RAIL

Customer solutions for a more efficient and cleaner future
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Ricardo plc

A history of rail innovation & world class technology. Ricardo covers the whole spectrum from research and development, through product design to select manufacturing.

Ricardo plc is a leading global provider of product innovation, engineering solutions, clean technology, strategic and environmental consulting. Through our advanced and well-equipped technical facilities in North America, Europe and Asia we serve a wide and balanced customer base including the market-leading brands across a range of industrial sectors, as well as government agencies and national and international regulatory authorities. We are a public company quoted on the London Stock Exchange and are a constituent of the FTSE techMark 100 index.

Since Ricardo was founded nearly a century ago, the company has enjoyed an international reputation for highly successful technology-led product innovation and development expertise, delivering profit-enhancing solutions on a worldwide basis. With our internally funded research activity and proven ability to attract the best of international scientific and engineering talent, Ricardo has been able to maintain its technical edge; this has provided us – and our customers – with crucial first-mover advantage in highly competitive markets.

Ricardo’s deep technical knowledge and wide industrial experience are particularly apparent in the transportation sectors that we serve. These sectors range from passenger cars and motorcycles to commercial, agricultural and off-highway vehicles, railway locomotive power and marine propulsion systems. Key areas of expertise include low-carbon gasoline, diesel, hybrid and fuel cell powertrain technologies; the latest driveline and transmission systems; control electronics and software development; vehicle systems integration; combustion systems enabling the optimised use of renewable bio-fuels, and the engineering of the latest concepts in wind energy and tidal power.

Ricardo is capable of taking on the toughest of engineering and strategic consulting challenges and has an enviable track record of delivering exacting projects on time and to budget. Our most important asset is our team of dedicated professionals – of which nearly three quarters are highly qualified, multi-disciplined engineers and technicians.

Our core values include respect for all our stakeholders and absolute integrity in our honest and ethical approach to our work; central to our ethos, too, are the creativity and the innovation that have defined the very character of Ricardo for almost a century, and the passion and commitment to our work that underscore everything we do for our customers.

Creativity in collaborative working is one of Ricardo’s fundamental principles; it is no coincidence that time and again, major international clients across multiple industries repeatedly return to Ricardo for successful project delivery and commend the seamless way that Ricardo people integrate into project teams.

Ricardo - a history of investment in world-class technology concepts.

Recent technologies include:

**Twin Vortex Combustion**
Low soot combustion system which enables Tier4 interim emission compliance without aftertreatment.

**Kinergy**
Ricardo has developed expertise in all components of a mechanical hybrid system and has a suite of patents to protect IP.

**SARTRE**
Vehicles and robotic systems working together to provide active cruise control with automatic steering, brake and active safety.
Rail support services

Our rail support services focus on the key industry issues to ensure that our clients benefit from the game changing technologies that we bring to the rail industry.

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**Reducing Cost**

Exploiting new technology to enable operators to do more for less

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**Increasing Capacity**

Through our extensive experience in Intelligent Transportation Systems we can accommodate the continuing increase in passenger numbers

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**Customer Satisfaction**

Improved reliability, performance and comfort

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**Carbon Reduction**

Driving up powertrain efficiency and reducing weight

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Targeted solutions
For an international industry

The deep industry knowledge and expertise of our rail sector team enables us to bring a fresh and targeted approach to our international railway customers.

**Our portfolio of advanced technologies targets:**
- Increasing Capacity
- Carbon Reduction
- Customer Satisfaction
- Reducing Cost

**Strategic skills input**

Ricardo has a clear mission to deliver an entirely new range of strategic skills into the international rail industry, including technical consulting, engineering, technology and production work and is equipped to make a substantial and positive impact for our rail clients in terms of tangible considerations such as energy efficiency, quality, robustness and whole life costs.

Gamechanging benefits within the rail industry can be delivered by adapting the suite of skills already available such as advanced engineering technologies, mechanical, electrical/electronic systems integration experience, strategic analysis capabilities and state-of-the-art production skills. These have all been developed and honed in the highly competitive industries to which the company is constantly exposed.

