations *(see inset on next page)* for the individual forces required to accelerate the rotating mass of a bicycle wheel, the non-rotating mass of the frame and their contributions to the total effort required to accelerate bike and rider.

Using typical data for a lightweight road cycle, the real world example gives a clear indication of the potential gains from weight reduction of the wheel and frame.

We can see that reducing the wheel inertia does have a beneficial effect over reducing non-rotating mass. In reality, weight saved from the wheels is likely to be up to 75% more beneficial than an equal weight saving from other parts of the bike.

However, the beneficial effect over reducing weight in the wheels versus the rest of the bike as a percentage is reduced further when the extra force required to maintain constant speed is calculated.

### When a vehicle stops accelerating, is force still required to make a wheel rotate?

Yes, because we have energy losses due to friction, aerodynamic drag and tyre rolling resistance to overcome.

### Is the force of rotation made more significant when climbing a gradient? If so will the distribution of weight through the wheel have an effect on this?

When climbing a gradient the force required to maintain constant speed is increased.

If the rider cannot provide the required force to maintain constant speed, the bike will slow down. The rate at which it slows down is governed by the equation for force required to accelerate the bike (in physics, speeding up and slowing down are both a change in speed and hence an 'acceleration', but one is positive and one is negative). Since mass reduces the level of acceleration, the bike slows down less quickly the greater the mass.

This effect is well known as momentum.

But slowing down is reduced more if wheel mass increases, due to the inertia effect. So high wheel mass and inertia is desirable for maintaining speed up a gradient.

However, if the rider wishes to increase his speed up a gradient, then the effect of inertia is the same as on the flat where low inertia is desirable.

### So where should you try to conserve the most amount of weight from a wheel? Is a wheel which is lighter at its furthest extremities (its circumference) more effective than one which is heavier?

It is advantageous to concentrate the mass at the hub, for minimum inertia, however this has to be balanced against the need for sufficient strength and stiffness.

### When a wheel rotates it develops a certain gyroscopic, stabilising force, is that right?

Yes. When a rotating inertia is rotated about a second axis, a gyroscopic torque is produced which resists the rotation. This means that if a rotating bike wheel starts to fall over, a gyroscopic force will act to slow down the rate at which it falls.

### If so, will a heavier wheel be a more powerful gyroscope than a lighter one? Would this be desirable?

A higher inertia wheel would have a more powerful gyroscopic effect. A bike is kept upright by the riders balance and use of counter steer. By slowing down the rate at which the bike can fall over, the gyroscopic effect of the rotating wheel is helping the rider balance the bike by giving more time to make balance and counter steer corrections.

### How might this affect cornering?

This is more complicated. In order to corner, the bike must be leaned into the turn. This is achieved by a combination of counter steer (so small that most riders don't realise they are doing it) and movement of the riders weight towards the direction of turn, to make the bike start to fall in this direction. As the bike falls, so the tyres will generate a sideways force towards the direction of turn. This sideways force produces a centripetal acceleration which acts sideways at the centre of gravity of the bike and rider and tries to stand the bike up again. Hopefully these two effects balance, and the bike negotiates the desired turn at a balanced lean angle.

We have already said that gyroscopic effects reduce the rate of lean of the bike, however there is a second gyroscopic effect. This is a result of the rate at which the rider turns the handlebars. The faster the handle bars are steered, the greater the gyroscopic resistance to being turned. As for the case of leaning the bike, the faster the wheels are rotating about the spindle axis and the higher the inertia, the greater the gyroscopic resistance torque. So high inertia makes it more difficult to turn the handlebars – good for stability, but

# The maths behind the science

## Newton's Second Law:

- Force ($F$) = mass ($M$) × acceleration ($a$) (translational motion)
- Torque = Inertia × rotational acceleration (rotational motion)
- Torque = $F$ × tyre radius ($r$)
- Inertia ($I$) = $M$ × [distance from axis of rotation ($k$)]$^2$
- Rotational acceleration ($\alpha$) = translational acceleration ($a$) / $r$

The total force required to accelerate a bicycle might be summarised as:

$F_{ACCEL} = (M_{BIKE} + M_{WHEELS} + M_{RIDER}) \times a + (I \times \alpha) / r$ where, replacing $I$ and $\alpha$; $F_{ACCEL} = (M_{BIKE} + M_{WHEELS} + M_{RIDER}) \times a + (M_{WHEEL} \times k^2 \times a / r) / r$

This simplifies to:

$F_{ACCEL} = (M_{BIKE} + M_{WHEELS} + M_{RIDER} + M_{WHEEL} \times k^2 / r^2) \times a$

So, the extra force to accelerate a the rotating wheel is

$M_{WHEEL} \times k2 / r^2 \times a,$

And this is added to the force required to maintain constant speed on a flat surface:

$F_{CONSTANT}$ speed = rolling resistance ($F_{RR}$) + friction ($F_{FRICTION}$) + aerodynamic drag ($F_{DRAG}$)

But when climbing a gradient the equation becomes:

$F_{CONSTANT}$ speed = $F_{RR} + F_{FRICTION} + F_{DRAG} + M \times$ gravity × gradient

Where gradient is expressed as a ratio i.e. 1/10 for a 10% gradient. If the rider cannot provide this force, the rate at which the bike will slow down can be found by rearranging the equation to:

$F_{ACCEL} = (M_{BIKE} + M_{WHEELS} + M_{RIDER} + M_{WHEEL} \times k^2 / r^2) \times a$

Which becomes:

$a = F_{RIDER} - F_{RR} + F_{FRICTION} + F_{DRAG} + M \times$ gravity × gradient
$(M_{BIKE} + M_{WHEELS} + M_{RIDER} + M_{WHEEL} \times k^2 / r^2)$

## A Simple Example:

- Total bike mass (including wheels) = 5 kg
- Wheel mass = 0.9 kg
- Rider mass = 75 kg
- k = 0.35 m (~27 inches) – assumes wheel mass is all concentrated at rim
- r = 0.40 m (tyre outer radius)

$F_{ACCEL} = (75 + 5 + 2 \times 0.9 \times 0.35^2 / 0.4^2) \times a$
$F_{ACCEL} = 81.378$ Ns²/m

The force to accelerate the cycle above is 81.378 Ns²/m lightening the bike frame by 0.6 kg reduces this to 80.778 Ns²/m, so 0.74% less force is required.

$F_{ACCEL} = (75 + (5 - 2 \times 0.3) + 2 \times 0.9 \times 0.35^2 / 0.4^2) \times a$
$F_{ACCEL} = 80.778$ Ns²/m

However, by lightening each of the wheels by 0.3 kg (0.6 kg off the cycle in total) the force required to accelerate is reduced by more than lightening 0.6 kg from the frame, so 1.3% less force is required.

$F_{ACCEL} = (75 + (5 - 2 \times 0.3) + 2 \times (0.9\text{-}0.3) \times 0.35^2 / 0.4^2) \times a$
$F_{ACCEL} = 80.319$ Ns²/m


harder to initiate a turn and lean the bike. However, it also requires less quick reactions to maintain a stable lean angle during a turn.

### What effect does the weight of wheels have in general stability?

As with many things related to human control of dynamic machines, there is a sweet spot for wheel inertia and the resulting gyroscopic effects. Too little and the bike will be difficult to keep stable in a straight line and through turns, too much and the bike will lose agility. In theory, very high inertia and the resulting gyroscopic effects could slow the response rate to such a degree that it becomes unstable again, as the rider is forced to make exaggerated inputs to try and get response.

In summary, in the world of competition cycling, reduced wheel mass and inertia gains a distinct advantage over non-rotating mass reduction on the bike.

Back in the automotive world, the same science is at play, affecting the efficiency of our vehicles and the amount of energy they consume. Four wheeled vehicles may not rely on gyroscopic effects to balance roll and prevent overturning, but they still have a noticeable influence on vehicle cornering agility.

Fortunately, they still succumb to the application of physics, enabling us to understand where we should target investment between rotating and non-rotating mass reduction in order to achieve the best balance for whole vehicle efficiency.

Writer: Steve Williams
△ Manager Vehicle Dynamics CAE

TOP: The Lotus Type 108 bicycle was used in the 1992 Barcelona Olympics by Chris Boardman who won the 4,000 m pursuit. The first British cycling medal won in the Olympics for over 72 years

# SHAPING THE FUTURE OF ALUMINIUM

*Solution heat treatment forming and in-die quenching (HFQ)*

**The increasing demand for more fuel efficient vehicles in order to reduce Carbon Dioxide ($CO_2$) emissions is a significant challenge for the automotive industry. Cars are responsible for approximately 12% of the total European Union (EU) emission of $CO_2$, the main greenhouse gas. Weight reduction is the most effective route to achieving mandatory EU legislation for future emission targets. In addition, lightweighting is the key to achieving world class vehicle driving dynamics, as characterised by the high performance sports cars produced by Lotus.**

Lotus Engineering has been working closely with Imperial College London, to develop an innovative aluminium forming process (solution heat treatment, forming and in-die quenching: HFQ), for the manufacture of lightweight, high strength aluminium pressings.

Pressings with complex geometry have been successfully formed whilst retaining the full mechanical strength of the AA6082 T6 alloy tested.

