Technical Support for CAE analysts

Simon White

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Ricardo – Not Just Software

Ricardo delivers world class strategy, engineering and technology programmes to the global automotive, transportation, defence and energy industries, focussed on the enduring drivers of value enhancement, efficiency and emissions improvement.

- For more than 20 years Ricardo Software products have been at the forefront of Automotive CAE technology.
- Our products have a customer base of hundreds of users worldwide including many of the worlds OEM’s, Tier 1s and suppliers.
- Ricardo Software is one of the premium suppliers of automotive analysis software tools.
- However Ricardo Software is just one part of an industry leading automotive engineering consultancy.
- This is fundamental to delivering state of the art software tools and also providing back up via world class consulting support.
Ricardo Overview

Ricardo delivers world class strategy, engineering and technology programmes to the global automotive, transportation, defence and energy industries, focussed on the enduring drivers of value enhancement, efficiency and emissions improvement.

Company

- Established in 1915 and Independent
- £179 million revenue (FY 08/09)
- More than 1,600 employees with more than 1,300 technically qualified and engineering staff
- Global presence in 17 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 focussed
- Specialist manufacturing and assembly capability niche product applications
### Ricardo Client Base

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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Logos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>Audi, BMW, Mercedes-Benz, Volkswagen, Toyota, Honda, Audi Sport</td>
</tr>
<tr>
<td>High Performance Vehicles &amp; Motorsport</td>
<td>Porsche, Bugatti, Daimler, Scania, Paccar, Perkins, McLaren, AMG</td>
</tr>
<tr>
<td>Commercial Vehicles</td>
<td>Volvo, Mitsubishi Fuso, Daimler, Scania, Paccar, Freightliner</td>
</tr>
<tr>
<td>Agricultural &amp; Industrial Vehicles</td>
<td>Claas, Deutz, JCB, Bosch, John Deere, LIEBHERR, Echlehart</td>
</tr>
<tr>
<td>Motorcycles &amp; Personal Transportation</td>
<td>Piaggio, Harley-Davidson, Royal Enfield, BSA, Ducati, BMW, Honda</td>
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<tr>
<td>Marine</td>
<td>Rolls-Royce, Volvo Penta, Bergen Shipping, Suzuki, Hyunaid, MTU</td>
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<tr>
<td>Rail</td>
<td>Bombardier Transportation, FPT, Voith, EDF, Duke Energy, BP</td>
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<tr>
<td>Clean Energy &amp; Power Generation</td>
<td>bp, Duke Energy, Shell, Qinetiq, EDF, Openhydro</td>
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<tr>
<td>Defence</td>
<td>TACOM, UK MoD, U.S. Navy, General Dynamics, Damen, FMV, BAE Systems</td>
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<tr>
<td>Government</td>
<td>CARB, California Air Resources Board, IE Institute for Energy, ECN</td>
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## Ricardo Product Services

Ricardo Software is just one part of a unique vehicle and powertrain systems engineering approach that considers integrated solutions for the entire product lifecycle.

### Core Expertise

<table>
<thead>
<tr>
<th>Gasoline Engines</th>
<th>Light Duty Diesel Engines</th>
<th>Heavy Duty Diesel Engines</th>
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</thead>
<tbody>
<tr>
<td>Dual Clutch Transmissions (DCT’s)</td>
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<tr>
<td>CVT’s and Automatics</td>
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<tr>
<td>Heavy duty/military</td>
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<tr>
<td>Driveline and Transmission Control</td>
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<tr>
<td>Vehicle communications – V2I, V2V</td>
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<tr>
<td>Battery pack design – mech., thermal, and electronics</td>
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<tr>
<td>Battery system dev’t and validation</td>
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<td>Vehicle to Grid electronics and software</td>
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<td>Technology road map and CO₂ strategy</td>
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<td>Product and technology strategy</td>
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<td>SONAR NVH benchmark programme</td>
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<td>Economark CO₂ benchmark program</td>
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<td>Advanced concept demonstration</td>
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<td>Integrated engine &amp; system modelling</td>
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<td>Prototype and Series LD engine design</td>
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<tr>
<td>Powertrain application and calibration</td>
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<tr>
<td>Warranty and product cost reduction</td>
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<tr>
<td>Niche high performance and motorsport</td>
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<tr>
<td>Motorcycle and scooter engineering</td>
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<tr>
<td>SI Gasoline/CNG engines for MD/HD</td>
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<tr>
<td>All types of heavy duty/large diesel engine</td>
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<tr>
<td>Bespoke Military and UAV engines</td>
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<tr>
<td>New engine concepts &amp; combustion cycles</td>
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<tr>
<td>Forensic services and failure analysis</td>
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### Delivered Projects

