



## The Varied Landscape of UK Innovation

**EVS26, Los Angeles  
May 2012**

# Ricardo Overview



Ricardo is an engineering consultancy, delivering world class strategy, engineering and technology programmes to the global automotive, transportation, defence and energy industries

## Company

- Established in 1915 and independent
- £196.5 million revenue (FY 10/11), up 21%  
£162.8 million revenue (FY 09/10)
- More than 1.600 employees with more than 1.300 technically qualified and engineering staff
- Global presence in 16 locations

## Values



RESPECT • INTEGRITY • CREATIVITY & INNOVATION • PASSION

## Positioning

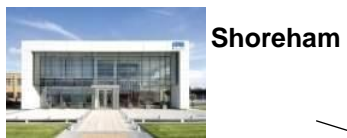
- Emphasis on achieving enhanced value propositions for our clients
- Multi-sector oriented with relevant domain expertise
- Global footprint with local understanding
- Strategic perspectives and consulting
- Unique holistic vehicle and powertrain experience
- Systems engineering approach that considers integrated solutions for the entire product lifecycle
- Significant self-funded R&D investment
- Technology led product innovation
- Extensive production vehicle and major sub-system introduction experience
- Delivery focused
- Specialist manufacturing and assembly capability niche product applications

# Ricardo Locations

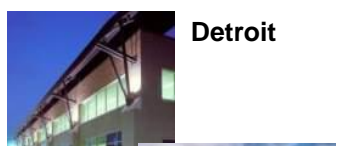
Our Global footprint allows us to understand the local needs of our clients