A well-respected team of rail industry professionals has been recruited by Ricardo to ensure that our outstanding engineering and technology capability gained in other industries offers the greatest possible return on investment to our Rail Clients.

We are not talking about providing marginal improvements. We’re talking about significant improvements such as 20-30% energy cost reductions – these are compelling benefits for any potential customer.
Capabilities & benefits

A global resource focussed on your specific challenges: Ricardo expertise spans all transport modes, power generation and clean energy. All of our technology and capability is available to apply to rail.

Innovative Ricardo technologies:
Innovative technology based solutions – including intelligent route planning and management, advanced energy storage solutions, waste heat recovery and advanced vehicle to vehicle control systems.

- Fully adaptable high capacity battery management systems available for implementation with a wide range of cell chemistries
- Kinergy contactless, energy dense, high speed flywheel utilizing a patented magnetic coupling providing a highly compact design with potential for up to 4 units of >1MJ storage on a multiple unit
- Waste heat recovery systems
- Alternative fuels: LNG, CNG, Ethanol

Key benefits of the Ricardo service:
- Independent, objective and practical advice tailored to the needs of rail sector customers
- Expertise with in-depth sector knowledge and thinking from multiple transportation sectors
- High quality, efficient and rigorous design process and expertise
- Access to world leading experts in engine, transmission and control technology and systems
- Access to non-railway supply chains, reducing costs and improving competitive advantage
- Multi-modal transportation expertise
- Faster introduction of reliable and high quality technology, products and innovations
- Strong track record of successful technology research, including the negotiation of external sources of funding

Global test facilities

78 Engine test facilities
Steady state, semi anechoic and high dynamic test beds. Road Load Simulation (RLS), Constant Volume Sampler (CVS) and heavy duty transient capability.
- Performance and Emissions beds. Steady state and dynamic. Configurable to utilise advanced techniques such as auto-mapping and Vehicle Calibration on Testbed (VCOT).
- Durability beds configurable to undertake most current test sequences including those with thermal, shock and motoring stages. Operation on a 24/7 schedule as appropriate.

Prototype manufacturing and assembly
Fully equipped manufacturing and inspection workshops capable of with low-volume production capability.

Battery System Development Centre
The 1,200 square foot facility is located on the Ricardo Detroit Technology Campus in Belleville Michigan and focuses on the safe development of Li-Ion and NiMH battery packs.

Driveline
2 and 4WD fully dynamic rigs, semi-anechoic chamber, gearshift durability, functionality and lubrication development rigs.

Mechanical development
Comprehensive mechanical development capability on components or sub-systems. Component motoring (incl. engine simulator), tilt rigs (loaded and unloaded), torsional vibration, bending and fatigue, coolant and lubrication flow, hot gas rig, block testing, FIE

7 Vehicle test facilities
Emissions chassis dynamometers up to 150kW climatic capability (-25 to +40°C). Dedicated gasoline dilution tunnels, motorcycle emissions, durability and semi anechoic vehicle chamber for emissions testing, calibration development, NVH development and durability testing.

Chemistry
Full chemical capability. On- and off-line techniques (GC, MS, FTIR, TGA). Specialists in particle sizing (facilities incl. SMPS, MOUDI & Aerosizer).

Electrical and electronic
Hardware in the loop (HIL) is used to replace or supplement the validation of ECU’s & systems on vehicles or test beds.
Prioritised capabilities

A clear strategy to address energy efficiency, quality, robustness and whole life costs.

Reducing Cost
Improving performance whilst minimizing costs

Overview
Whether in periods of fast economic growth or in a climate of austerity, the need to maximize the value of investments in rail transportation is an imperative worldwide. Ricardo brings to the rail sector its innovative skills and high quality engineering processes that are capable of delivering actionable strategies and practical solutions that minimize cost while maintaining or improving performance.