| BMW K1300 Motorcycle engine upgrade | Global Light Truck Engine for Ford | ~7 litre I6 Tier4f and performance upgrade |
| New MPI & DI, 4 cyl engine family | World market calibration Renault/Suzuki | 10 litre I6 HD Eu4/5 engine for Hyundai |
| GM Global V6 engine NA/TC, MPI/GDI | New 1 litre 2 cyl engine for Coopers Pty | Tier 3 / 4 Calibration for Perkins |
| New low cost, low friction MPI/DI <1L 3 cyl | New 3/4 cyl 1~1.3 litre family for EU/Asia | Class 8 US10 emissions + OBD upgrade |
| BMW Mini - Gas & Flex Fuel | New world first aluminium architecture | 30cm bore engine upgrade plus SI CNG |

### Technology Offering

| High efficiency lean & EGR boosted DI (flex) | Minimum cost low CO₂ Solutions | Very low soot combustion systems |
| High torque 2/4 stroke switching technology | EU6 and Tier3 emissions strategy | High efficiency SCR system integration |
| Spray-guided DI research engine (flex fuel) | Very low engine out NOx technology | Practical low cost Tier4 solutions |
| New boost systems for downsizing | Low cost engine design | High Pmax Engine Design |
| Accelerated product development process | State of the art calibration process | FC reducing technologies |

### Delivered Projects

- Global Light Truck Engine for Ford
- World market calibration Renault/Suzuki
- New 1 litre 2 cyl engine for Coopers Pty
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- New world first aluminium architecture
- ~7 litre I6 Tier4f and performance upgrade
- 10 litre I6 HD Eu4/5 engine for Hyundai
- Tier 3 / 4 Calibration for Perkins
- Class 8 US10 emissions + OBD upgrade
- 30cm bore engine upgrade plus SI CNG

### Technology Offering

- MT Shift Quality (GSQA)
- Ricardo Shaft and Bearing (SABR)
- Hi Efficiency AMT and DCT Actuation
- DCT and AMT Controls
- Telematics, V2I, V2V communication
- Active safety & Autonomous drive
- Rapid prototype battery mgt system
- Safety critical software
- Electronic design for grid applications
## Ricardo Product Services

Ricardo Software is just one part of a unique vehicle and powertrain systems engineering approach that considers integrated solutions for the entire product lifecycle.

### Core Expertise
- Hybrid vehicle control strategies
- Concept and Architecture Definition
- Safety systems design & integration
- Electrical System design
- Hybrid Engine & Transmissions Systems

### Delivered Projects
- Production intent Hybrid Systems
- Efficient-C Full Diesel hybrid
- Plug-in hybrid Control strategies
- Hybrid vehicles for military application
- Feasibility and Design studies

### Technology Offering
- Complete Hybrid & electric vehicle programmes
- Systems Integration
- Advanced thermal management
- Control Algorithms for Advanced Hybrid

### Hybrid & Electric Systems
- Full programme delivery
- Prototype manufacture
- Powertrain integration & NVH
- Military vehicle development & build
- Systems Integration