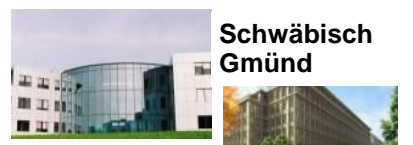
## Ricardo UK



## Ricardo USA



## Ricardo Germany



Munich

## Ricardo Czech Republic



## Presence in Russia



## Ricardo Japan



## Presence in Korea



## Ricardo Italy



## Ricardo India



## Ricardo China





# Ricardo Client Base

Represented across a number of key market sectors each with unique drivers



## Passenger Car



## High Performance Vehicles & Motorsport



## Commercial Vehicles



## Agricultural & Industrial Vehicles



## Motorcycles & Personal Transportation



## Marine



## Rail



## Clean Energy & Power Generation



## Defence

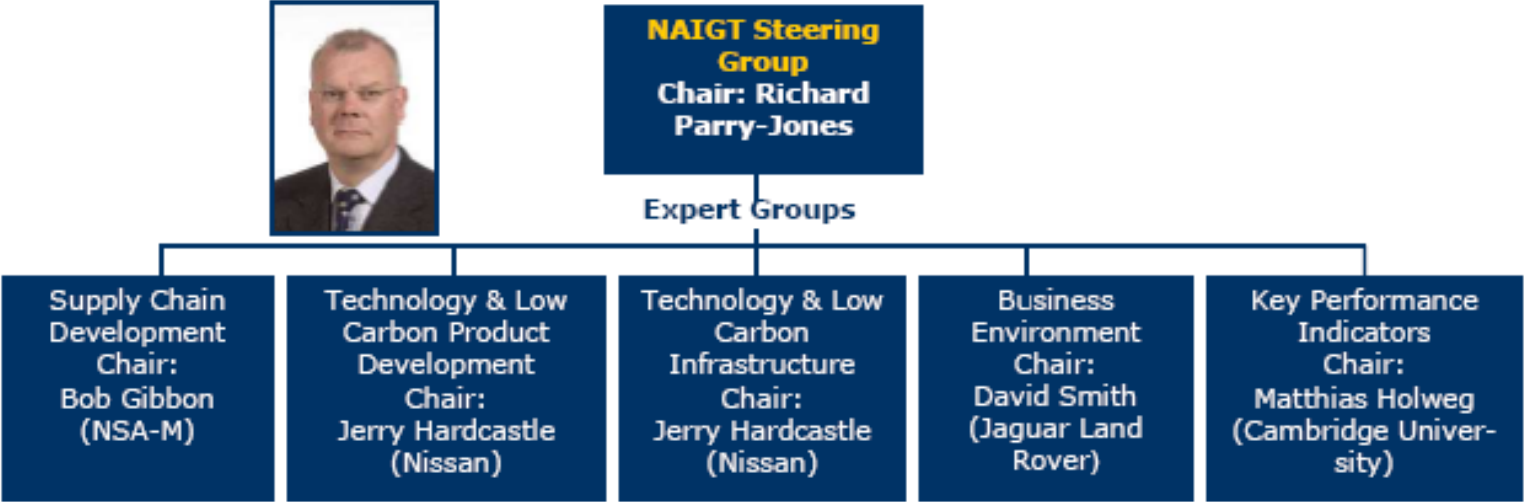


## Government

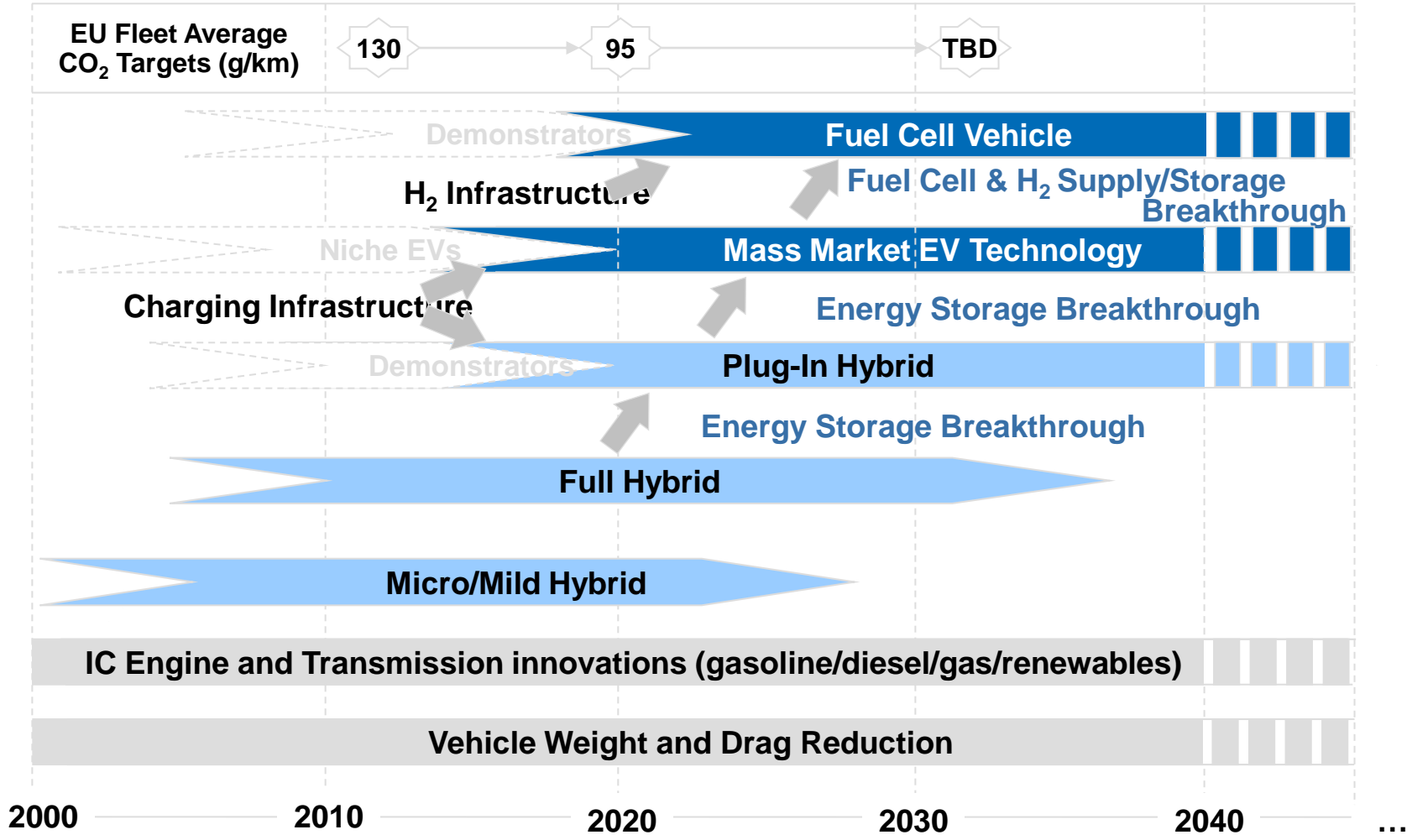


# The UK automotive industry is strongly networked with groups such as the Automotive Council and LowCVP

- In 2009/2010 the UK Automotive industry formed the New Automotive Innovation and Growth Team, later followed by the Automotive Council.
- Together they delivered a technology roadmap for the industry, and worked with government to define strategic R&D priorities