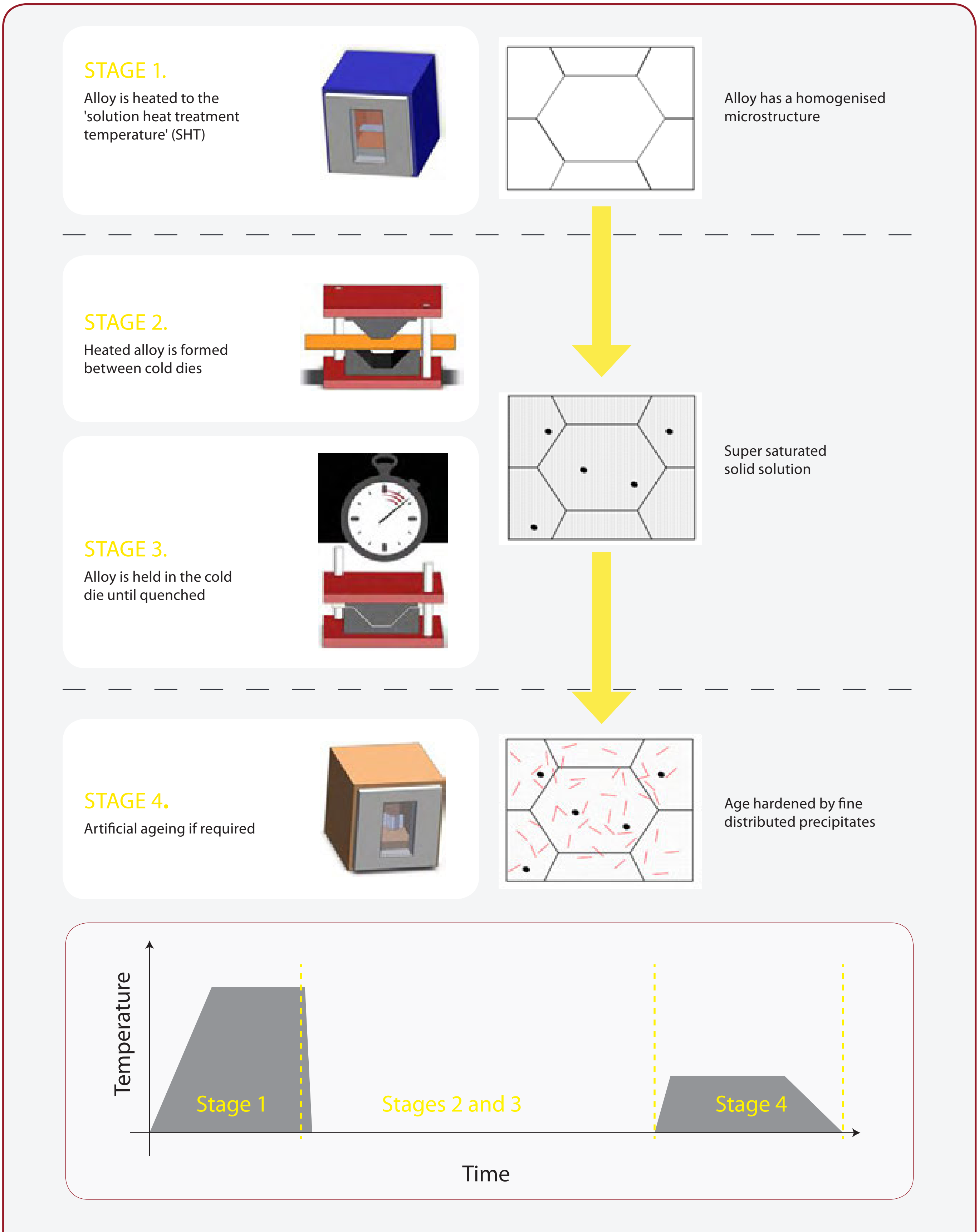
The Engineering team at Lotus has determined through computer aided engineering (CAE) simulation that up to 20% mass reduction is achievable for selected panels manufactured using HFQ, compared to cold pressed aluminium grades currently utilised for vehicle structures.

## HFQ forming technology explained

Lotus has supported the development of the patented HFQ process with Imperial College to achieve a highly innovative technology for the production of lightweight, complex aluminium pressings.

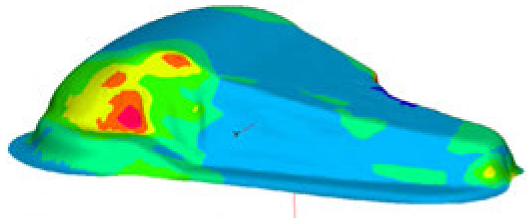
Lotus first recognised the potential of HFQ several years ago as a process which could enable a weight reduction for automotive aluminium chassis, body and closure structures, in addition to aerospace, rail and military applications.

HFQ is a hot forming process for aluminium which enables several benefits when compared against cold stamping, the most significant of which is improved formability of the material allowing the manufacture of extremely complex, single piece deep drawn panels which would otherwise be infeasible using conventional stamping methods. In addition to




Schematic of the four stages in a typical HFQ process

HFQ rear bulkhead panel forming simulation with major strain contour and experimental panel



the improved formability, post forming artificial ageing treatment ensures the aluminium pressing achieves full strength mechanical properties, enabling a potential reduction in panel thickness leading to vehicle mass reduction.

The first stage is to heat an aluminium sheet in a furnace to reach the solution heat treatment temperature of the material. The blank is cut from a sheet of standard heat treatable grade material, using conventional equipment and is transferred to a press and formed between a cold punch and die tool.

The tools remain closed to allow rapid cooling of the formed part until the pressing is quenched. Quenching freezes the microstructure of the aluminium in a supersaturated solid solution state. If a heat treatable aluminium alloy is used, the part can be artificially aged to increase the strength of the pressing, approximately 2.5-3.0 hours for aluminium grade AA6082 is required to achieve peak strength, compared to the 9 hours standard ageing time for this alloy.

The reduction in ageing time is due to the dislocations developed during the forming stage, as they provide nucleation sites for precipitates which is the mechanism by which the alloy achieves full strength.

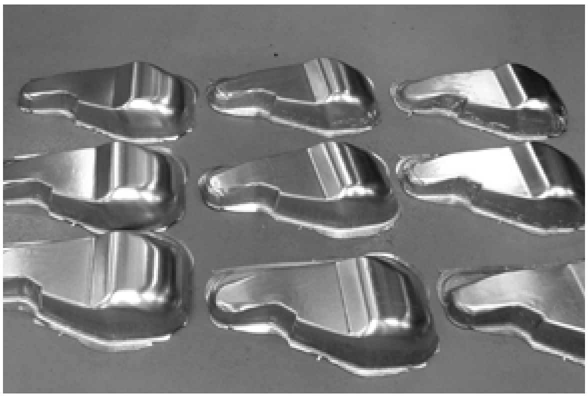
The final artificial ageing time required to achieve peak strength is therefore dependent on the strain attained during the forming process. The HFQ thermo-mechanical processing cycle has been developed to ensure the final microstructure-mechanical property relationship enables full alloy strength.

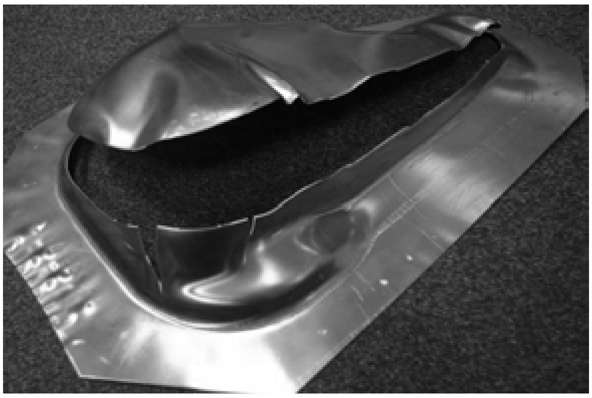
## The influence of forming speed and temperature

Forming speed is a critical factor with respect to achieving a successful pressing with the HFQ forming process. An appropriate forming speed is required in order to utilise the enhanced material ductility and strain rate hardening in the hot state.

If the forming speed is too low, blank cooling in the binder area will occur, which is detrimental to the material flow during the press forming operation. In addition, the strain rate hardening effect is pronounced at higher forming speeds, which is beneficial for the uniform thickness distribution of the formed part.

In general, a low forming speed is detrimental to HFQ forming since the hot blank will cool excessively in contact with the tool binder surface, which impedes the draw of the blank into the die. In addition, low forming speed leads to a lower strain rate and thus a reduced strain rate hardening effect, which may lead to





The left image shows a selection of successfully pressed deep drawn rear bulkhead pressings formed using the HFQ process using AA6082 T6 Aluminium

The right image shows tearing of the same panel and material as a result of conventional forming at room temperature localised necking.

However, if the forming speed is excessively high, formability could be reduced. It is therefore critical to the success of the forming process that the correct forming speed is used for the HFQ process.

## HFQ forming technology benefits and applications

The HFQ process enables high elongation levels of up 70% at elevated temperature, allowing extremely deep drawn aluminium pressings to be manufactured, which until now would be infeasible using conventional cold forming.

The first image (bottom left page) shows a selection of successfully pressed deep drawn rear bulkhead pressings formed using the HFQ process using AA6082 T6 aluminium, the second image shows tearing of the same panel and material as a result of conventional forming at room temperature.