### Vehicle Systems
- Plan and implement Tech. Strategy
- Concept selection & feasibility study
- System optimisation & simulations
- Proof of concept and demonstration of new advanced technologies

### Advanced Technology
- Commercial truck – North America
- Commercial truck – Japan
- ITEC FTTS military hybrid vehicle
- IAI TaxiBot Aircraft Tug Demo
- Innovation concept demonstrations

### Software
- Reduced cost Li-ion battery
- Strategic Market Analysis
- EU FP6 Project to assess technology in the field of Hydrogen & Fuel Cells
- Advanced combustion engine with 60% thermal efficiency

### Strategic Consulting
- Ricardo software consists of ca 60 people
- 75% involved in product development
- Expert developers for each field
- World class, multi language support

### Ricardo Software
- Ricardo Software is used on all CAE projects carried out by Ricardo Consultancy group and is the preferred toolset of most major OEM’s and suppliers
- Advanced power train modelling software offering unique tools to reduce development times and cost whilst increasing productivity

### Management Consulting
- Due Diligence Premium Car Company
- Turnaround Management Bus Company
- Product Cost Down MD Truck
- Low Cost Country Sourcing Powertrain
- Launch Support New Aircraft

### Strategic Consulting
- Integrated Cost Reduction
- High Value Problem Resolution
- Market & Product & Technology Strategy
- Due Diligence
- Engineering Efficiency Improvement
### Ricardo Project Examples

Ricardo has extensive experience in delivering high profile, industry benchmark products that deliver enhanced value to our customers

<table>
<thead>
<tr>
<th>High Profile Hybrid Vehicle Programme for Beijing Olympics</th>
<th>Near Zero Emission Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Two vehicle types: Stop/start micro-hybrid, and a mild hybrid</td>
<td>- Integrated diesel system with capability to meet all current and future worldwide emissions standards</td>
</tr>
<tr>
<td>- Vehicle engineered to European emissions requirements</td>
<td>- Achieves 5-10% fuel economy improvement; &gt;90% NOx emissions reduction; performance &amp; driveability improvement</td>
</tr>
<tr>
<td>- Full design of electric machine, electronic control module, battery system and safety critical software</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Increased Mobility &amp; Efficiency</th>
<th>Emissions &amp; Cost Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Concept design &amp; analysis for high power density hybrid steer-drive transmission (wheel and tracked variants)</td>
<td>- New down-sized 3 cylinder naturally aspirated engine family</td>
</tr>
<tr>
<td>- Detailed steering perform simulation to determine steering loads &amp; size gears, shafts, clutches etc.</td>
<td>- Turbo and DI variants with class leading performance, fuel economy, refinement and emissions</td>
</tr>
<tr>
<td>- Prototype transmissions procured and assembled at Ricardo</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emissions Reduction</th>
<th>New Product Development</th>
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</thead>
<tbody>
<tr>
<td>- Development of a new SI lean burn CNG bus engine</td>
<td>- Total engineering programme management:</td>
</tr>
<tr>
<td>- EU 5 and EEV emissions levels</td>
<td>- multi-platform</td>
</tr>
<tr>
<td>- Focus on improved drivability</td>
<td>- multi-customer</td>
</tr>
<tr>
<td>- Concept study and Performance simulations</td>
<td>- multi derivatives</td>
</tr>
<tr>
<td>- Comb. system, gas system and turbocharger matching</td>
<td>- Base engine design, development and validation, delivered 12 months faster than customer process</td>
</tr>
<tr>
<td>- Engine calibration + Durability test</td>
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CAE at Ricardo

Ricardo has a long history of using computer aided engineering analysis to deliver engineering programmes

- Most Ricardo Software products originated from routines developed by our engineering teams to aid with design and analysis
- Today Ricardo relies heavily on front loading projects with analysis in order to cut design timescales, testing and ultimately program delivery times
- Innovation and an understanding of exactly what is possible in terms of analysis is vital in order to offer a leading consultancy service
- With a global CAE team comprised of more than one hundred analysts who work on a diverse range of applications, Ricardo has a huge amount of analysis experience
- Customers of Ricardo benefit from this wealth of expertise through the projects we deliver
CAE at Ricardo
Ricardo have a deep understanding of tools and techniques and how best to integrate them into the development process.