# The Consensus Product Roadmap, mutually agreed by OEMs, defines future direction to develop products that will benefit UK plc



# A Common Research Agenda was developed - a hypothesis on the R&D required to deliver the Consensus Product Roadmap



	<b>SHORT TERM</b> 5 – 10 years from production	<b>MEDIUM TERM</b> 7 – 15 years from production	<b>LONG TERM</b> 10 – 20 years from production
	<b>INDUSTRY</b>		<b>UNIVERSITIES</b>
<b>Propulsion</b>	<ul style="list-style-type: none"> <li>IC engine optimisation</li> <li>Boost systems for downsizing</li> <li>Flexible valve/actuation for engines/transmissions</li> <li>Low cost compact e-motors</li> </ul>	<ul style="list-style-type: none"> <li>Higher efficiency IC engines</li> <li>Capacitive boost systems</li> <li>All electric actuation systems</li> <li>Optimised range extender engine</li> <li>Lower cost e-motor</li> <li>Heat energy recovery (e.g. E-turbine)</li> </ul>	<ul style="list-style-type: none"> <li>Super high efficiency motors (superconducting)</li> <li>New IC engines with 70%+ thermal efficiency</li> <li>Advanced heat energy recovery (e.g. thermoelectric)</li> <li>Motor/Fuel Cell materials</li> </ul>
<b>Energy Storage</b>	<ul style="list-style-type: none"> <li>Improved quality / durability 200+ Wh/kg &amp; \$800/kW.h cost battery systems</li> <li>Low cost power electronics</li> </ul>	<ul style="list-style-type: none"> <li>Next gen batteries 300+ Wh/kg and \$500/kW.h cost</li> <li>Flexible power elec. modules</li> <li>Other forms of energy recovery (mechanical/chemical etc)</li> </ul>	<ul style="list-style-type: none"> <li>3<sup>rd</sup> gen batteries 400+ Wh/kg &amp; \$200/kW.h cost</li> <li>New low cost solid state power conversion systems</li> <li>Hydrogen storage technology</li> </ul>
<b>Vehicle Efficiency</b>	<ul style="list-style-type: none"> <li>Lightweight structures and interiors</li> <li>Low rolling resistance tyres / brakes</li> </ul>	<ul style="list-style-type: none"> <li>New vehicle classes and configurations</li> <li>Combination of function to reduce weight / cost</li> <li>Minimised weight / losses</li> </ul>	<ul style="list-style-type: none"> <li>Flexible re-configurable multi-utility vehicle concepts</li> <li>50% weight reduction from 2008</li> <li>Advanced aerodynamic concepts</li> </ul>
<b>System Control</b>	<ul style="list-style-type: none"> <li>Information enabled control (Topology, V2V, V2I, traffic etc.)</li> <li>Optimised vehicle energy mgmt.</li> <li>Intelligent thermal management</li> </ul>	<ul style="list-style-type: none"> <li>Advanced information enabled control</li> <li>Intelligent P/T and HVAC mgmt.</li> </ul>	<ul style="list-style-type: none"> <li>Autonomous P/T and vehicle control integrated with active safety</li> </ul>
<b>Energy + Fuel Supply</b>	<ul style="list-style-type: none"> <li>Optimised 1<sup>st</sup> gen biofuels processes</li> <li>New 2<sup>nd</sup> gen biofuel processes</li> </ul>	<ul style="list-style-type: none"> <li>Intelligent energy / re-fuelling infrastructure (e.g. fast charge)</li> <li>Industrial scale demonstration of new 2<sup>nd</sup> gen biofuel processes</li> </ul>	<ul style="list-style-type: none"> <li>3<sup>rd</sup> gen biofuel processes</li> <li>2<sup>nd</sup> gen industrial scale biofuel production infrastructure</li> </ul>
<b>Processes + Tools</b>	<ul style="list-style-type: none"> <li>Process + delivery tool development and connectivity</li> </ul>	<ul style="list-style-type: none"> <li>Auto-optimisation methods using virtual systems</li> </ul>	<ul style="list-style-type: none"> <li>Artificial Intelligence to deliver complex multi-criteria system optimisation</li> </ul>