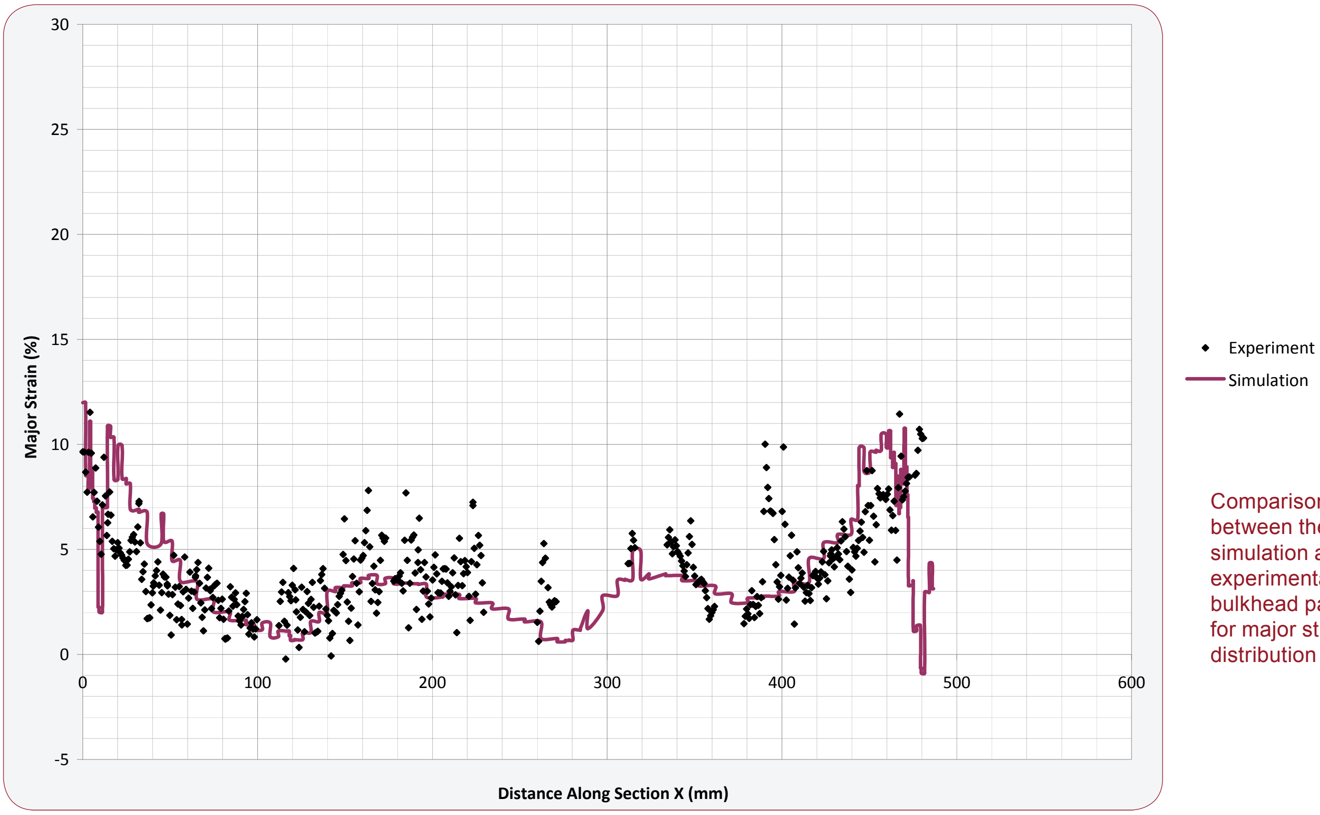
The failure characteristics of the conventionally pressed cold formed part are consistent with tearing at the very initial stage of forming. The improvements in formability achieved using the HFQ process, opens many opportunities with respect to offering improved design freedom, in combination with the high levels of strength achievable.

Uniaxial tensile tests conducted on samples removed from HFQ panels gave a maximum yield strength of 304 MPa.

HFQ therefore enables the opportunity to form more complex panels with increased levels of part integration, allowing the deletion of panels which may have been previously required to either provide the final geometry of the structure or increase the strength of the assembly.

Typical examples of applications where HFQ panels will add significant benefit include primary vehicle structures such as door inner panels, bulkhead crossmembers, A– and B–pillar reinforcements, which offer forming challenges due to their complex geometry, particularly with respect to aluminium.

In addition, these panels demand a high level of strength leading to a requirement for multiple pressings, often including advanced high strength steels or hot pressed steels in order to meet vehicle crash targets.




Comparison between the forming simulation and experimental rear bulkhead panel for major strain distribution

Potential mass reduction opportunities for HFQ exist by the deletion of pressings through improved part integration and by gauge reduction for structures where strength is a key factor.

Improving part integration has the added benefit of reducing press and assembly tool investment and associated maintenance costs, reduced assembly operations, logistics and potentially reduced bill of material cost.

In addition to improved formability and strength, HFQ offers additional benefits which include a reduction in pressing springback.

Springback or elastic recovery is an issue with aluminium and is more severe than that experienced with steel for conventional press forming.

The application of methods for reducing the severity of springback require input during the engineering and press tool design phases.

Because the forming stage of the HFQ process occurs at elevated temperature, research carried out by Imperial College with a U-shape bend test shows that springback is reduced with increasing blank temperature.

Using HFQ to reduce springback is particularly relevant for the dimensional control of channel sections such as longitudinal pressings.

## HFQ press forming simulation

Numerical work has been carried out to develop a finite element (FE) model to simulate the HFQ forming process.

Validation of the simulation results against experimental tests has shown good correlation. A FE model was developed to accurately represent the anisothermal nature of the HFQ forming process.

Geometry models of the blank and press tools were imported into the software and meshed using thermally coupled shell elements to account for heat transfer between the blank and tool parts.

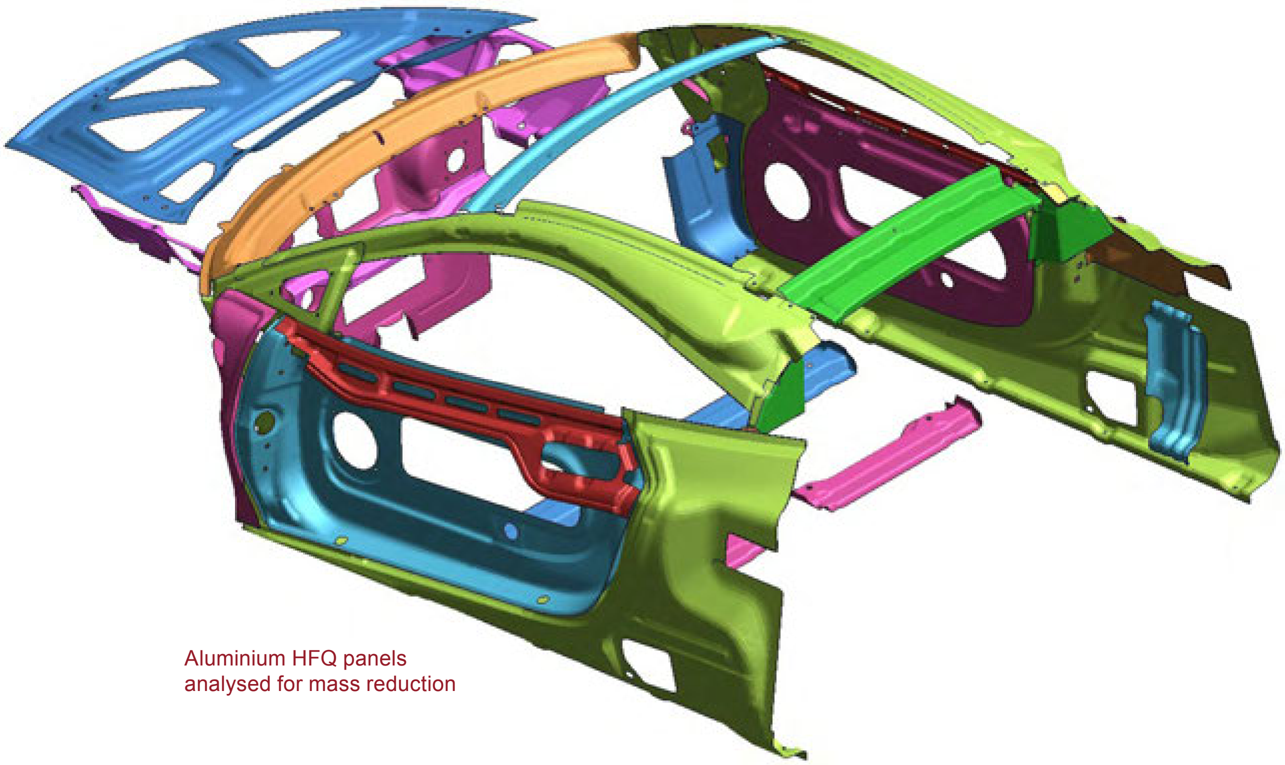
A comparison between the simulation and experimental results was conducted by measuring the major and minor strains across a surface section of the bulkhead panel.

Good agreement between the experimental and simulated major strain distributions was achieved since both results follow the same trend, which validated the FE model.