Emerging Technology
- New technology
- Addressing specific concerns
- Building understanding and understanding trends
- Combined with testing to build confidence
- Rarely applied at concept stage

- Piston system friction prediction
- Heat treatment stress prediction
- Casting residual stress simulation
- Timing drive noise simulation
- Real time engine
- Probabilistic failure assessment

Developing Tools
- Proven technology
- Improving accuracy and speed
- Regularly applied in design and development
- Accepted by engineering community to add value and improve product

- Dynamic stress analysis
- Link-by-link modelling of chains
- Crankcase breathing simulation
- Engine radiated noise simulation
- Turbocharger gas flow simulation
- Combustion simulation

Embedded Technology
- Fully trusted methods
- Hardware development rarely required
- Highly automated process embedded early in engineering programme

- FEA stress analysis
- Crankshaft stress analysis
- Water jacket coolant flow simulation
- Engine performance simulation
- Piston bowl specification
- Intake and exhaust noise prediction
## CAE at Ricardo

Through the use of leading edge CAE and simulation capability Ricardo is able to reduce programme timing, hardware reliance and cost.

<table>
<thead>
<tr>
<th>PHASES</th>
<th>CONCEPT</th>
<th>ENGINEERING</th>
<th>VALIDATION/QUALITY</th>
<th>LAUNCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>MILESTONES</td>
<td>Kick-Off</td>
<td>Concept Approval</td>
<td>Design Prototype</td>
<td>Production Intent Prototype</td>
</tr>
<tr>
<td>Time to Job 1 (Months)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

### CAE Field

- **Engine Cycle Simulation**
  - Performance Simulation
  - Combustion modelling
  - Thermal analysis of Head / Block / Manifold
  - Intake and Exhaust Port Development

- **Classical Analysis and Mechanical Simulation**
  - Bearing Analysis
  - Damper Design
  - Crankshaft 3D vibration
  - Crankshaft Stress / Fatigue
  - Connecting Rod Optimisation
  - Piston / Pin Analysis
  - Cam and Spring Design
  - Valvetrain Dynamics
  - Piston System Analysis

- **Engine Structural Analysis**
  - Cylinder Head and Gasket Thermal / Stress / Fatigue
  - Connecting Rod Analysis
  - Cylinder Block Stress / Bore Distortion
  - Exhaust Manifold Thermal / Stress / Fatigue
  - Crankshaft Stress / Fatigue Analysis
  - Powertrain NVH

- **Fluid Dynamics**
  - Water Jacket optimisation
  - Port Flow / Combustion / Manifold Optimisation
  - Catalyst Optimisation
  - Intake and Exhaust Port Development

### Key CAE Tools

- Vsim, DoE, Fast
- Matlab, Simulink, Adams, Mathcad, Dymola
- Abaqus, Nastran, Optistruct, Magnasoft
- Flowmaster, Amesim, Star
Ricardo Technical Support Agreement

Ricardo Software customers can access this knowledge directly through a Technical Support agreement with Ricardo

Technical Support Agreement (TSA)

- A Technical Support Agreement is a service agreement offered by Ricardo to clients to provide quick and flexible support
- Funded via an annual fee, TSA’s offer a convenient method to access Ricardo’s unique resource of tens of thousands of man years of product development experience
- For CAE users a TSA could be used to access engineering support from Ricardo’s highly experienced CAE teams to bridge the gap that exists between software specific support and and fully outsourced consultancy projects

- Instant access to technical specialists
- Troubleshooting and review of model results
- Definition and review of analysis processes
- Best practices for testing and data gathering
- Model build and validation
- Technology transfer
- On site support
- Benchmarking of tools
TSA Services