# The industrial and R&D capabilities of the UK were assessed against the future requirements of the automotive industry

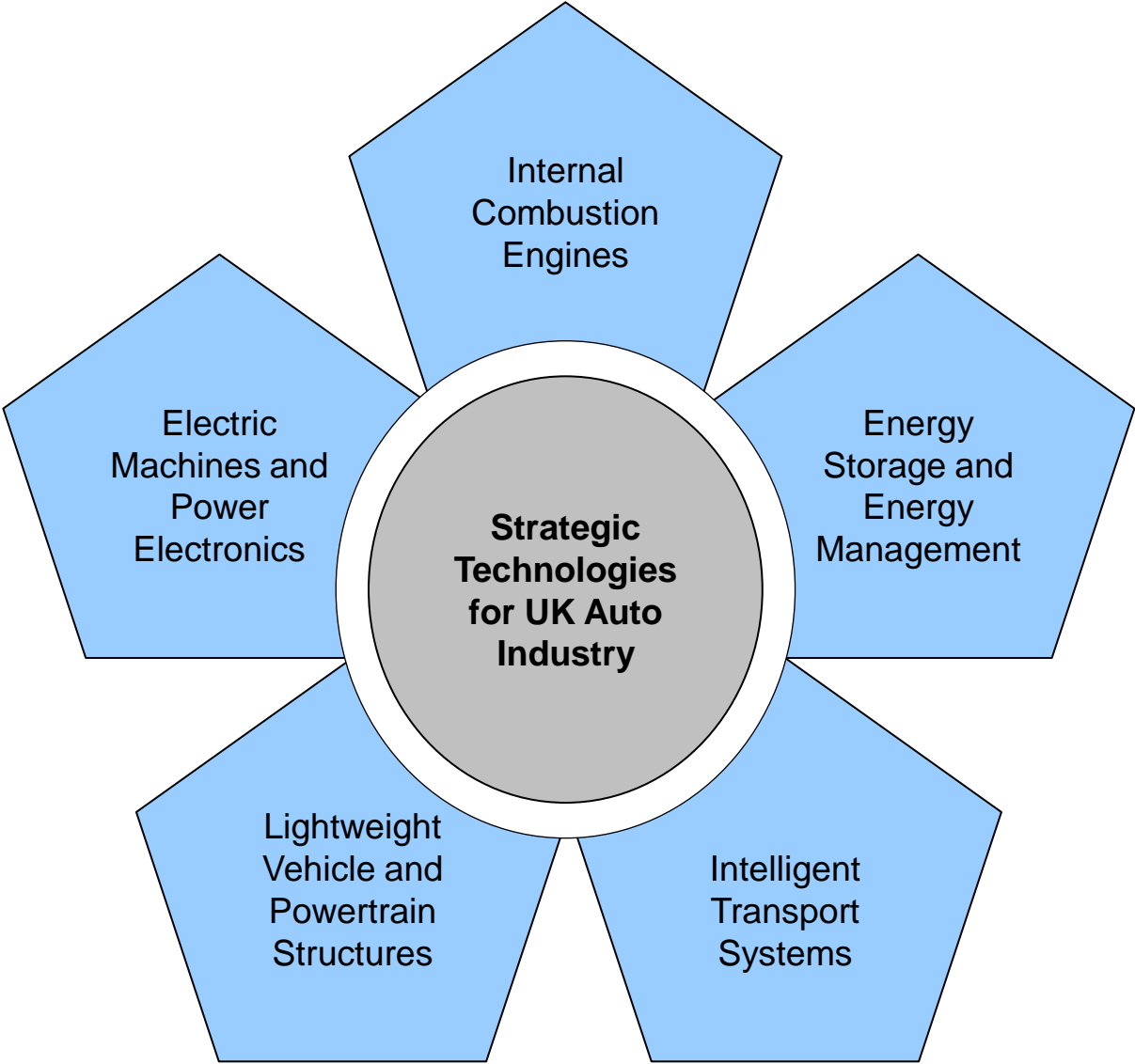
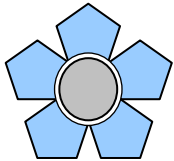


