



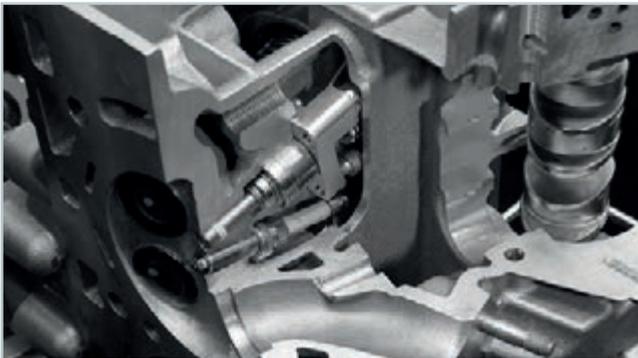
## INNOVATIVE POWERTRAIN SOLUTIONS

Improving efficiency while maximising performance – this has always been at the heart of Lotus' philosophy. Today, this has more relevance than ever before, as there is a real urgency to slow the decline of fossil fuel reserves and reduce emissions.

As a car manufacturer, Lotus understands the need to find efficient and cost-effective solutions to meet these challenges while maintaining a viable business case. This means we are ideally placed to help our clients produce more efficient vehicles and powertrains that do not sacrifice performance.

Lotus Engineering's approach for minimising the CO<sub>2</sub> impact of transport is to focus on improvements in the areas of engine efficiency, alternative powertrains and reducing the CO<sub>2</sub> footprint of the fuel or energy source for the vehicle.

There is currently much investigation into alternative forms of propulsion, but making conventional internal combustion engines even more efficient remains a priority.



### POWERTRAIN ENGINEERING SERVICES

- Advanced powertrain engineering
- Design and development of new engine architectures
- Powertrain profile and strategy development
- Advanced research and development
- Evaluation and development of next generation technologies
- Engine upgrades and new applications
- Calibration and control systems
- Powertrain manufacturing consultancy

### POWERTRAIN EXPERTISE

- Strong analytical foundations
- More than 20 years experience in delivering powertrain engineering projects
- A track record of innovation and leading edge technologies
- Over 10 'clean sheet' engine programmes
- Over 15 engine upgrade programmes
- Multi-geographical location and delivery capability

# FRESH IDEAS CLEANER ENGINES

We have a history of pioneering new engines, with a proven ability to design and develop powertrain architectures for clean, efficient engines using technology that is suitable and viable in series production.

Smaller, more efficient, but more powerful engines are recognised as an important route to cleaner transport. Our knowledge of combustion, engine design, calibration and production places

us at the forefront of downsized engine development. And with pressure charging, direct injection and new valvetrain technologies fundamental to effective engine downsizing, our impressive track record with these technologies makes us the experts in this field.

Importantly, we also realise that the engine is integral to the whole driving experience, so our approach is to maintain

driveability and responsiveness even when downsizing aggressively.

We have the expertise within Lotus to design and produce cost-effective downsized engines that result in vehicles that are a pleasure to drive.

With new engine architectures, we know that sometimes challenging convention for better emissions, performance and cost can also be the best way forward.

Projects such as OMNIVORE and the Lotus Range Extender engine are two of the most recent examples of Lotus Engineering again pushing the boundaries of engine technology.



## PROJECT NEF ENGINE ARCHITECTURES

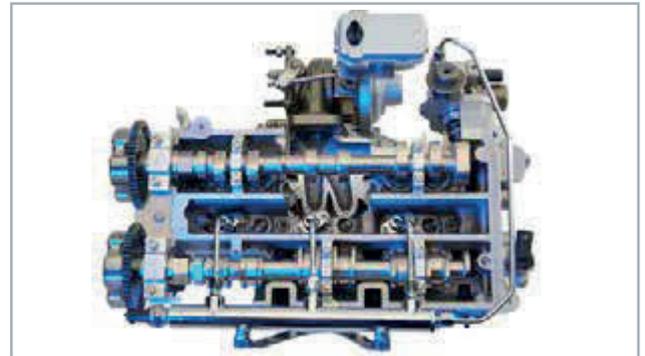
The directive for the project was to produce a high performance engine family without the need to resort to exotic materials or manufacturing technology, allowing manufacture around the world.

The engine is a supercharged 3 litre V6 DOHC engine, mounted longitudinally in the front of the vehicle.

Like all products from Lotus, it follows the adage of "performance through light weight", in that the engine weighs just 171 kg (fully dressed, dry weight).

One of the key demands of the automotive industry is to produce engines with not only low emissions and high fuel economy but also extremely good performance.

These two demands for performance and economy are not normally compatible unless there is a significant change in the engine development strategy.



## PROJECT SABRE GASOLINE DIRECT INJECTION

The Low CO<sub>2</sub> vehicle concept is demonstrated in an Opel Astra and uses a Lotus Engineering-designed pressure-charged three-cylinder 1.5 litre gasoline engine integrated with a number of Lotus and Continental technologies.

It features an integrated exhaust manifold design, centrally-mounted injectors, cam profile switching for lift and timing, a high pressure fuel pump, and a mild hybrid drive.

The Low CO<sub>2</sub> Astra provides a CO<sub>2</sub> reduction of 15% against the naturally aspirated 1.8 litre four-cylinder engine version of the same vehicle, whilst providing performance equivalent to the 2.2 litre version.

Lotus Engineering's Cam Profile Switching (CPS) system incorporates lobed tappets that vary valve lift and timing. The Lotus system is produced under licence by INA and is used by Porsche in its 'VarioCam Plus' system.