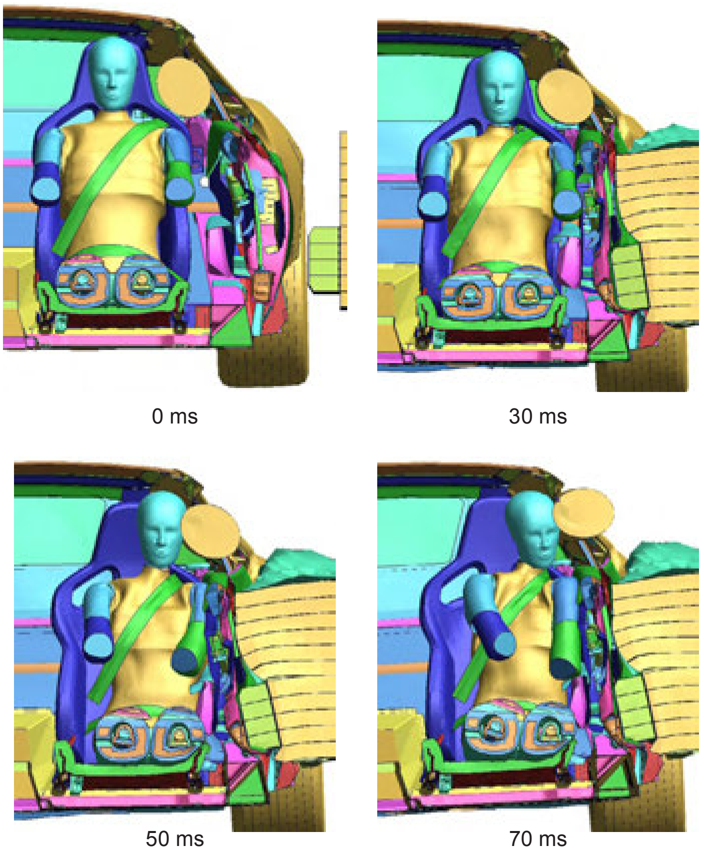
Further simulations have since been conducted which support the correlation.

## HFQ vehicle mass reduction analysis

In order to assess the potential mass reduction enabled by HFQ pressings, Lotus carried out CAE analysis on a selection of thirty six aluminium panels from an aluminium body



Aluminium HFQ panels
analysed for mass reduction




Occupant injury analysis using HFQ aluminium panels

structure.

Analysis was carried out to determine the structural response of the vehicle during offset deformable barrier, federal side impact and federal roof crush events prior and post changing selected panels from cold pressed AA5754 H111 to HFQ AA6082 T6 grades.

Lightweighting was achieved by reducing the thickness of the selected panels, which enabled a mass reduction of up to 20% using the high strength 6082 T6 HFQ aluminium alloy, with comparable performance to the baseline aluminium structure.

Euro offset deformable barrier simulation carried out at 56 km/h with a 40% offset, resulted in similar peak footwell intrusion and door aperture reduction with the reduced mass HFQ panels.

Federal side impact simulation also showed similar peak door intrusion and fuel tank protection levels for the baseline and reduced mass HFQ model.

Occupant injury analysis showed that all dummy injury criteria where comparable or improved using the reduced gauge high strength HFQ panels versus the baseline model, and within both Lotus' and legal requirements.

Roof crush analysis at three times the vehicle mass showed similar performance against the baseline.

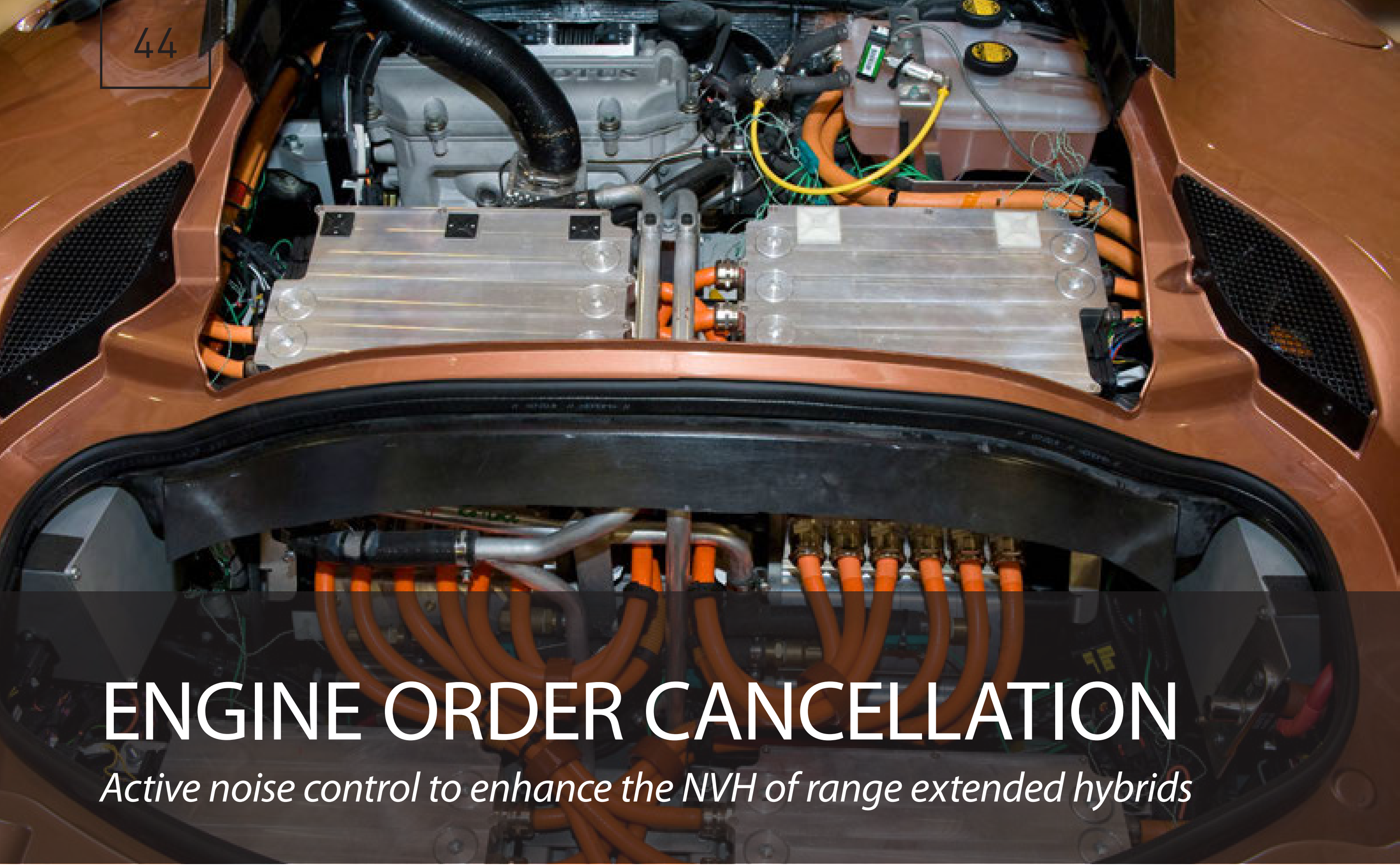
## Conclusion

Aluminium is increasingly being incorporated into vehicle structures as manufacturers strive to reduce vehicle weight in order to meet performance and emission targets.

HFQ provides a new enabling manufacturing method for the production of complex high strength aluminium pressings, with the potential to further reduce mass of both steel and conventionally pressed aluminium structures.

Lotus Engineering will continue in its development of the HFQ process to ensure the benefits this exciting technology has to offer are maximised for future exploitation.

Writer: John Sellors
△ Exec. Engineer Materials and Manufacturing



# ENGINE ORDER CANCELLATION

*Active noise control to enhance the NVH of range extended hybrids*

**As a range extender generator is provided to supplement the EV capability on a series hybrid, it is not a system in constant operation, indeed on many short or low speed journeys it will not operate. Therefore the attributes and requirements of such an engine are slightly different to a conventional engine.**

The range extender engine and generator system needs to be as lightweight and compact as possible (fewer cylinders) with a fast engine warm up (low thermal mass and close coupled catalyst), low back pressure exhaust and a simple mounting system. The ideal operating strategy should be for maximum efficiency.

One of the major expectations for users of all vehicles is consistency in its operation and behaviour. This means not only range, performance and speed but also the noise performance. This is a key issue for users of hybrid vehicles where the expectation of these vehicles is a capability of very low interior noise levels.

The intermittent and unpredictable operational noise of a small highly loaded engine is a major concern for customers and the requirement for an acceptable cost effective solution to this problem is a serious issue for manufacturers.

We are aware of several manufacturers who run the range extender in different modes and efficiencies at different vehicle speeds to maintain an acceptable level of refinement.

The conventional NVH solutions for powertrain noise would all tend to be prohibitive in terms of cost, weight, package or efficiency.

Active noise control offers an effective solution as shown in the following example of the Lotus Evora 414E series hybrid concept car.

The Lotus designed range extender range extender as fitted in the Lotus Evora 414E series hybrid is a 1.2 litre, 35 kW, three cylinder aluminium monoblock engine, integrating cylinder block, head and exhaust manifold with a close coupled catalyst. The range extender generator and inverter is an axial flux synchronous motor-generator with the engine flywheel integrated into generator rotor which is directly mounted to the crankshaft.

It is primarily designed and operated for efficiency, not refinement. Above 12 kW output the engine runs at wide open throttle and the output power is regulated by changing engine speed (3,500 rpm max speed).

With regard to the NVH performance of the engine it is not surprising that a small lightweight 3 cylinder engine operating at full load has less than ideal NVH characteristics.

The interior noise is dominated

by high noise levels at engine firing, noise acceptability is further reduced due to the fact that the engine operation is intermittent and is linked to battery state of charge and system load demand rather than vehicle speed and driver demand. The large NVH difference between when the engine is and is not running serves to highlight this issue.

This makes the 414E an ideal platform to demonstrate the benefits and performance of the HALOsonic active noise technology, specifically for the application of active engine order cancellation (EOC) within the cabin.

The graph shows a linear interior noise spectrum up to 200 Hz for the engine operating at 3,000 RPM (50 Hz) generating around 30 kW electrical power.

The black line shows the interior noise with EOC switched off and the black line with EOC switched on.