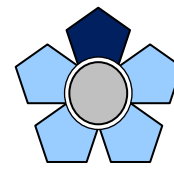
		Short Term	Medium Term	Long Term	Comments
<b>Propulsion</b>	<b>A: Internal Combustion Engines</b>				<ul style="list-style-type: none"> <li>Limited Tier 1 product development and manufacturing, however high levels of integrated engine development by OEMs &amp; consultancies</li> <li>Many categories have good potential for medium and long term</li> </ul>
	<b>B: Electric &amp; H2 Propulsion</b>				<ul style="list-style-type: none"> <li>Both electric motors and power electronics have good capability to meet product roadmap, especially in medium and long term</li> <li>Fuel cell systems currently appear slightly weaker</li> </ul>
	<b>C: Transmissions &amp; Drivelines</b>				<ul style="list-style-type: none"> <li>All categories only show low or medium potential for all timescales</li> <li>Advanced transmission fluids are an exception – here the UK has world-leading capabilities</li> </ul>
	<b>D: Energy Storage</b>				<ul style="list-style-type: none"> <li>Mechanical energy storage (flywheels) and battery pack and integration are strong categories for the UK</li> <li>Limited capability and potential in other categories in this area</li> </ul>
	<b>E: Vehicle Efficiency</b>				<ul style="list-style-type: none"> <li>Strong in the category of lightweight structures</li> <li>Limited capability and potential in components for low rolling losses. Situation improving for other technology categories in medium to long term</li> </ul>
	<b>F: Control Systems</b>				<ul style="list-style-type: none"> <li>Evidence shows high capability and potential in many categories in this area when focussed on software development. The UK has limited potential in hardware development and manufacturing</li> </ul>
	<b>G: Energy &amp; Fuel Supply</b>				<ul style="list-style-type: none"> <li>Most categories show good capability to meet requirements of product roadmap in the correct timescales</li> <li>More challenges exist relating to hydrogen infrastructure in the long term</li> </ul>
	<b>H: Development Processes &amp; Tools</b>				<ul style="list-style-type: none"> <li>Evidence suggests this is a strong area for the UK across all categories</li> </ul>

Colours in chart above show range of variation within each technology area for which a significant number of individual categories deviate from the average rating



# And five priority R&D areas were identified





# Internal Combustion Engine

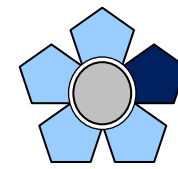
- Development of the internal combustion engine offers the most effective short term route to CO<sub>2</sub> reduction. The UK already has all the necessary elements of the supply chain from research to mass production
- There are strengths to be leveraged such as companies with a fundamental expertise in combustion technology, active fuels and lubricants companies and expertise in motorsport engine technology. The weakness is the lack of significant numbers of Tier 1 suppliers



Ford Dagenham – Engine Assembly line

## PROPOSAL

***Invest in the development of the next generation low CO<sub>2</sub> engine technologies and the development of engines for Range Extended Vehicles.  
Study how to attract key Tier 1 suppliers of engine components to participate in UK development activities***



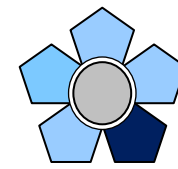
- Energy storage and Energy Management are fundamental technologies to support the mid and long term low carbon vehicles, hybrid, electric vehicles and fuel cell vehicles
- The UK has fundamental research ability in battery chemistry, flywheel technology and capacitors. The weakness is that the UK has an underdeveloped supply chain to move from start up companies to mass production of these technologies
- Some OEMs have elected to conduct this activity in house but there are other OEMs that are actively seeking external partners. There is an opportunity to encourage the product development and supply chain capability around integration of these components into vehicle ready systems – i.e. the packaging of cells into packs and the supply of packs, or the combination of flywheels and batteries



Axeon – supplier of lithium-ion battery systems

## PROPOSAL

***Invest in the research and development of Energy Storage and Energy Management systems. Study how to develop an integrated UK supply chain for these technologies***



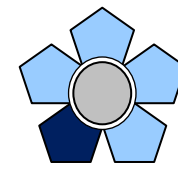
- Transport telematics and communications technologies have huge potential to reduce the environmental impact of transport, improve the customer experience, increase productivity through reduced congestion, and improve the efficiency, safety and security of transport networks.
- The technology provides benefits to new and old, conventional, hybrid and electric vehicles
- With a concerted effort, the UK can position itself as a major player, not only in the European market, but also in other major markets around the world, including North America and Japan



TRL Pedestrian detection target tested at InnovITS Advance test facility at MIRA UK.