Designing for low cost:
- Reducing rolling stock unit cost of production
- Reducing fuel consumption
- Waste heat recovery systems
- Diesel engine optimisation
- High quality business case analysis of technology options

Powertrain
- Extension of asset life
- Improving existing diesel train powertrains
- Engine re-sourcing
- System optimisation
- Powertrain root cause mitigation

Increasing Capacity
Accommodating the continued increase in passenger numbers

Vehicle platooning
Ricardo are currently platooning vehicles for highways and developing systems that can be adapted for rail
- No mechanical/physical coupling
- Advanced vehicle to vehicle communications
- Autonomous control strategies and technologies
- Driver monitoring and safety systems in lead vehicle
- Developed using Ricardo’s proven safety critical processes
- Location-aware vehicles

Vehicle performance
- Enhanced driveline
- Boost from captured waste energy
Customer Satisfaction
Meeting consumer expectations and enhancing the customer experience

Overview
Ricardo has a wide range of capabilities which can enhance the customer experience through improved reliability, performance and comfort

Enabling positive competitive differentiation for rail vehicles
Increasing safety
- Safety critical electronic system and software design
- EMC

Improved passenger environment
- Noise reduction
- Vibration reduction

Key benefits
- Transferring expertise from for step improvements in fuel efficiency and emissions
- Optimised emissions technology solutions
- Access to proprietary Ricardo technologies such as the ultra-low particulate twin vortex combustion system
- Comprehensive emissions development testing facilities
- Access to advanced proprietary software for combustion system development
- New engine designs or retro fit upgrades
- Global delivery teams for local delivery of international projects

Carbon Reduction
Driving up powertrain efficiency and reducing weight

Overview
We are global leaders in medium duty engine development for commercial vehicle and off-highway markets, providing class-leading low emissions and high performance, fuel-efficient and robust technologies and new engine designs. With our portfolio of available technologies we are ideally placed to assist you in the development of your propulsion systems.

Improved reliability
- Failure root cause analysis
- Mitigation

Performance improvement
- Increased power
- Optimised weight
- Improved efficiency

Technologies and equipment to differentiate
- Small Compact energy dense flywheel
- Gearbox designs
- Powerpack design
- Noise and vibration reduction

Delivering Value Through Innovation & Technology
Ricardo case studies and capabilities
Case Study –  
**Improving existing diesel powertrains**
Delivering existing powertrains to modern levels of reliability and cost

**Ricardo role**
Ricardo has deep knowledge in understanding engine and powerpack dynamics to deliver existing powertrains to modern levels of reliability and cost.
- Development and improvement of existing power trains
- Making alternative suppliers available to the Rail Industry
- Reduction of power train first cost and LCC

**Situation and objective**
- Reliability Improvement
- Investigation into cause of reliability issues

**Results and benefits**
- Reduced fuel consumption
- Improved performance
- Reduced emissions
- Improved reliability

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**Case Study – **
**Ricardo Flywheel**
DMU regenerative braking system research project

**Ricardo role**
System based on Ricardo’s flywheel high energy density storage system. Ricardo has developed expertise in all components of a mechanical hybrid system and has a suite of patents to protect IP.
- To eliminate the need for vacuum seals a non-penetrative magnetic coupling system is used to transfer kinetic energy through the housing.
- High efficiency bearing solutions are being developed for the flywheel.

**Situation and objective**
The ground-breaking research project aims to create industry first by providing an environmentally-friendly regenerative braking capability for diesel commuter trains. Ricardo has joined forces with fluid power expert Artemis Intelligent Power and world-leading rail technology expert Bombardier Transportation.

**Results and benefits**
A cost-effective solution that could be retrofitted to existing rolling stock as well as incorporated into new rail vehicles. To demonstrate a complete rail driveline incorporating this energy storage technology, the system will be coupled to a wheel-set supplied by Bombardier and will be tested on a dynamometer rig at Artemis’s facility in Midlothian, Scotland. It is anticipated that a follow-up project will progress to installing and testing the system on an operating train.
Ricardo and Israel Aerospace Industries have developed a new towing vehicle concept (TaxiBot). After an initial feasibility study, Ricardo developed a detailed programme for IAI to take the concept to the level of a working demonstrator vehicle with full capability. Ricardo’s involvement included requirements capture, conceptual design, detailed specification design, manufacture and demonstration of the first TaxiBot demonstrator vehicle.

