HYDROGEN GAS TURBINES & THRUST GENERATION

UK Capability and Overseas Landscape

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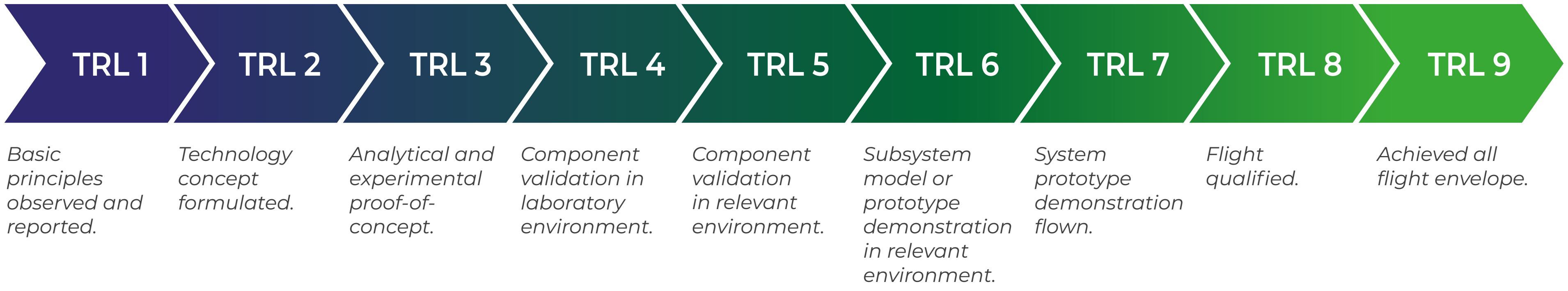

Figure 1 – Technology has been assessed against the NASA Technology Readiness Level (TRL) scale

UK CAPABILITY

The UK has world-leading gas turbine technology, and is well placed to pivot in to liquid hydrogen technologies. There is currently no UK supplier capability for liquid hydrogen burning gas turbines for aerospace applications. The barriers to entry into aerospace are high, especially for systems with complex integration challenges such as the gas turbine, increasing the likelihood that an existing aeroengine manufacturer will be first to market with a hydrogen-burning gas turbine engine.

Rolls-Royce is a leading aeroengine manufacturer headquartered in the UK with a long established track record in delivering aerospace gas turbine technology programmes. Rolls-Royce Power Systems in Germany is investigating hydrogen for power generation applications, including fuel cells and the Rolls-Royce MTU 500 'hydrogen ready' reciprocating gas engine.

Due to the expected novelty in hydrogen handling, system control and burning of hydrogen within the combustor, the global technology maturity is assessed at Technology Readiness Level (TRL) 2.

Very early concept formulation and combustion trial work accompanied by early plans for manufacturing validation and development.

Figure 2 – Global TRL levels for hydrogen handling, system control and burning of hydrogen within the combustor

Rolls-Royce previously owned combustor manufacturing capability but it recently integrated its former combustor manufacturing site in Hucknall, UK into ITP Aero (a subsidiary headquartered in Spain) before selling ITP Aero to Bain Capital in 2021. Through Rolls-Royce and ITP Aero the UK is in a strong position to deliver the development required by the combustion roadmap.

Reaction Engines in conjunction with Airborne Engineering and S&C Thermofluids have tested gaseous hydrogen combustors on a research programme in the UK.

UK CAPABILITY

The capability of Dowty Propellers is recognised for their ongoing development of technologies that are essential to maximise propulsive efficiency. This is significant for emerging fuel cell technologies with low power densities where minimising peak power demand is key to reducing overall system mass.

UK academia is very active in combustion technology. Cranfield University has successfully burned hydrogen within the EU-funded ENABLE H2 project. Cardiff University also tests with a range of gases including hydrogen in its Gas Turbine Research Centre. Loughborough University (National Centre for Combustion Aerothermal Technology) is heavily used for the testing and development of current combustion technology, and is expected to be able to burn hydrogen for rig testing.
Cambridge University's Whittle Lab also undertakes activity across the whole turbomachinery landscape. Manufacturing technology development has historically been undertaken across the UK's network of research organisations including in the High Value Manufacturing Catapult.

OVERSEAS LANDSCAPE

The countries with leading hydrogen gas turbine capability are France, Germany, USA, Japan and Sweden.

In France, an aerospace and space industry consortium including Safran will utilise hydrogen propulsion knowledge from the space industry to develop hydrogen gas turbines under the Hyperion project. Safran and GE Aviation have also partnered on project RISE which will develop an open fan engine capable of running on hydrogen.

Siemens Energy in Germany is aiming to run 100% hydrogen for power generation applications by 2030 and has already demonstrated 100% hydrogen burn on some systems.

In the USA, GE Gas Power has experience in running gas turbines on hydrogen.

Japan, under the Japanese Aerospace Exploration Agency (JAXA) programmes, is developing hydrogen storage, pumping and combustion research, seeking to transfer technology from space and hypersonic successes, along with aiming to have an industrial gas turbine running on 100% hydrogen by 2025.

In Sweden, the Zero Emission Hydrogen Turbine Centre (ZEHTC) has developed a power distribution demonstrator facility centred around a hydrogen burning gas turbine.