## PROPOSAL

***Investigate the societal problems which ITS can resolve, considering the four facets of information presentation – infrastructure to car, car to car, car to driver, and infrastructure to driver. Create ITS technology roadmap to supplement the Low Carbon Technology Roadmap***



- The UK has expertise in lightweight aluminium and steel vehicle technology, lightweight motorsport technology and niche vehicle development and manufacturing skills. The UK Aerospace industry provides an opportunity for cross industry collaboration. All the supply chain elements are present in the UK but are not necessarily linked today
- Lightweight vehicle and Powertrain structures are applicable to all future Low Carbon vehicles. Lightweight technologies could be a disruptive force in terms of vehicle manufacturing and assembly method

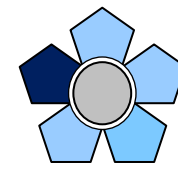


Jaguar XK – Utilises aluminium extrusions and body panels to reduce weight

## PROPOSAL

***Invest in an integrated collaborative research programme and consider if there would be merit in investing in the development of a lightweight concept vehicle to explore the opportunities. Promote collaboration between Automotive and Aerospace companies in the UK***





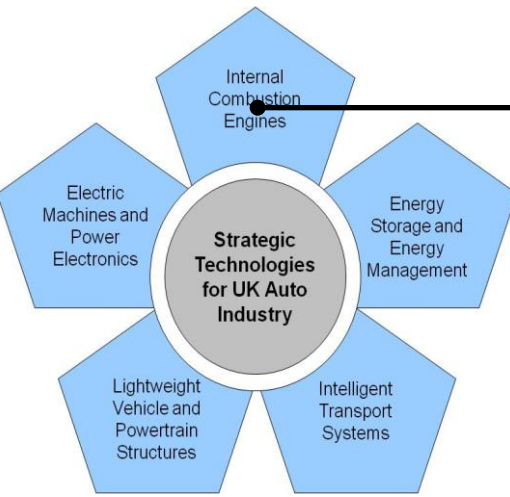
- The UK has some excellent fundamental technology around Power Electronics and Electrical Machine design
- There is an opportunity to develop a world class design engineering capability in this area. However there is no supply chain to develop these technologies to mass production at this time
- The UK may have aspiring companies in this field but it is unclear how to develop the supply chain to compete with the emerging competitive countries



## PROPOSAL

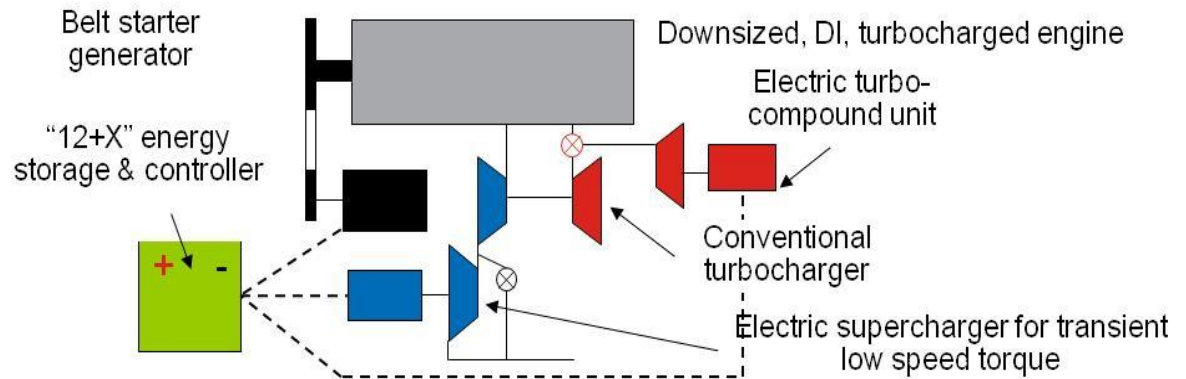
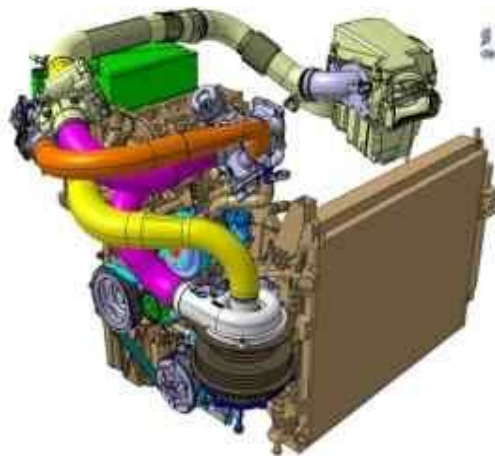
***Invest in the research and development of Power Electronics and Electric Machine systems. Study how to develop an integrated UK supply chain for these technologies***

