EASA Certification Roadmap on H2 International Workshop

H2 Direct Burn Technology and the specific hazards related to H2 Burn in a gas turbine

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Rolls-Royce Hydrogen Projects

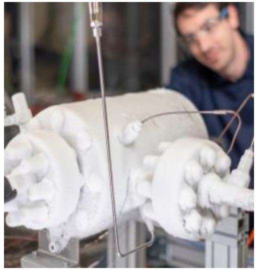
WotAn
LuFo VI, Call 2
Rolls-Royce led

Fundamentals and modelling of H2 combustion
- Simulation
- Experimentation
- Model validation

HyEST
UK ATI
Rolls-Royce led

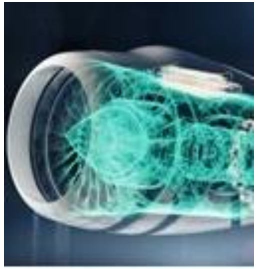
Sub-system architecture and combustion techno.
- Hydrogen combustion
- Methods and tools
- Materials and coating technologies

LH2GT
UK ATI
Rolls-Royce led



System architecture, hydrogen control and fuel system
- LH2 pumping
- Heat management
- H2 valves, actuation & sensing
- Fuel metering and control
- Safety

RACHEL
UK ATI
Rolls-Royce led

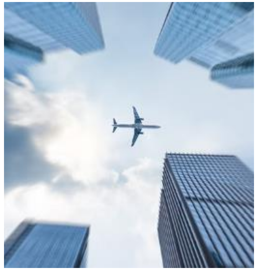


Key technologies and integrated powerplant
- Nacelle development
- Supporting systems
- Electrical systems
- Heat exchangers
- Gas tanks
- Aerostructures

CAVENDISH
EU Clean Aviation
Rolls-Royce led

Integrated ground engine testing and requirements for future flight test
- System integration
- Facilities
- Engine test
- Permit to fly study

CONCERTO
EU Clean Aviation
Rolls-Royce supported



Certification req^{TS} to bring new products to market and into service faster
- Future regulations
- Means of compliance

HEAVEN
EU Clean Aviation
Rolls-Royce led

Developing the scalable UltraFan® architecture and suite of technologies
- UltraFan technology study
- Hybrid-electric technology

Gas Turbine Technology

- Fuel Conditioning
- Fuel Management
- Combustor

Gas Turbine Operation

- Safety
- Maintenance Intervals
- Refuelling Procedures

Airframe Integration / Aircraft Performance

- Fuselage Volume
- Fuel Tank Integration
- Weight Distribution

Aircraft Operation

- Payload/Range Relationship
- Tankering & Ferry Range Capabilities
- Market & Operational Economics

Test early, trial-fast, learn-by doing with structured de-risk

Lavoisier (2022)

- HybAE2100 donor
- Green hydrogen gas demonstration

- Safe fuel handling
- Starting, ignition, shutdown and control stability

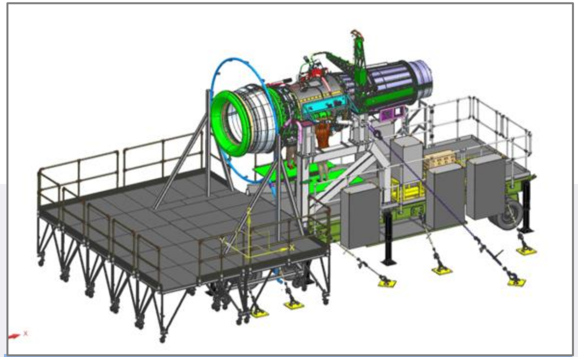
- Test at Boscombe Down (UK)

Engine zero (2024)

- Pearl 15 donor with novel hydro-mech- and thermal management system

- Engine oil heat management, coolant: N2 / hydraulic loop
- VSV actuation
- Combustor fuelled by 100% SAF

- Indoor test at Germany in standard pylon configuration



Engine H2

- Fully redressed Pearl 15
- 100% hydrogen distribution-, control- and combustion system
- Integrated engine zero technologies

- Engine handling, operability, maintenance aspects, H2 safety
- Prove mobile engine test stand and facility