KEY MESSAGE

Development of a hydrogen burning gas turbine will require the establishment of test infrastructure at whole engine, system and sub-system level.

The key technology development work for the design and manufacturing communities will focus on designing novel features in the combustor. Test infrastructure will be required from single sector combustor at sub-scale up to a full size multi-burner combustor module. The FlyZero team has not yet identified existing UK test facilities capable of delivering cryogenic hydrogen to a full-scale combustion test chamber.

The UK has extensive capability in the design and manufacture of combustor components for kerosene powered aeroengines through Rolls-Royce and its supply chain. There is strong capability in combustion within the UK research community, for example Cambridge, Cardiff, Cranfield and Loughborough Universities.

RELATED FLYZERO FURTHER READING

The ATI FlyZero project developed its technology roadmaps through a combination of broad industry consultation and assessment of technologies by experts. Technology assessment was carried out both by the FlyZero team and by approximately 50 industrial and academic organisations that partnered with FlyZero to support delivery. During the project, FlyZero developed three concept aircraft and used this exercise to gain a deep understanding of requirements and challenges for systems and technologies, which have been reflected in the roadmaps. Further detail of these technologies and developments can be found in the following reports, available to download from **ati.org.uk**:

FlyZero

Zero-Carbon Emission Aircraft Concepts
Report
Ref. FZO-AIN-REP-0007

Technology Roadmaps
Report
Ref. FZO-IST-MAP-0012

Workforce to Deliver Liquid Hydrogen Powered Aircraft
Report
Ref. FZO-IST-PPL-0053

Hydrogen Aircraft

Aerodynamic Structures
Technical Report
Ref. FZO-AIR-REP-014
Roadmap
Ref. FZO-AIR-MAP-0015
Roadmap Report
Ref. FZO-AIR-COM-0016
Capability Report
Ref. FZO-AIR-CAP-0066

Electrical Propulsion System
Technical Report
Ref. FZO-PPN-REP-0028
Roadmap
Ref. FZO-PPN-MAP-0029
Roadmap Report
Ref. FZO-PPN-COM-0030
Capability Report
Ref. FZO-PPN-CAP-0070

Thermal Management
Technical Report
Ref. FZO-PPN-REP-017
Roadmap
Ref. FZO-PPN-MAP-0018
Roadmap Report
Ref. FZO-PPN-COM-0019
Capability Report
Ref. FZO-PPN-CAP-0067

Fuel Cells
Technical Report
Ref. FZO-PPN-REP-0031
Roadmap
Ref. FZO-PPN-MAP-0032
Roadmap Report
Ref. FZO-PPN-COM-0033
Capability Report
Ref. FZO-PPN-CAP-0071

Hydrogen Gas Turbines & Thrust Generation
Gas Turbine Technical Report
Ref. FZO-PPN-REP-020
Thrust Devices Technical Report
Ref. FZO-PPN-REP-021
Roadmap
Ref. FZO-PPN-MAP-0022
Roadmap Report
Ref. FZO-PPN-COM-0023
Capability Report
Ref. FZO-PPN-CAP-0068

Cryogenic Hydrogen Fuel System & Storage
Fuel System Technical Report
Ref. FZO-PPN-REP-024
Fuel Storage Technical Report
Ref. FZO-PPN-REP-025
Roadmap
Ref. FZO-PPN-MAP-0026
Roadmap Report
Ref. FZO-PPN-COM-0027
Capability Report
Ref. FZO-PPN-CAP-0069

Cross-Cutting

Aircraft Systems
Ref. FZO-AIR-POS-0013

Airports, Airlines, Airspace - Operations & Hydrogen Infrastructure
Ref. FZO-CST-POS-0035

Advanced Materials
Ref. FZO-IST-POS-0036

Lifecycle Impact
Ref. FZO-STY-POS-0034

Sustainable Cabin Design
Ref. FZO-AIR-POS-0039

Compressed Design and Validation - Culture and Digital Tools
Ref. FZO-IST-POS-0038

Advanced Manufacturing
Ref. FZO-IST-POS-0037

ABOUT FLYZERO

Led by the Aerospace Technology Institute and backed by the UK government, FlyZero began in early 2021 as an intensive research project investigating zero-carbon emission commercial flight. This independent study has brought together experts from across the UK to assess the design challenges, manufacturing demands, operational requirements and market opportunity of potential zero-carbon emission aircraft concepts.

FlyZero has concluded that green liquid hydrogen is the most viable zero-carbon emission fuel with the potential to scale to larger aircraft utilising fuel cell, gas turbine and hybrid systems. This has guided the focus, conclusions and recommendations of the project.

This report forms part of a suite of FlyZero outputs which will help shape the future of global aviation with the intention of gearing up the UK to stand at the forefront of sustainable flight in design, manufacture, technology and skills for years to come. To discover more and download the FlyZero reports, visit **ati.org.uk**

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FlyZero contributing companies*: Airbus, Belcan, Capgemini, easyJet, Eaton, GE Aviation, GKN Aerospace, High Value Manufacturing Catapult (MTC), Mott MacDonald, NATS, Reaction Engines, Rolls-Royce, Spirit AeroSystems.*

These roadmaps have been developed with a view to accelerate zero-carbon technology development and maximise the potential future value for the UK. They are unconstrained by the availability of funding.

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