# Ricardo is actively developing leading edge technologies in each of these areas

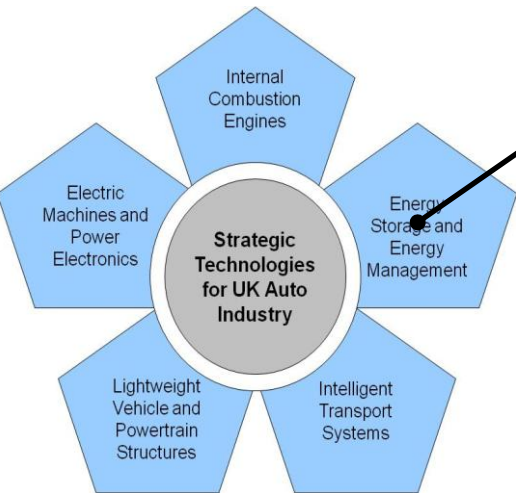


## INTERNAL COMBUSTION ENGINES

- Downsized diesel and gasoline engines with class leading CO2 and emissions
- Micro-hybridisation at 12V to 48V – synergistic with downsizing for cost effective hybridisation
- Novel engine designs for range extenders, offering light weight, low noise and vibration, and compact package

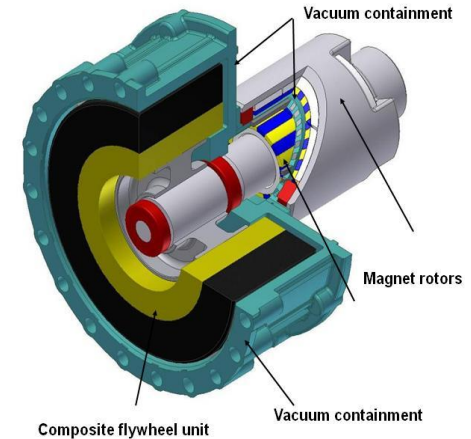
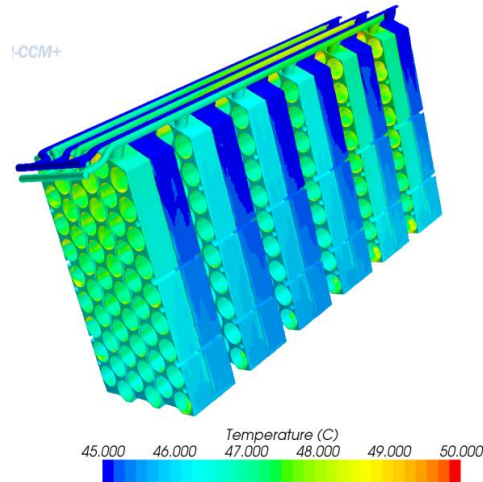


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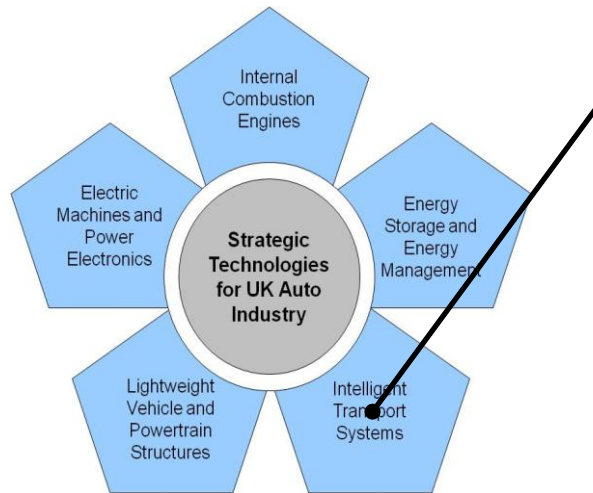


## ENERGY STORAGE AND ENERGY MANAGEMENT

- Robust battery management systems for even the most challenging of battery chemistry
- Lightweight battery structures with excellent thermal management and robustness in operation
- Flywheel energy storage for high power applications



