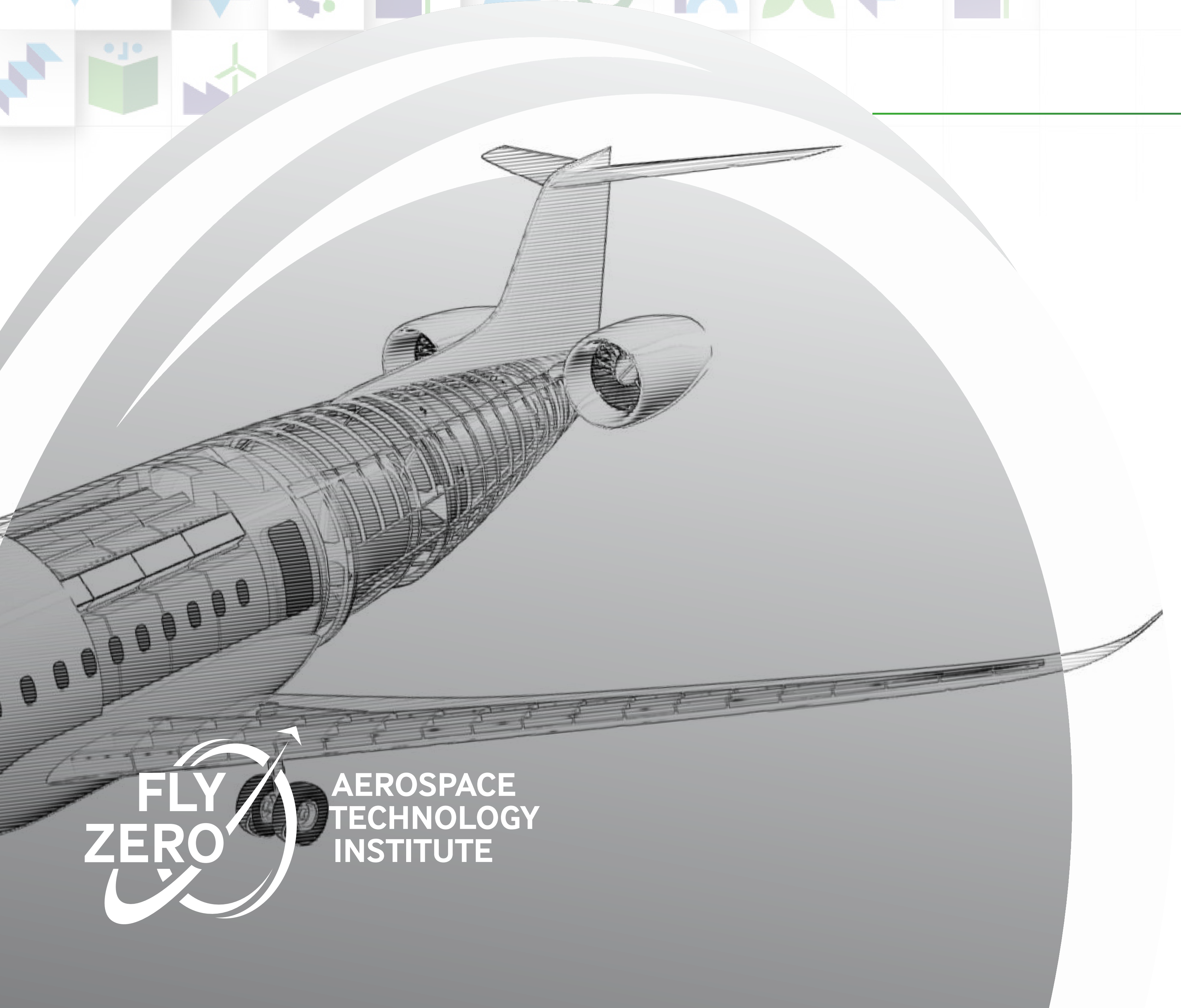


FLY ZERO AEROSPACE TECHNOLOGY INSTITUTE

AERODYNAMIC STRUCTURES

UK Capability and Overseas Landscape

FZO-AIR-CAP-0066

Published March 2022

CONTENTS

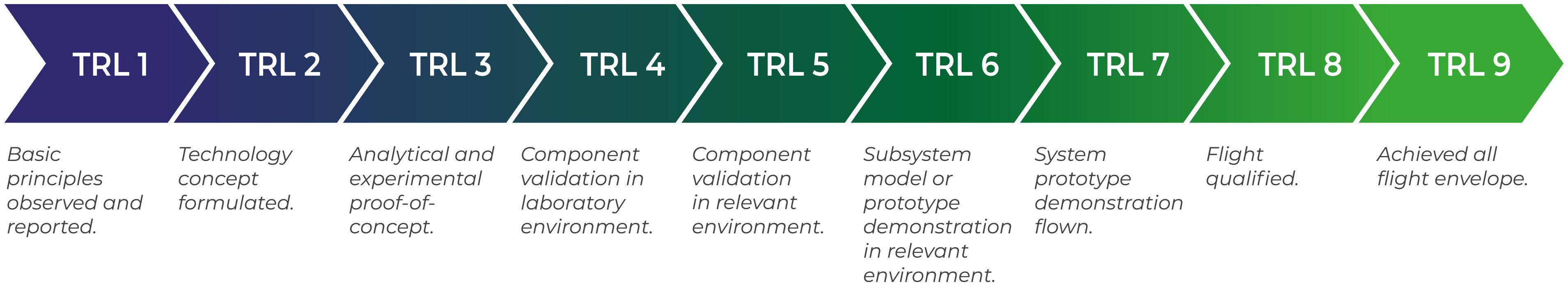


Figure 1 – Technology has been assessed against the NASA Technology Readiness Level (TRL) scale