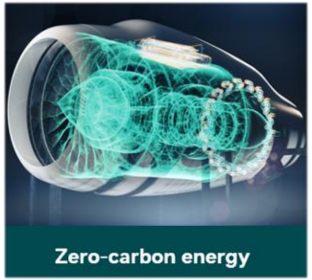
- Outdoors Test at NASA Stennis

H2 Combustion Rig Test Programme

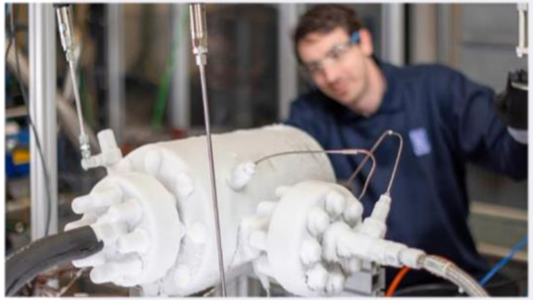
H2 Fuel System Rig

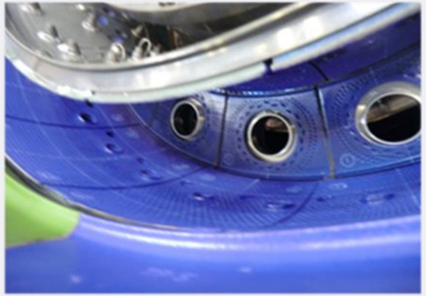
Today's H2 test experience

- Lavoisier green hydrogen gas demonstration
- Engine Zero has proven the hydro/mechanical system and the hydro / gas cooling system. Provided thermal data for more accurate H2 heat management modelling. Demonstrated reliable operability of the novel VSV actuation and control system
- Liquid hydrogen pump test programme commences providing data for engine operability requirements.
- Completion of expansive aero-derivative hydrogen combustion test programme
- Validation on full annular rig at HBK5 2023 & 2024 up to 100% MTO Pearl engine conditions utilizing an unchanged Pearl production combustor with a new H2 fuel injector and H2 fuel manifold (TRL4 achieved)
- *RR Power Systems H2 powered reciprocating engines running already in service*



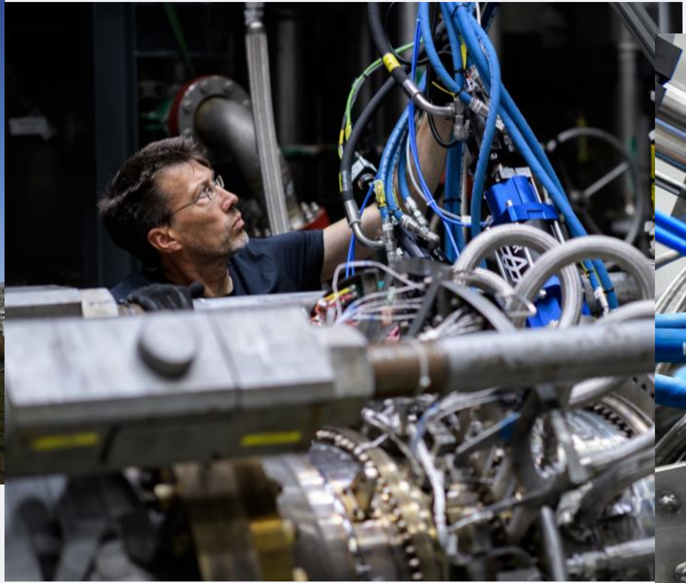
H_2EART
Hydrogen Injector for Eco-Friendly Aviation with Rolls-Royce Technology





Innovation in optical diagnostics for direct H2-burn

- Leap of insight due to patented DLR technology
- Accelerating decarbonisation of aviation at full pressure conditions [40 bar]



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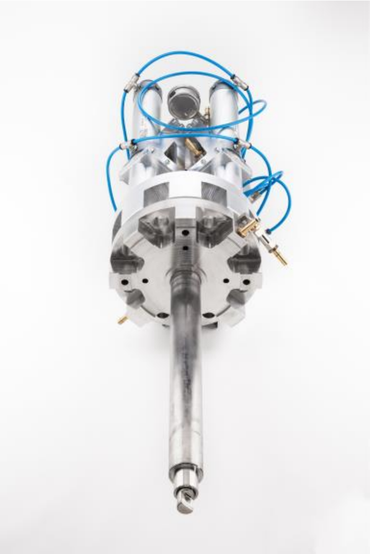
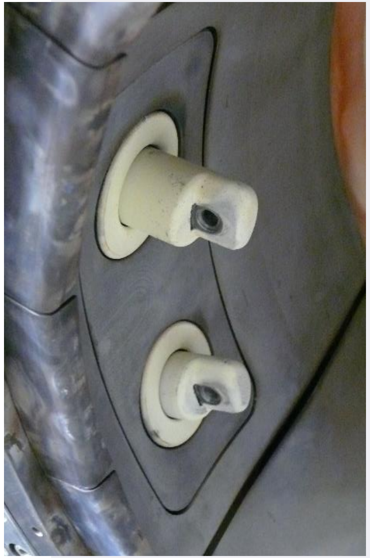
Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