Initial system tuning was for the main dominant orders 1.5E (75 Hz) and 3.0E (150 Hz) which are at levels of more than 20 dB above the background noise. The test result shows that these dominant orders have been completely cancelled.

The residual noise peaks at 2.5E (125 Hz) and 3.5E (175 Hz) could also be reduced if required as the system has the capability to cancel up to 4 separate engine harmonics.

The fact that the engine is designed to run at moderate speeds and has only 3 cylinders produces a characteristic dominated by low frequency noise which is an ideal application for active noise control which is most effective in the range up to 250 Hz.

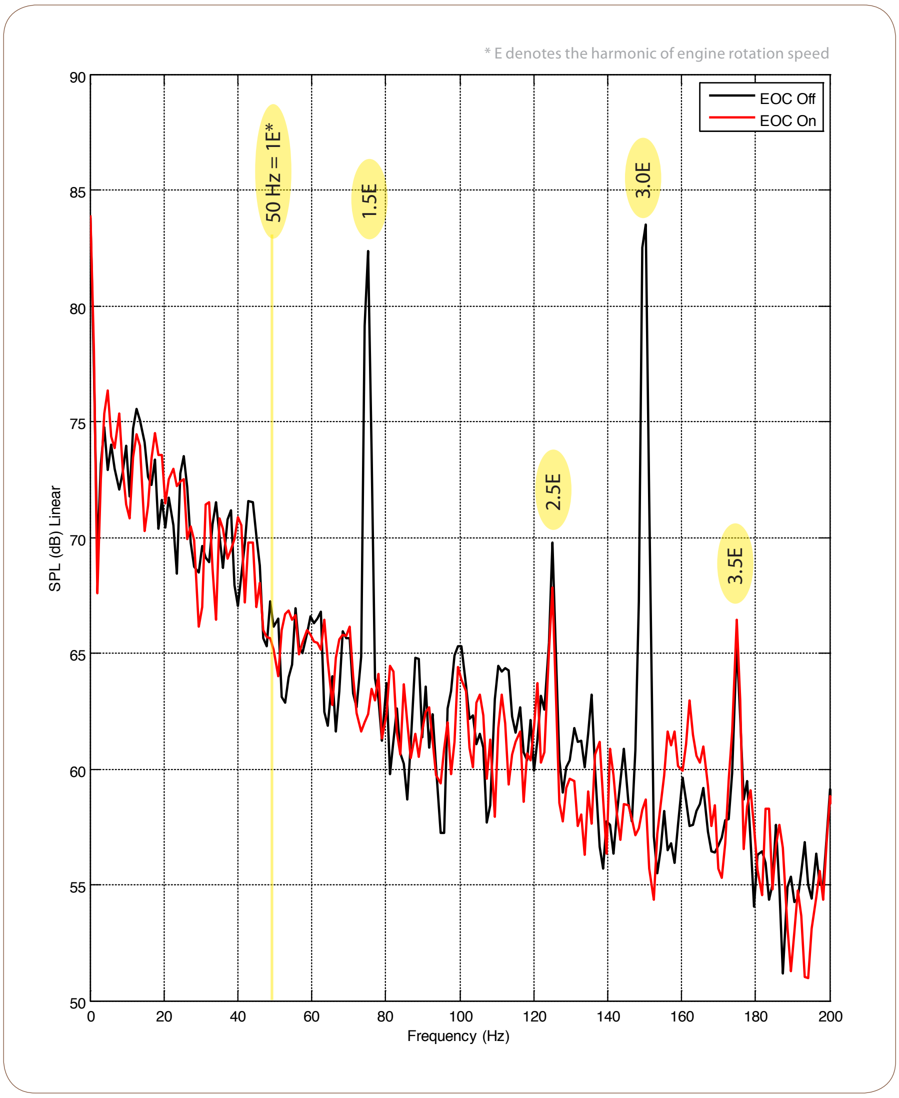
Following on from this initial result the development plan is to maximise the overall cancellation at all relevant engine orders and then to optimise the performance for the transient engine switch on and off events.

The 414E will also be equipped with interior sound synthesis to provide an enhanced driving experience with full gear change simulation giving the capability for improved driving control and energy efficiency though simulated engine braking and performance boosting. It is a fundamental requirement of this technology to ensure that the customer only hears one engine sound that is linked to his driving inputs and behaviour and is not confused by the residual drone of the range extender when it is operating.

This example clearly shows the major benefits of using this technology on this type of vehicle.

In conjunction with Harman International production ready solutions have been developed for this technology so it is ready and available for integration into vehicle programmes.

**Writer: Colin Peachey**
△ Group Chief Engineer (EEI)




The graph shows the interior noise in the cabin of the 414E with and without active noise control

# STATE OF THE INDUSTRY

*Dave Leggett takes a quarterly look at the automotive world*


**Well, that's another Frankfurt Show done. As ever, plenty to marvel at, including the exorbitant accommodation bill for a supremely modest hotel that, like many others, makes the most of the big automotive circus coming to town.**

Paris is next year (the two alternate, with Frankfurt's Messe vast showground turned over to the aftermarket's Automechanika in the even number years when IAA is not on). Before then, there's Geneva, the neutral one. Paris is a big one for the French carmakers and Frankfurt is the big one for the German OEMs.

The atmosphere in Frankfurt seemed pretty upbeat, the German OEMs competing with their usual IAA show largesse.

Volkswagen revealed that 150 tonnes of steel were used to construct its Frankfurt exhibition stand, that it took 24 days to construct, a planning period of eleven months and came with over 2,300 lamps requiring some 90 kilometres of cables. And there were 53 vehicles on show.

## Volkswagen goes electric

For Volkswagen, this year's IAA was about electric vehicle offerings. We had the e-up! and the e-Golf. Volkswagen held off for a long time in the hope that there might be some breakthroughs in battery technology. Now it has committed itself to putting the first A- and C-segment EV hatchbacks from a European brand into production, while Audi takes a different tack by instead launching parallel hybrid electric vehicles (PHEVs). Will the A3 e-tron sell better than the e-Golf? Possibly, though VW is hedging its bets, with a plug-in hybrid version of the Golf set to follow.

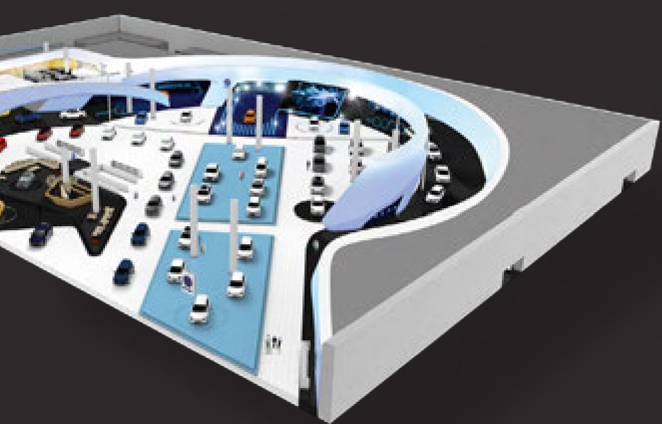
The real story with these cars is yet to be told, and will not be reported until 2014. That is when we will begin to see if lots of European buyers, and Germans in particular, can be enticed to buy these plug-in vehicles.

The Volkswagen Group has set certainly its sights on global market leadership in electric mobility. "*We are starting at exactly the right time. We are electrifying all vehicle classes, and therefore have everything we need to make*


*the Volkswagen Group the top automaker in all respects, including electric mobility, by 2018,*" said VW Group CEO Martin Winterkorn.

Winterkorn is convinced that Volkswagen is in a strong position: "*We have the most comprehensive approach to tomorrow's mobility. From highly-efficient, eco-friendly diesel, gasoline and natural gas-fuelled engines to classical hybrids, purely battery-driven vehicles and plug-in hybrids; no other automaker can match the broad range we have to offer.*"

Oh, and there's also the Porsche Panamera S E-Hybrid, another plug-in model.



## About David Leggett

David Leggett has been editor of just-auto since 2000. He has been analysing the auto industry for over 25 years in analyst, forecasting or B2B publishing roles. He is frequently asked for media interviews or to present at industry conferences.

David also plays a leading role in the development of just-auto's expanding research portfolio.

He joined just-auto from the Economist Group's Economist Intelligence Unit (EIU) where, as director of automotive forecasting, he played a key role in the integration and development of forecast-orientated automotive data to the EIU's electronic product portfolio.

Formerly, he was director of forecast services at CSM Europe, the European arm of US-based auto industry analysts CSM Worldwide, where he developed the European Light Vehicle Forecast Service for automotive clients across the world.

Previous appointments include senior associate with Global Insight (then DRI) and senior economist with the UK's automotive trade body, the Society of Motor Manufacturers and Traders (SMMT).

While at Global Insight in the mid-1990s he led the company's expanding analysis of automotive emerging markets, especially in East Asia.

David holds an honours degree in Economics from the University of East Anglia, Norwich, UK.

### Tesla, the investors' super-darling this year

One stand that caught my eye was Tesla's. It was low-key, but pretty crowded. Plenty of people were clustered in and around the Model S sedan on display. If they can sell the 20,000 they are hoping to shift this year, they'll be keeping their investors very happy. And here's the thing. Tesla has been the 'super-darling' of the investment community for the past year. At the beginning of the year, the Tesla share price was a little over 30 dollars. At the time of writing it is over 190 bucks. Incredibly, Tesla's market capitalisation is approaching half that of super profitable BMW. But Tesla may make and sell 20,000 cars this year (if all goes well) and BMW is advancing on 2 million cars a year and is established all over the world, has been around for decades and so on.