The TSA can be used to access a range of services offered through the Technical Support Services Group.
Technology Transfer
Technology Transfer allows customers to access processes and techniques developed by Ricardo over many years on countless development programmes

Technology Transfer

- Ricardo can deliver a series of Technical Transfer activities tailored to our clients requirements
- Delivered by a Ricardo experts in the particular field of work, the session are intended to enable customers to gain an insight into the latest Ricardo analysis techniques and processes of critical interest to their own business
- The technology transfers are presented at a time and location of the customer’s choosing. This service can be made on an individual basis, or in the form of a seminar to a selected department / team
- Technical Briefings can be provided on a single topic. Several topics can also be packaged together into a series held over one or more days

Typical Topics include:
- Underbonnet Cooling
- Crankshaft Analysis
- Real time engine modelling
- Conjugate heat transfer
- DOE and Optimisation
Technical Assistance
Ricardo will assist our clients with general enquiries which can often be answered quickly by telephone or e-mail.

Direct Telephone, E-mail or on-site access to Ricardo Experts

- Our clients often require a quick answer to a general enquiry.
- Direct access to Ricardo experts provide an easy and accessible route when a rapid response is needed.
- The service is used to gain Ricardo insight and opinion where a large report or study is not required.
- Typical deliverables consist of:
  - Telephone conversation with a Ricardo technical expert.
  - Teleconference with a selection of Ricardo technical experts.
  - Short presentation style report.
  - Email response.
- Typical queries include:
  - Boundary conditions for thermal analysis.
  - Knock prediction.
  - Model correlation advice.
  - Results troubleshooting.
Small Projects
A TSA can be used to fund discrete analysis jobs where capability or resource is a problem for the customer

Analysis Consultancy

- High quality analysis from Ricardo experts with deep subject knowledge and experience
- Fast turnaround times
- Analysis using a range of industry standard tools

- Typical subjects include:
  - Engine Cycle Simulation
  - Classical Analysis and Mechanical Simulation
  - Engine Structural Analysis
  - Fluid Dynamics
  - Acoustic Analysis
The Powerlink Database contains the most comprehensive collection of powertrain and vehicle-related material in the world – currently over 220,000 abstracts, with over 500 being added each month. The Database also contains detailed engine data, which is fully searchable. Copies of documents indexed in the Database are available through the Document Delivery Service. The database is accessed via a secure area on the Ricardo website and is updated on a weekly basis. Scope:

- Conference proceedings
- SAE Papers
- Industry magazine articles
- www.ricardo.com/technical-news
Using a TSA
The mechanism for making use of the Technical Support Agreement (TSA) is straightforward

1. The funds in the account are immediately available for use on receipt of an agreed request from our clients.

2. The account manager will discuss the request with the relevant experts within the Ricardo global organisation and will outline a brief scope, price and timing for delivering the required information to the customer.

3. Once the activity has been agreed, the account manager will project manage the task to ensure delivery of the activity.

4. The account manager will inform the client’s TSA contact if the budget is in danger of being completely used up and will make arrangements for our clients to "top up" their budget, if necessary.

The fee for service in subsequent years can be adjusted taking the previous year's use into account.
Summary

- A TSA is designed to be flexible and fast
- It provides access to our consulting engineering teams in order to provide support above and beyond the software specific support provided by Ricardo Software
- An annual TSA fee is agreed with the customer to cover anticipated annual support, training, technology transfers etc.
- With funds in place Ricardo can respond to requests for support without the need for detailed proposals, purchase orders and invoicing
- Support can be provided in a variety of ways and can range from a short email or telephone support to outsourced analysis tasks or even large technology transfer activities
- TSA funds can be topped up throughout the year and unused funds can be carried over to the next year
- TSA funds can also be used to access other Ricardo services and do not have to be tied to a specific discipline
- Ricardo currently has TSA agreements with over 60 companies worldwide across a number of different sectors