# UPGRADES AND NEW APPLICATIONS

It often makes sense to upgrade and apply new technologies to existing powertrains to enhance performance, improve efficiency and emissions, and adapt the engine to new applications.

For the client, this provides the benefits of longer life for their existing engines while adapting to changing market requirements providing further choice to their customers through an expanded product range.

We have decades of powertrain integration experience and we are experts in pressure charging, valvetrain technologies and engine control, all key to extracting great efficiency, performance and longevity from engines.

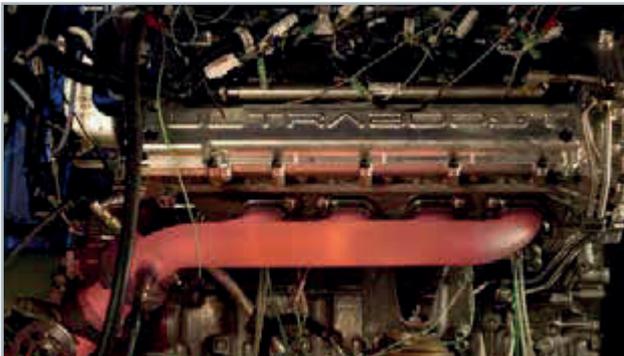
We have an approach that concentrates on technologies that are affordable and practical for production, while still being consistent with fun-to-drive, more efficient vehicles.

How the engine fits into the vehicle is important, and with our wider expertise in many aspects of vehicle engineering, we can ensure that engines can be fully integrated with the vehicle package, fuel system, chassis system and electrical architecture.

Calibration and software experience, and our own control systems for niche applications, enable us to achieve desired performance characteristics

for a range of powertrain and fuel types whilst meeting future legislation.

Through our complementary expertise in hybrid and electric vehicles, we can also adapt engines for hybrid applications.



## PROJECT ULTRABOOST EXTREME ENGINE DOWNSIZING

The Ultra Boost research project is to produce a new powerful, highly efficient concept engine.

The concept will deliver an expected 35 per cent CO<sub>2</sub> tailpipe reduction compared to a 5.0 litre naturally aspirated V8 engine whilst maintaining performance, emissions and transient response, and improving fuel efficiency, and emissions.

The consortium includes engineering experts, a premium automotive manufacturer, innovative suppliers, academics and an oil company.

The Ultra Boost engine uses a novel pressure charging technique and advanced combustion system to enable a downsized engine concept that returns diesel-like fuel economy with gasoline levels of engine refinement.

Over the next three years the partners will utilise their collective skills and expertise in engineering, design, combustion modelling, fuel and lubricants to develop the highly pressure charged, downsized engine.



## PROJECT OMNIVORE COMBUSTION RESEARCH

The OMNIVORE engine concept features an innovative variable compression ratio system and uses a two-stroke operating cycle with direct fuel injection. It is ideally suited to flex-fuel operation with a higher degree of optimisation than is possible with existing four-stroke engines.

The engine concept features a monoblock construction that blends the cylinder head and block together eliminating the need for a cylinder head gasket, improving durability and reducing weight.

In this case, the application of a monoblock is facilitated by the absence of the requirement for poppet valves. A novel charge trapping valve in the exhaust port allows asymmetric timing of exhaust flow and continuous variation of the exhaust opening timing.

The OMNIVORE research engine uses the Orbital FlexDI fuel injection system which produces fine in-cylinder fuel preparation irrespective of fuel type and, together with air pre-mixing, allows efficient two-stroke combustion and low-temperature starting, whilst offering singular opportunity for advanced HCCI control.



Over 20 Years of Powertrain Programmes

CAPABILITIES AND SERVICES	
Advanced Powertrain Engineering	<ul style="list-style-type: none"> <li>• Engine down-sizing and alternative fuels expertise</li> <li>• Internal combustion range extender engines for a new breed of hybrid electric vehicles</li> <li>• Base engine design, integration, technology demonstration vehicle build and controls implementation</li> <li>• Concept definition and product profiling to complete engine programme delivery</li> </ul>
New Engine Architectures	<ul style="list-style-type: none"> <li>• Development of new engines and engine families</li> <li>• Cost effective technology application</li> <li>• Complete turn-key solutions to fully integrated on-site consultancy</li> </ul>
Powertrain Upgrades and New Applications	<ul style="list-style-type: none"> <li>• Identifying the right propulsion system hardware for a given application</li> <li>• Predictive tools to support technology evaluation and Lotus proprietary energy management solutions</li> <li>• Pressure charging</li> <li>• Mild hybridisation for use with hybrid electric vehicles</li> <li>• Gasoline direct injection expertise</li> </ul>
Calibration and Control	<ul style="list-style-type: none"> <li>• Over 20 years experience in engine calibration</li> <li>• Lotus ECU, fully compatible with latest emissions, diagnostics, EMC and safety requirements</li> <li>• Optimised fuel economy and performance whilst meeting emissions legislation targets</li> <li>• Development and calibration for alternative fuels</li> <li>• In-house testing, development and certification capability</li> </ul>
Research and Development	<ul style="list-style-type: none"> <li>• Internal combustion optimisation</li> <li>• Research, development and proof of concept projects</li> <li>• Lotus single cylinder research engines</li> </ul>
Manufacturing Consultancy	<ul style="list-style-type: none"> <li>• Supporting design, implementation and operation of powertrain manufacturing facilities</li> <li>• Design for manufacture and assembly</li> <li>• Engine component cost optimisation and component sourcing</li> </ul>



**UNITED KINGDOM**

Potash Lane  
 Hethel, Norwich  
 NR14 8EZ

Phone: +44 (0)1953 608423  
 eng-uk@lotuscars.com