Endoscopic system captures optical data to visualise new combustor technology reaction zones in high TRL facilities

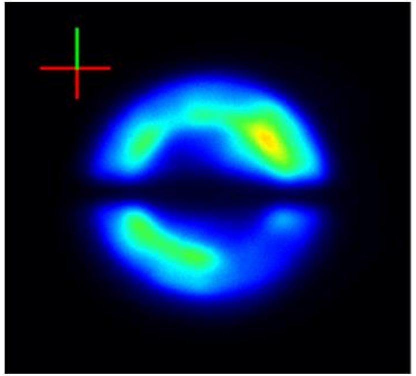
Combination of the unique combustion testing facilities with advanced measurement technologies

➔ **Measurement technology accelerates the development of low-emission combustion chambers**

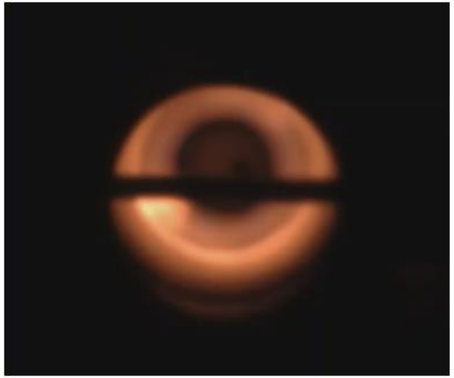




For UV (reaction zone) and VIS (hot spots) analysis, the Optical Duct provides additional optical data:



UV visualisation of a combustion oscillation in the H2/NG mixture



Thermal emission in the VIS of a flashback event at 95 % H2 [1]

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aufgrund eines Beschlusses des Deutschen Bundestages

[1] J. Koomen et al., High pressure testing with optical diagnostics of a hydrogen retrofit solution to eliminate carbon emissions, ASME GT2022-82652, June 13-17, 2022, Rotterdam, The Netherlands

Combustion subsystem challenges

- H2 metering and pressure control (Very low H2 mass flows at ignition)
- Transient engine performance (due to 100% efficiency, risk of compressor stall)
- Leakages, embrittlement of fuel system components
- Corrosion. Integrity of ceramic bonding – to be verified
- Whole system integration.

Impact on the engine

- **Ignition**: No issues using existing engine ignition system
- Lean blow-out (Weak extinction): Superior to Jet-A1
- Efficiency: 100% at any condition
- Thermo-acoustics: Similar to Jet-A1 (resonance impact on FMU control to be tested on GH2 engine)
- **Emissions**: All zero, except NOx and increasing quantity of H_2O vapor.
- **Turbine**: Temperature field similar to Jet-A1 (by design), no risks
- **Thermals**: Similar wall temperatures as for Jet-A1, no risks
- **Hardware:** Combustor retrofittable with H2 burners and manifold. Significant changes on the dressed engine (complexity, weight, fire prevention….)
- Altitude **relight**: Superior to Jet-A1 ,based on low TRL test experience (future ALT test scheduled)

EASA help needed

- Definition and requirements of fire zones for GH2 and LH2 applications:

  Existing and applicable:
  - Designated Fire Zone.
  - Fire Zone
  - Fuel Leakage Zone

  Do we need new definition due to the different types of threats ?
  - Fire Withstanding Zone
  - Heat Withstanding Zone

  Considering different types of threats:
  - Micro flames, Torching flames
  - Deflagration
  - Explosion

- Need of H2 leakage detection / fire detection and fire suppression systems ?

- Standardised means of compliance demonstration
  - Standard H2 burner flame(s) and characteristics
  - Standard H2 fire test(s) procedure
  - Definition of H2 Fireproof and Fire resistant (e.g. Temperature and Heat Flux Density, Duration for different types of flames)

Thank you