**Situation and objective**

Aeroplane taxiing is a particular area of focus for fuel efficiency improvements. Aircraft engines are used as an inefficient means of low-speed ground manoeuvring so that the pilot can be in sole control of the aeroplane. TaxiBot allows the pilot to remain in control whilst using a more efficient towing vehicle.

**Results and benefits**

Ricardo has successfully delivered the robotic, pilot-controlled towing vehicle demonstrator which reduces emissions and noise and offers substantial fuel savings. The TaxiBot concept is capable of operating with both wide and narrow bodied commercial airliners; it requires no modification to the aircraft, taxiways or runways, and only minor changes to airport infrastructure.

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**Case Study – Eco taxiing**

Reducing the cost, noise, pollution and CO₂ emissions of global air travel

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**Ricardo Role**

Ricardo and Israel Aerospace Industries have developed a new towing vehicle concept (TaxiBot). After an initial feasibility study, Ricardo developed a detailed programme for IAI to take the concept to the level of a working demonstrator vehicle with full capability. Ricardo’s involvement included requirements capture, conceptual design, detailed specification design, manufacture and demonstration of the first TaxiBot demonstrator vehicle.
Case Study – Diesel Multiple Unit powerpack technology roadmaps

High quality business case analysis of technology options

Ricardo role
Ricardo have mapped out Multiple Unit powerpack technology for a major manufacturer to enable high quality business decisions through application of both technical and business expertise.

Situation and objective
- Objective analysis and technology roadmapping with no bias to any one supplier
- Review of technology options in adjacent markets to ensure a wider review of options available
- Builds high confidence business cases reducing repeat costs in analysing investment cases

Results and benefits
- Clear mapping of how hybrid technology evolves
- Independent review of market options
  - Technical assessment
  - Economic assessment
- Analysis of market drivers on technology
- Technology route maps with recommendations
- Technical solutions for each stage of route map
- Showed that Diesel Multiple units can become 50-80 year ‘onboard power source’ multiple units, allowing long term investment in new DMUs as economically viable

Case Study – Powershift transmission design for Caterpillar

Ricardo role
Ricardo undertook a ‘clean sheet’ design of a range of new powershift transmissions, providing an experienced design team to expedite the project. The project began with fundamental studies of transmission concepts incorporating a high level of component rationalisation.

Situation and objective
The design effort was backed by leading edge CAE tools and techniques which included the use of the Ricardo Powertrain library, finite element analysis as well as structural analysis and optimisation.

Results and benefits
The new transmissions were successfully introduced to market in a reduced timescale, with improved component rationalisation and performance.
Case Study –

SARTRE

Road train using vehicle-to-infrastructure and vehicle-to-vehicle communication

Ricardo role

- Vehicles and robotic systems working together provide larger benefits than vehicles operating in isolation. Ricardo are part of a team developing road train technology

Situation and objective

- A road train develops behind a lead vehicle utilising automatic steering and brake and active safety and cruise technology
- Following vehicles are free to join and exit as required

Results and benefits

- Reduced fuel consumption and greenhouse gas emission
- Improved traffic flow and journey times
- Increased driver and passenger comfort and convenience
- Reduced accidents
- Autonomous road train
- Maximum passenger freedom
- Maximum drag reduction
Ricardo Rail Capability –
Root cause failure analysis and mitigation

Ricardo role
Improving safety and reliability by getting to the root cause of unexpected failures

Situation and objective
Ricardo has extensive experience of root cause failure analysis on rail vehicle systems including engines, gearboxes and cooling systems

Results and benefits
- Getting to the real root cause is vital to avoid repeat failures and their associated cost and safety consequences
Case Study –

**Alternative fuels**

Ricardo role
Assisting a North American class 1 railroad to assess the implications of using liquified natural gas as fuel in place of distillate diesel.

Situation and objective
Ricardo reviewed the options for storage, transport and distribution of the LNG, including the locomotive tender along with available engine conversion technologies. Particular attention was paid to identifying “Red Flag” issues which could affect reliability.

Results and benefits
Significant benefits, particularly in reduced emissions are possible, especially when annual fuel consumption is measured in millions of gallons.