There's no comparison between the two makers. But Tesla has the eye of investors. Company founder, CEO and talisman Elon Musk is a clever guy, a visionary as well as an entrepreneur.

And in the execution of the Model S, Tesla has pulled off quite an achievement. That said, it perhaps looks just a little unbalanced and you have to wonder how long the investor honeymoon will last. The Model S did look very good in the flesh at Frankfurt, undeniably (and, as well as nice body lines, sports one of the biggest centre binnacle touch screens I have ever seen). Investors are getting excited about the next gen models and even lower price points from the guy they are coming to trust and believe may just have it in him to disrupt the auto industry or give it a severe jolt (or should that be bolt) .

I would just add a word or two of caution. The big 'dinosaurs' are not 'doing nothing'. General Motors, for one, has its eye on Tesla.

These guys have huge R&D resources at their disposal and GM, for one, is making some fairly aggressive sounds about where it wants to be with its next generation plug-ins. GM is looking for at least 20% improvement to the electric-only range on its next generation Volt (Ampera in Europe) electric vehicle range extender models. The current range-extender Volt is capable of travelling around 38 miles on battery power alone, before the petrol engine kicks in. GM CEO Dan Akerson summed up the challenge of going even further than 20%: *"If we can get it up to 50, 60 miles or more, we will, but that's going to be another three to four years out."*

It's also true to say that there could be some fizz in that soar-away Tesla share price. It could be vulnerable if things don't go according to plan or, more accurately, are perceived as not going to plan. Negative publicity may cause the investor herd to run the other way. One thing that got a bit of attention recently was a Tesla car in the US being involved in an accident that caused the vehicle to catch fire. There was a subsequent media brouhaha and the share price lost USD 20 in a matter of hours.

Perish the thought. An electric car involved in an accident and a subsequent fire. That wouldn't happen in a vehicle carrying a tank full of inflammable liquid would it?

It's perhaps a cautionary tale if you hold 'overvalued' (well, the value of anything is what people believe it to be worth, backed up with something called money) Tesla shares. But keep an eye on Tesla's progress with the Model S this year. If it hits that 20,000 target for Model S sales and avoids negative publicity, then the investor buzz and fizz may well intensify further.

How worried is the auto industry that Elon Musk has a properly disruptive business model? Not very, is the impression I have, but they won't ignore what he's doing in the electric vehicle space, either. It could provide them with important clues on how a very uncertain part of the market is going to evolve.


## The need to appeal to 'digital natives'

Another area of high-tech that presents vehicle manufacturers with a degree of uncertainty is 'vehicle connectivity'.

It's the term of the moment. Not only do you have to understand what Generation X wants, but now there is Generation Y and a group of people being termed 'digital natives'. Car manufacturers need to design cars that allow a new generation of 'digital natives' to continue their digital lifestyles while driving, according to a senior Hyundai manager I heard recently addressing a Vehicle Connectivity conference in London.

Johannes Heichel, Manager of Product Planning, Hyundai European R&D Centre, said that a new generation of 'digital natives' wants to be always connected with friends and relatives and that includes while they are driving a car.

Who are these people and what characteristics do they have? He defined 'digital natives' as those typically born after 1980, aware of the digital world and how to use it, using computers and mobile tools as the main form of communicating and also increasingly using social media as their main platform for communication.

*"The expectation is that we have to allow the digital lifestyle while driving,"* he said. *"Connectivity is very important and we must also offer a very good and up to date HMI experience.*

*Emotional design is also critical for digital natives, they do not buy ugly cars, and they want good design, 'digital aesthetics'."*

So, have you got that? They want to be connected, they want to be in comfortable and cool cars, with a great HMI experience. The whole package has to support their modern day values, which are based on experiences, gap years, music festivals, smart gadgets, brands like Apple, renting rather than 'owning' and being constantly connected to friends and family. Every generation is different and has its own take on the world. I suspect, though, that some of them will discover that, actually, they do like to drive cars. And that the smart phone does have an off button.

**Writer: Dave Leggett**

# VISION 2020

*As the EU targets for economy and emissions get ever closer...*

TOP: Mercedes Benz have invested millions on a new wind tunnel and other testing facilities

**As the regulatory pressures on the automotive industry in Europe ramp up, Ian Adcock reviews the range of activities aimed at reducing weight and improving fuel efficiency.**

It is, perhaps, serendipitous that 2020 is the target date for vehicle manufacturers to achieve 95 g/km of $CO_2$ for their products as it has certainly focused all their vision on meeting that ambitious target. If they miss it, they face a swingeing EUR 95 fine per vehicle from the first gram exceeding that figure onwards.

Even a current Ford Fiesta powered by that paragon of fuel-sipping virtue, the one-litre EcoBoost, would be subjected to a EUR 380 penalty since in today's state of tune it emits 99 g/km $CO_2$.

So, imagine the consequences if you're producing a Mercedes-Benz G-Wagen with its six-litre V12 (397 g/km since you're asking).

Recent research from PA Consulting Group underlines what an uphill challenge the OEMs face, some more than others. According to their research by Thomas Goettle, the big German OEMs BMW, Mercedes-Benz and VW are facing multi-million Euro fines of EUR 500 million each for the first two, with VW facing a fine approaching EUR 1 billion.

Manufacturers can't afford big financial penalties of that magnitude which is why the scramble is on to meet the $CO_2$ levels demanded by Brussels.

Trouble is, the low hanging fruit has gone: light-weighting through increased use of aluminium, high strength steels, magnesium and plastics is on the increase as, too, is the trend towards downsized engines with direct injection and turbo-charging combined with increasingly efficient dual clutch gearboxes and automatic transmissions (with 8, 9 and 10 speed 'boxes being developed by Hyundai and

investigated by GM).

PA Consulting sees increased incentives for electric vehicles (EVs) as part of the solution, but at the recent Frankfurt IAA there appeared to be a rowing back by the industry on electrification. And that's despite the fact that Volkswagen debuted a series of EVs and the Formula E race challenge was unveiled.

Professor Dr. Thomas Weber member of the board of management Daimler, responsible for group research and Mercedes-Benz cars development, told me this: *"In all potential scenarios, all vehicles will still have a combustion engine on board. You could also say that 80% of all vehicles will have an electric motor."*

*"But that's linked to what is your key message as a brand? Electrification without a combustion engine will take place but will take 10-30 years because a plug-in range extender and hybrids based on efficient downsized, down speeded engine with an additional electric motor will be prevalent.*

*"The only thing that will go down in numbers is a pure internal combustion engine, but the question is 'How fast?'"*

*"I think it's clear that the combustion engine, based on all we know about fuel, oil etc., will stay for a long time. We definitely have enough oil and it will remain cheap; the only driver that could change the game is climate discussion and if we really see a dramatic increase in bad weather. It will be a long path to these new technologies, but it will always be an internal combustion engine with downsized efficient engines and better aerodynamics in the first lane; in the second lane hybridisation, full hybrids plus plug-in hybrids; and, finally, in the third lane EVs and fuel cells."*

*"We need all these technologies around the world, and with a clever architecture strategy we can combine, for a specific country, the right power train."*


If all, or most of, the low hanging fruit has gone then what are the OEMs to do?

Aerodynamics is one, obvious, area where percentage point gains in $CO_2$ can be made, says Dr Jeff Howell, lead engineer aerodynamics Tata Motors European technical centre, who explains that *"a 10% drag reduction will give 2% gain in fuel economy."*

These are slim improvements to the EU target however, as the European drive cycle is weighted towards urban rather than quicker, highway driving. Pininfarina's Andrea Benedetto, who is responsible for product development, points out that Mercedes-Benz wouldn't have spent a reputed 2,500 hours in the wind tunnel for its latest B-class unless it was making hidden gains. *"If you look at the B-class spats, its aero shape is extremely complex and its specific to that vehicle, the A-class design is different again,"* he says. *"The principles you can develop across the line, but the fine tuning and shape is influenced by many surrounding parts,"* he adds.

TotalSim's Rob Lewis believes rising fuel prices will force manufacturers to adopt flush underbodies, despite the cost, weight and complexity. The resulting 5% gain in drag reduction will be worth it.

A solution nearer to hand are active grille shutters; controlled by specially developed actuators which enable high cooling capacity through maximum air flow in the open position. But when closed, reduce drag and the time necessary to bring the engine up to operating temperatures achieve fuel savings of 1% on average in the European driving cycle.

Active shutters, says Röchling's Dr. Klaus Pfaffelhuber, manager advanced development, should be used in concert with the company's engine encapsulation system that uses low-weight reinforced thermoplastics (LRWT). Testing the 15 mm thick Isoraloft insulation on a 1.6 diesel at 12 °C resulted in a 40% reduction in warm up time, 10 K more heat retention after seven hours and a 2-3 g/km $CO_2$ reduction with the added bonus of an 8 dBa reduction in sound levels.

Although difficult to retrofit, Pfaffelhuber predicts it will come to market in the 2020 timeframe, adding only about 1.75 kg to the car's weight and EUR 30-50 price increases which, he claims, would be rapidly recouped in fuel savings.

Closing the gap to the 2020 limits is going to be a bigger challenge for larger and heavier vehicles and it is this sector that Johnson Controls is targeting with its first 48-volt lithium-ion micro hybrid battery combined with a 12-volt starter battery that has, claims Ray Shemanski, vice president and general manager global original equipment business power solutions, the potential to save up to 15% fuel consumption savings. Available for testing from December of this year Shemanski says that internal research predicts that by 2020, 25% of new cars could be fitted with these batteries.