# Ricardo is actively developing leading edge technologies in each of these areas



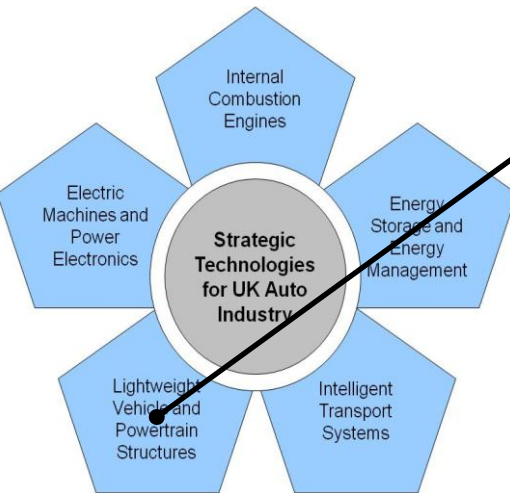
## INTELLIGENT TRANSPORT SYSTEMS

- Location based powertrain control allows low and zero-emissions zone compliance for hybrids
- Driver feedback and training to improve safety and CO2
- Route recognition and route prediction allows for knowledge based control of powertrain for safety and CO2
- Platooning for future safety and CO2 improvements





# Ricardo is actively developing leading edge technologies in each of these areas



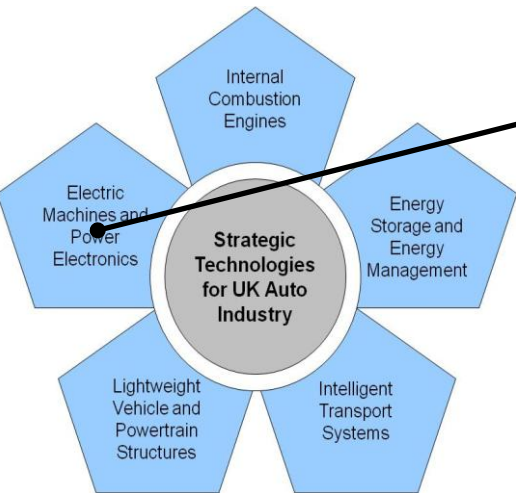
## LIGHTWEIGHT VEHICLE AND POWERTRAIN STRUCTURES

- Structural optimisation through computer aided engineering
- Topology and topography optimisation based on identification of key loadpaths
- Use of Aluminium spaceframes, composite panels and advanced high strength steels
- Advanced rig tests to prove out component durability under representative conditions



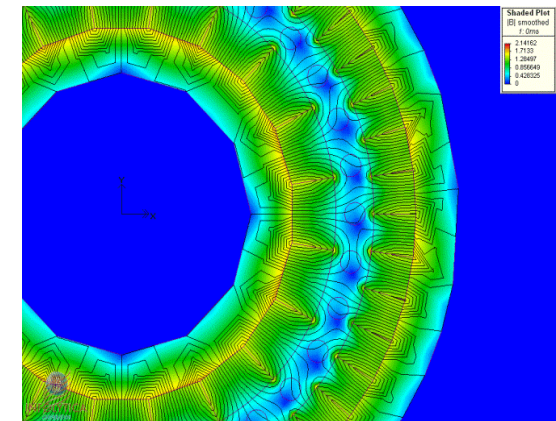
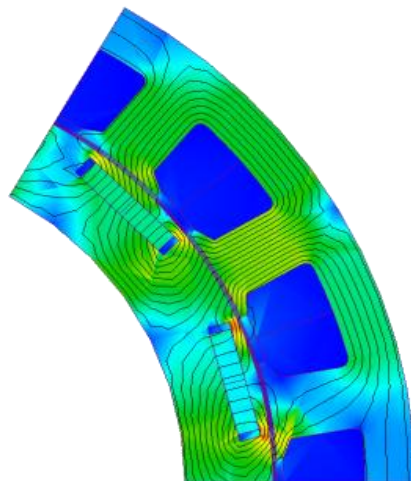


# Ricardo is actively developing leading edge technologies in each of these areas



## ELECTRIC MACHINES AND POWER ELECTRONICS

- Machine design for permanent magnet, induction and switched reluctance machines. 50W to 10MW
- Efficient and durable power electronics for inverters and DC-DC converters
- Magnetic couplings and gears – especially for high speed (60krpm) applications



## Concluding Remarks

- Over the next decade we will see an increasing range of powertrain types in the marketplace
- This opens up opportunities for new technologies and supply chains
- The UK has a strong design and innovation capability – in both industry and academia
- It is well networked and has adopted a strategic approach to R&D investment – aligned to the industry technology roadmap
- The next decade will be the most exciting in the automotive industry in a century



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