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Ricardo Rail Capability –

**Safety critical electronic & control system development and design**

Safe and reliable engineering solutions

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Ricardo role
Specialists in taking a concept from the drawing board to the full production version in rapid timescales. Rapid prototyping and advanced R&D techniques

- Modelling and simulation tools (i.e. AutoFMEA)
- High quality safety critical circuit and software design
- Ultra-reliable design techniques developed by Ricardo
- Reverse engineering of legacy systems
- Full engineering lifecycle to IEC61508 (from which CENELEC standards were derived)
- Driver Advisory Systems experience
- Extensive research in ground-breaking technologies
- Modular and COTS product design and production

Situation and objective
- Vehicle to Vehicle communications and Intelligent Transportation solutions
- GPS/GNSS technologies in the vehicle control and monitoring environment
- Driver Advisory Systems – hazard warnings, efficiency and carbon monitoring

Results and benefits
- Reduced R&D costs and timescales via a well tried and proven process
- Safe and reliable engineering solutions
- Modularised/COTS approach to product development rather than bespoke everything
- Cutting edge technology and refreshingly different approach to the conventional rail supply chain
- Successful complex systems integration is the norm, not the exception
- Knowledge transfer from our extensive research activities
Case Study –
Helping JCB create the ‘world’s cleanest off-highway engine’

Removing emissions at source for mining, industrial, agricultural, and construction equipment and vehicles

Ricardo role
Ricardo was appointed by JCB to design and develop a new world class 4 and 6 cylinder engine family. The target was to be best in class for manufacturing costs, fuel economy, torque back-up and noise and vibration.

Situation and objective
Ricardo was responsible for the complete design and analysis, prototype procurement and build of the engine as well as performance and emissions. Targets were met through the use of design for manufacture and assembly, early supplier involvement and the early use of CAE, FEA and CFD.

Results and benefits
Start of production was achieved as scheduled in November 2004. Warranty and reliability at launch were better than with any other previous diesel engine. The costs and performance targets were all met including the lowest cylinder head costs on the market in this class. Best in class engine NVH was achieved within the Ricardo database.

Case Study –
JCB Dieselmax

The fastest diesel car in the world

Ricardo role
Ricardo developed the JCB earth mover engine, made it horizontal, upgraded the air handling, included water injection and increased output to 750hp for the record breaker

Situation and objective
Ricardo, from cleansheet, designed the 4.4l 444-TCA, 175hp for JCB’s earthmoving equipment. Two of these engines needed to be modified to power the JCB Dieselmax.

Results and benefits
The fastest diesel car in the world 350.092 mph
Case Study –

Monorail driveline
Complete driveline design and prototype manufacture

Ricardo role
Design of an optimised driveline to fit within the existing vehicle architecture and provide a weight saving

Situation and objective
Ricardo designed the complete driveline comprising an epicyclic reduction gearbox mounted directly onto the traction motor, a 90 degree reduction bevel gearbox and driveshafts.

Results and benefits
A 250kg weight reduction was achieved and the design validated by testing of prototypes that were manufactured in-house at Ricardo.
Ricardo Rail Capability – Ricardo software
Complete suite of powertrain design and analysis tools

Ricardo role
Ricardo Software markets and supports a wide range of design and analysis software products developed specifically for application during the powertrain development and vehicle integration processes.

Results and benefits
Ricardo tools are generated specifically for transportation applications enabling fast efficient analysis

- Wave - 1D Gas Dynamics
- Wave-RT - Real-Time 1D Gas Dynamics
- VECTIS - 3D Powertrain CFD
- ENGDYN - Advanced Crankshaft Dynamics
- VALDYN - 1D Valvetrain and Multi-Body Dynamics
- FEARCE - Advanced FEA Workflow and Simulation
- PISDYN - 3D Piston Dynamics
- RINGPAK - 2D Ring Pack Dynamics
- SABR - 2D Shaft, Gear, and Bearing Simulation

Case Study – The Reduced cost Li-Ion (RED-LION) project
Proving the potential of alternative cell chemistries

Ricardo role
A two-year collaboration between Ricardo and QinetiQ with part-funding from the Department for Transport under the UK Energy Saving Trust Low Carbon R & D programme with the aim to develop an alternative Lithium-Ion (Li-Ion) cell chemistry that could be integrated within an HEV using a bespoke battery management system.