The 48-volt battery is designed to rapidly capture energy from braking and can support higher loads such as air-conditioning and active chassis technologies; whilst the 12-volt battery continues to power the starter motor, interior and exterior lights as well as infotainment systems.

Although the initial cost is quite high, between EUR 750 and EUR 900, in-house modelling has shown that the payback could be only 24 months for a driver averaging 15,000 km a year.

*"Customers have their own challenges, because each is closer or further from achieving those $CO_2$ requirements according to their model mix,"* Shemanski added.

Even changing the engine bearing to those using Federal Mogul's polymer IROX coating can result in 1 or 2 g/km saving claims the company's director, Application Engineering Bearings, Gerhard Arnold: *"Cutting the length of the interrupted groove, for instance, can reduce the oil flow through the main bearing without compromising the supply. That means you can then either increase oil pressure or reduce the size of the oil pump as you're pumping so much oil through the engine."*

But the real benefit of these bearings is their ability to withstand the higher demands of stop-start or hybrid engines. Arnold explains: *"With stop-start or hybrid applications it means you pass this area of mixed lubrication hundreds of times more than before… In the past an engine starts maybe 30,000-40,000 times, today it could be 500,000 with stop-start and for full hybrid it could be a million."*

Federal Mogul's polymer IROX coating, says Arnold, withstands 800-900,000 stop-starts on test engines *"and is an excellent solution to overcome this critical phase."*

Add another 4% that can be gained using a nano lubricant such as those developed by Miller Oils and the figures are beginning to stack up in the right direction. But they are still small compared to the big gains that some OEMs will need if they are to avoid those swingeing fines.

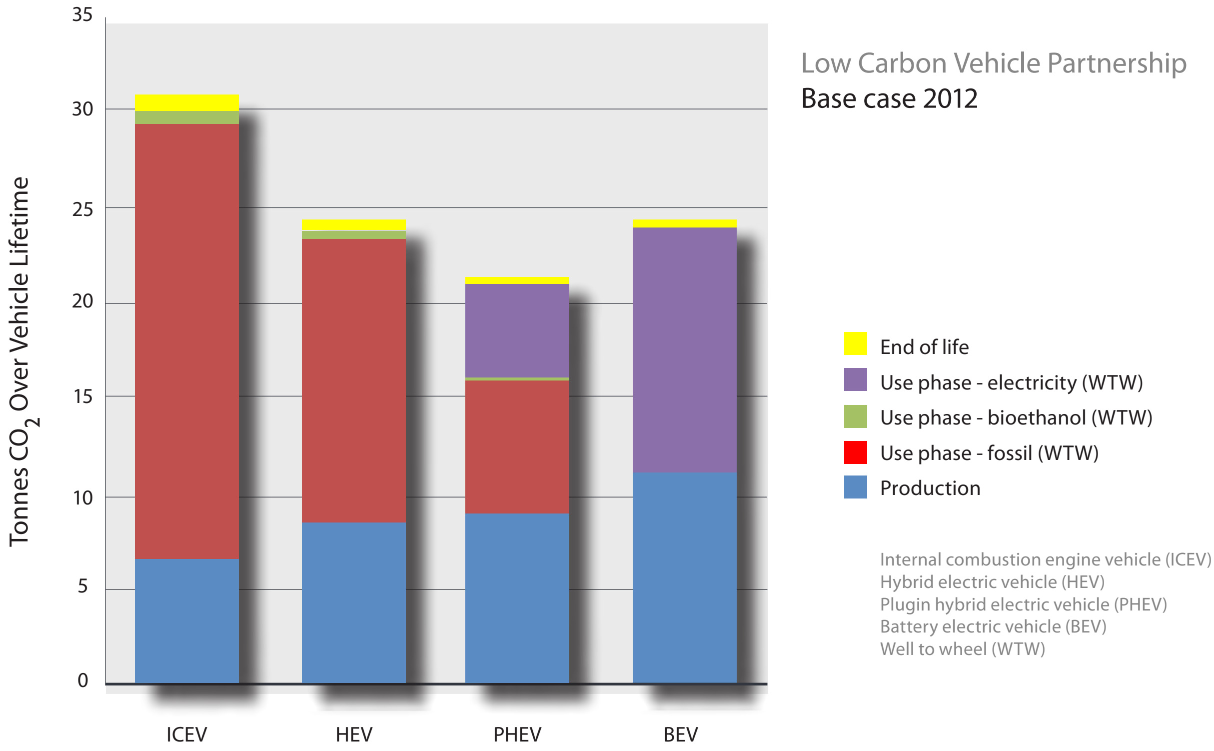
## Incremental approach to targeting reductions

PA Consulting's Thomas Goettle suggests that *"the EU could also look at multiplying the value of 'super credits' or, the better option, taking a more incremental approach to targeting emissions reductions, as it has done with the 2015 target. This could give carmakers until 2023 (instead of 2020) before 100% of their fleet needs to be on target for 95 g/km of $CO_2$ which could provide a more achievable option."*

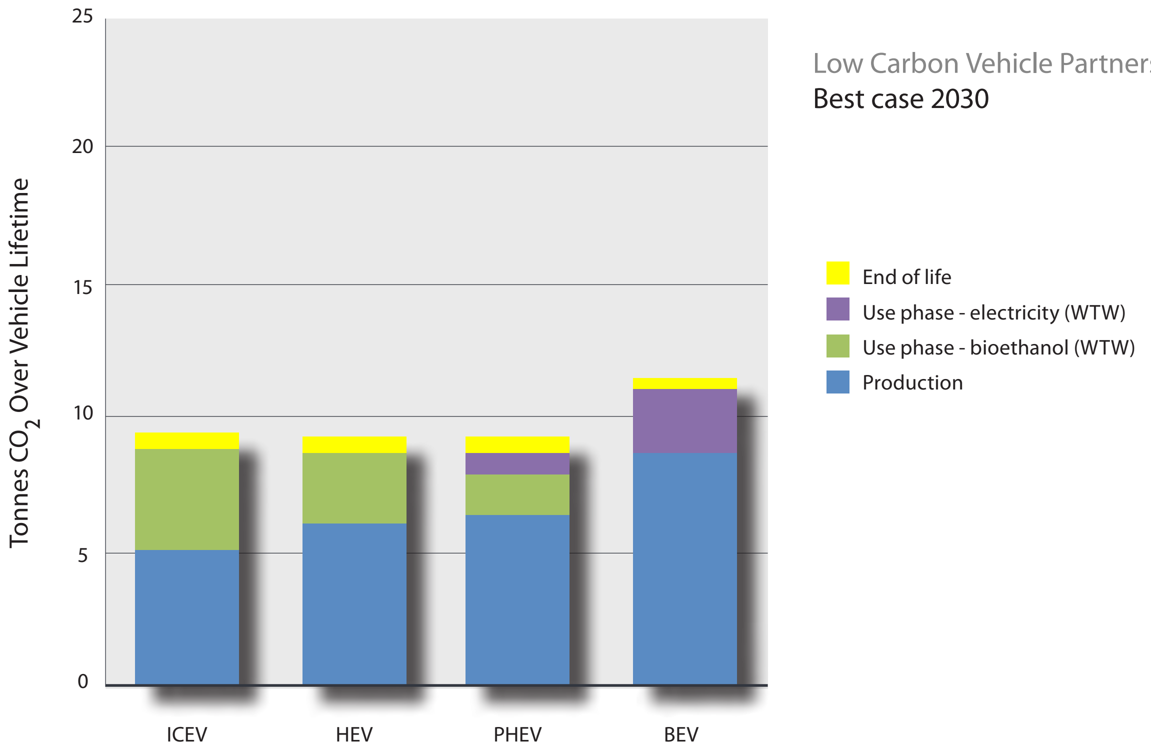
Environmentalists would argue that this is letting the OEMs off the hook, especially at a time when the United Nations Intergovernmental Panel on Climate Change (IPCC) has put the blame for climate change firmly on mankind's industrialisation of the planet.


LEFT: Active grille shutters by Röchling Automotive

BELOW: Johnson Controls 48 V lithium-ion micro battery




Low Carbon Vehicle Partnership
Base case 2012




Low Carbon Vehicle Partnership
Best case 2030

Graphs from the Low Carbon Vehicle Partnership (LowCVP) report *'Life-Cycle Assessment of Low Carbon Cars 2020-30'*

## Radical solutions

Clearly the clock cannot be turned back and with global sales of new cars constantly on the increase, especially in emerging markets and the BRICs, there need to be some radical solutions.

Clutch-by-wire, currently under development by Bosch could be part of the answer delivering a predicted 10% improvement in fuel economy. By replacing the mechanical link between the clutch pedal and the hydraulic actuator with an electronic sensor and an AC motor it allows manual gearboxes to be disconnected from the engine for the first time to allow stop-start coasting whilst driving. Typically, over a 100 km route this could mean the engine is switched off for a quarter of the journey.

Bosch is also developing 'stop-start coasting.' In this scenario at cruising speeds between 30 and 120 km/h when the driver backs off the throttle, the DSG is disengaged from the engine which is switched off. This leaves the car coasting under its own momentum until the driver either accelerates or brakes at which point the engine is restarted.

Unlike other stop-start systems this one closes the clutch to restart the engine at speeds above 30 km/h, a sensor in the transmission matching the engine speed to the correct ratio and road speed.

At very low engine speeds of 200 rpm the starter motor's speed is synchronised with the engine for restarting. Bosch claims a restart time of 450 milliseconds for a diesel and 300 milliseconds for a 1.4-litre TSI engine and a 10% real-life fuel saving.