Situation and objective
To prove the potential of the alternative cell chemistry, the RED-LION project set out to replace the battery pack used in the Efficient-C prototype HEV with one using new cells capable of demonstrating suitable material cycle life, capacity, specific energy, rate capability and safety. Custom cells were manufactured and packaged within a bespoke battery pack incorporating many novel features. Ricardo designed the overall battery pack to directly replace the existing unit, developing a new battery management system to manage the iron sulphide chemistry.

Results and benefits
A 20% reduction in weight was achieved along with significant cost savings through cheaper raw materials and a more energy efficient patented manufacturing process. A new battery management system based on a bespoke architecture has been adapted, which is fully adaptable to a range of cell chemistries and battery architectures.
Case Study –
Locomotive manufacturing cost reduction

Ricardo role
Ricardo was engaged by one of the major international train manufacturers to lead a comprehensive cost-down study of locomotive manufacture.

Situation and objective
Parallel work streams were carried out in both design and sourcing with full cost analysis including both production and infrastructure.

Results and benefits
Potential savings totalling 30% of unit cost were identified, the majority of which have since been realised.

Case Study –
Twin Vortex Combustion System
Meeting Tier 4 interim emission limits without aftertreatment

Ricardo role
An optimised combustion system for JCB has been developed by Ricardo’s engineering team from mid 2007 using 3-D CFD simulations with the aim to improve mixing and accelerate soot oxidation process during the combustion event. Spray analysis CFD outcomes have been validated against experimental data and nozzle spray visualization.

Situation and objective
Experiences from this research activity have been used to design a low soot combustion system for the new Ecomax JCB 444 engine which enables it to meet Tier 4 interim emission limits without aftertreatment. This system has been applied on other engines and different applications with successful results. Research is going forward to check benefits at high EGR rate (>40%) and rail pressure (2500bar).

Results and benefits
The experimental results achieved with TVCS confirm the opportunity for aftertreatment simplification and fuel consumption benefits. 0.015 g/kWh PM engine-out has been achieved over NRTC at <3.0g/kWh NOx. Also this combustion system has demonstrated flat response of smoke and fuel consumption versus timing and low sensitivity against swirl ratio and protrusion. Durability tests have shown very low soot in oil results and DF targets have been achieved on a significant number of prototypes. This combustion system can be applied on on-highway applications to simplify aftertreatment. For instance Euro 4 targets can be achieved either without aftertreatment or with a simple DOC. DPF can be used to meet particle number limits with passive regeneration strategy and limited thermal management to reduce fuel penalties over “real world” duty cycle.
Case Study –
GB rail powertrain efficiency improvements report

Ricardo role
Ricardo and TRL were contracted by the UK Department for Transport to investigate suitable technologies available for retro-fit to the existing DMU and locomotive fleet to reduce fuel consumption.

Situation and objective
Thirty Two technologies were assessed on a business case basis. Stakeholders feedback was gained from the industry and previous successes were examined.

Results and benefits
Seven technology packages were recommended for implementation.

Case Study –
Locomotive engine design and development

Ricardo role
Ricardo’s large engine team has undertaken many locomotive engine projects, from market studies, emission upgrades and performance improvements to many full clean-sheet designs.

Situation and objective
• Using leading in-house experience and software to optimise designs of high speed and medium speed locomotive engines.

Results and benefits
• World-class, high power density, high efficiency locomotive engine products that achieve low emissions.

Case Study –
Integrated cost reduction for a train manufacturer

Ricardo role
Ricardo has engaged with one of the major international train manufacturers to lead a comprehensive cost-down study of locomotive manufacture. Parallel work streams were carried out in both design and sourcing, with full cost analysis including both production and infrastructure. The result of this highly confidential study delivered a headline cost saving of 30 percent reduction in the unit cost of production.
Ricardo’s global locations

Local project delivery through Technical Centres in Europe, North America and Asia.

With offices and technical centres around the world we can support projects locally and work closely with our clients wherever they are in the world.

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