## Total lifecycle approach

None of these solutions are going to be inexpensive for either the OEM or the end customer so, should we accept that the internal combustion engine has, to all intents and purposes, reached its efficiency limit and be looking at other ways of determining $CO_2$ levels than purely based on tailpipe emissions?

That's certainly the view a recent report from the Low Carbon Vehicle Partnership (LowCVP) took, where it stated that the use of tailpipe $CO_2$ emissions will become *"almost irrelevant in terms of focusing on true carbon profiles"* of future vehicles (2030).

The study further emphasised the need for a life cycle approach in future automotive emissions regulations as vehicle production phase emission impacts become more significant.

*"This new research reinforces the need for a life cycle approach to emissions regulations,"* says Cees ten Broek, director, WorldAutoSteel.

*"Automakers and others are significantly reducing emissions associated with the vehicle's use phase through advanced powertrain technologies and fuels. With these efficiencies, the emissions generated during materials production and vehicle manufacturing become increasingly more important and should be accounted for."*

All significant legislation currently focuses on tailpipe or use phase emissions. A more thorough way of measuring automotive $CO_2$ emissions is by using life cycle assessment (LCA), which takes into account all of the emissions created during the life of a product from raw material production through to end-of-life recycling or disposal.

The value of a life cycle approach shows how production phase emissions become dominant with increasingly efficient powertrain technologies, while comparing total vehicle life cycle emissions for various powertrain and fuel technologies.

Ten Broek also notes that an LCA approach in regulations will provide greater design flexibility in meeting the regulatory requirements for vehicle fleets. *"A life cycle-based regulation will provide automakers with the ability to develop an optimal mix of technologies to achieve the intended emissions reduction target"* says ten Broek. *"One thing is certain, without LCA, we are not solving the vehicle emissions problem; we are merely shifting it to another vehicle life cycle phase."*

Over to you Brussels.

Writer: Ian Adcock

△ just-auto.com

# LOTUS MOTORSPORT

*Interview with Rupert Manwaring - Head of Lotus Motorsport*


**Lotus has, to put it mildly, plenty of motorsport pedigree. It's a vital part of the core Lotus brand values. As well as the headline involvement with the Enstone-based Lotus F1 team, there is much more going on that is aimed at racing enthusiasts and engaging with Lotus car buyers on the track. Dave Leggett found out more from Rupert Manwaring, Head of Motorsport at Lotus Racing.**

### Can you describe the main activities of Lotus Motorsport and your role?

We produce a range of track cars and pure motorsport cars, five or six models, starting with the Elise throught the Exige and up to the Evora. We design, build, sell and service customers from here, professional racing teams and private individuals. We supply cars to our dealers and distributors around the world.

All of the race cars now are based on our road car products, with the exception of the Type 125.

My job as head of motorsport means that I am very commercially focused and my job is to run a good department that works commercially.

### And you are steeped in motorsport yourself?

I started my career with Formula 1 in 1977 and stayed with it until 2002. I started as a draughtsman for Surtees and then got the chance to travel as a spares coordinator, organising bits and pieces for the team and eventually I became assistant team manager at Surtees, before moving to Brabham where I was assistant team manager when we won the World Championship twice. I eventually became a team manager at Team Lotus in the late 1980s, where I worked for four years.

Then I went to Tyrrell, where I was also team manager. In 1995 I decided to become commercial director at Tyrrell, looking at how we could raise funds. From then until 2002 I was heavily involved in finding money for F1 teams.

After that I spent 7 years as MD of Lola Cars then a 3 year stint at Ray Mallock, before joining Lotus Motorsport in 2011.

### While we are on Formula 1, can you describe the benefits to Lotus of the current licensing set up with the team based at Enstone?

Yes. We licence the Lotus name to the team and we are a commercial partner. We use Formula 1 for global brand recognition and that's working very well. So Formula 1 works on that level and then we have the racing cars from Hethel that bear a strong resemblance to the road cars. It's a nice mix.


### And the motorsport arm gets those Lotus race cars out there...

Yes, we have hundreds of cars racing every weekend all over the world and they give people the opportunity to see that Lotus cars excel at speed and in a race environment and so on. It's a strong message being delivered by example and association, with the track cars clearly sharing much DNA with Lotus road cars.

### How is Lotus Motorsport organised and run?

Lotus Motorsport is a separate department within Group Lotus. Everything is funded by the Group, but the drive is to make it self-sufficient. This year we have made very good progress towards that. We have very supportive shareholders and the clear focus is to produce racing cars that can be sold to people and return a profit.

We are quite a small department, with around thirty people directly, but we have access to many more in Lotus, including Lotus Engineering and we have a great resource base here.

TOP LEFT: Lotus Evora GX at Goodwood festival of speed
RIGHT: The Lotus Exige Cup R

### What are those thirty people in your department actually doing? How is the workload split?

My right-hand man is a guy called Gavan Kershaw who heads up the technical side of things, and was part of the Lotus Cars product development team, he is also a successful and competitive racing driver - he won a race a few weekends ago in an Evora GT4 at Snetterton. Gavan looks after a small engineering group but there's a large fully equipped workshop with a team of technicians who build and prepare the race cars.

There is a small sales department and there is a service and spare parts department for customers to bring their own race cars and road cars for the Hethel treatment. We have pretty much everything we need to look after ourselves, sell cars and support our customers.

We like to think of ourselves as proactive, nimble and able to react quickly if we need to.

### How do the Lotus Cup events work?

They are a fantastic opportunity and resource for us, both getting the cars into new markets and making the Lotus name very visible for market penetration. The Lotus Cup is open to all Lotus race car owners with their Elises, Exiges, Evoras and 2-Elevens. Each Cup Series is tailored for local needs and the region, so they are slightly different. The UK Cup Series is long established, has huge grids, is very successful and


has scope for racers to modify the cars, that sort of thing. The Lotus Cup Europe is also very successful and customers in that series prefer to buy standard Lotus motorsport product and race them.

We have a new Lotus Cup in Thailand which has been going for about 18 months. They started with Elises but are now moving on to the Exige V6.

Motorsport is fairly new in Thailand, so there isn't really the infrastructure is developing and the Elise is perfect there. We are also looking to add a race in China. We hope that the 'Greater China Race', planned for Macau, and being supported by our Lotus distributor in Hong Kong, will pave the way for a Cup series for China.

The Lotus Cups are all thriving, bringing Lotus enthusiasts together, reinforcing Lotus values and promoting the brand in places where the opportunities and potential are very sizeable.

**Any other places where Lotus Cup could eventually go?**

We have had interest in India and also the Middle East. It could be a little early for India. Over the next 2-3 years there could be another 4-5 new regions for the Cup.

TOP LEFT: The Lotus Evora GT4
TOP RIGHT: Lotus Driving Academy

**Are the racing models you produce expensive to engineer and develop?**

We are lucky that with a Lotus we are starting with a car that inherently comes with a lot of racing DNA in it. With the Cup cars, it is relatively straightforward to develop a Cup car from a road car. It starts getting more serious with the GT4 Evora; that was quite a major investment. Relatively speaking though, it's not too difficult to develop a racing car from a Lotus Car, and certainly less so than some of our competitors.

**The Type 125 with its F1-inspired appearance and performance (640 bhp in a car that weighs 600 kg) looks like it's getting towards the rarefied end of racing spectrum. How many customers would you get for a high-end package like that? Is there a typical buyer?**

So far we have sold four. Our customers are all businessmen, but they range in age from 35 to 60 years old. They are people who have spent a sizeable chunk of their lives immersed in the world of business, but who also have a huge passion for motorsport.

They want to drive the ultimate customer track car. The customers tend to find us. We are building two more cars at the moment for future customers.

We have a close relationship with T125 customers and so far it has been a pretty good experience.


### And the cost of the Type 125, to the customer?

GBP 550,000 for the car. And then there might be GBP 100,000 for a spares package. Circumstances vary. One owner already owns a race team, so he's pretty self-sufficient.

We have another guy in Bahrain who has no support at all and we fly out our mechanics and equipment when he wants to run the car, which is probably five times a year.

### How successful has the Evora GX – aimed at the US market and the Grand Am series – been in the US?

It's still early days with a new car, but we are very confident that we will be competitive in our class. We have had a third in class result already. Watch this space.

### How do you see endurance racing for Lotus?

For us it means the Lotus Evora; the GT4 and GTC have been used very successfully in endurance racing. The Evora is very easy on the tyres, it's very easy on fuel. We have had some fantastic results in longer races with class wins and podiums in Dubai, Budapest, Barcelona and Silverstone.

### How does the Lotus Driving Academy work?

We are very lucky here at Hethel to have a very nice test track. Lotus Motorsport runs the academy with eight cars. It gives us the opportunity to put on corporate events, but more importantly there are academy activities that can be simple 'fun days' or drivers coming here for one to one tuition. Lotus customers can improve their driving skills and also become more familiar with Lotus product.

The cars we use in the academy are all road cars, not race cars. It gives people the opportunity to experience the handling of the road cars on a track.

### How do you see the future of Lotus Motorsport?

The focus is to build good commercially based race cars. We are lucky because we have cars that are suitable for the emerging markets, cars that are easy to operate. There are several new regions around the world that are getting turned on to motorsport and we have the right products to penetrate those markets. And we also have cars that they can step-up into when they are ready.

We have made a really good start this year and we intend to continue that good work with further expansion globally. The focus is very much to build on what's working well, keep competitive and keep expanding around the world where we can see good growth opportunities.