UK CAPABILITY

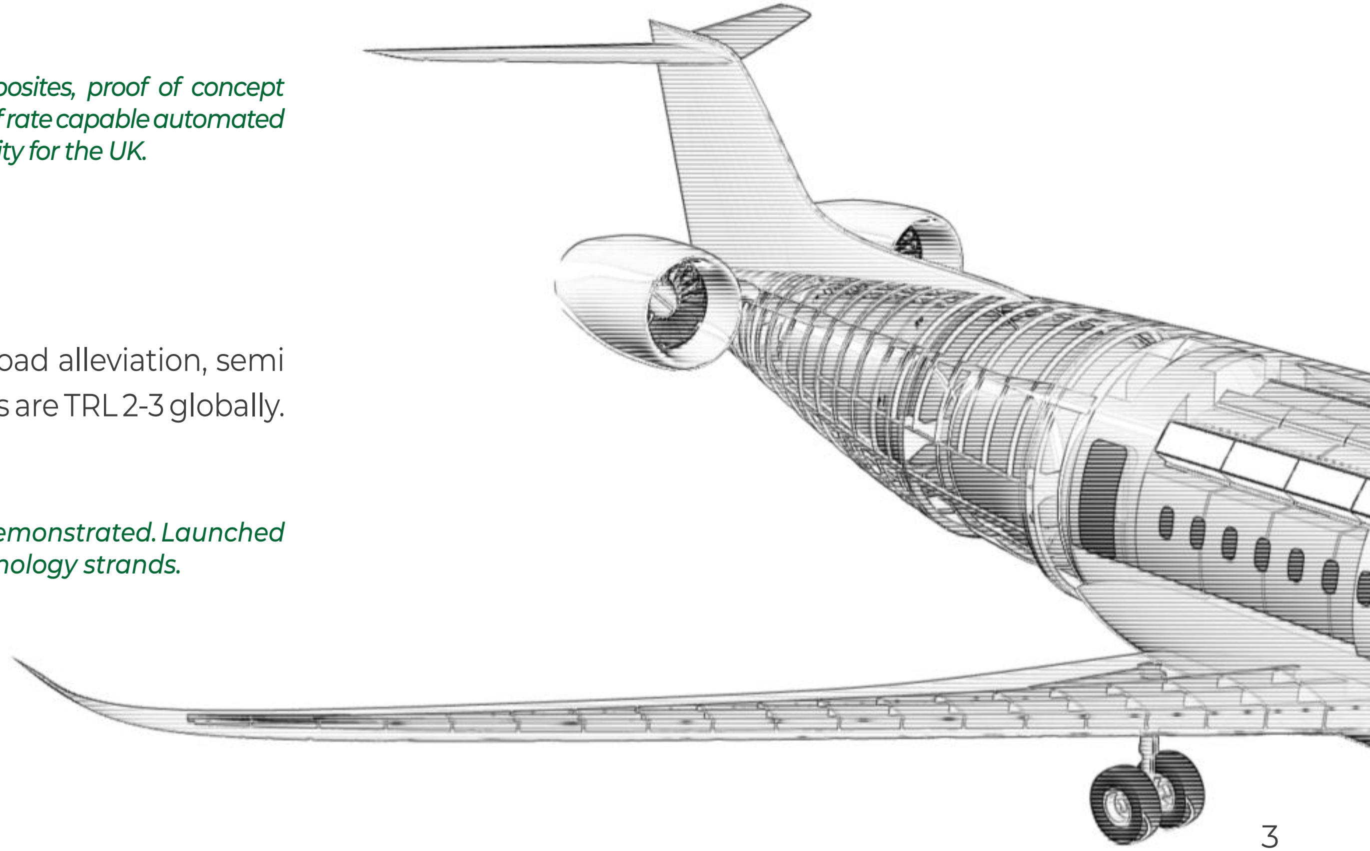
The UK has world-leading capability in wing design, manufacture and assembly.

Today's aircraft store fuel in their wings; however as cryogenic hydrogen is introduced, it will drive the need for optimised tanks, which could be stored either in the fuselage, in the wing, in 'cheek' pods or in external pods. The potential for a dry wing, where fuel isn't stored in the wingbox, offers significant opportunities for radical new wing design and manufacture. These can be grouped into four key streams of development.

The first stream is performance improvements which include enabling laminar flow, lift-to-drag ratio improvements, wing morphing and improved moveable devices. These range from TRL 2-5 globally. Some of the nearer term opportunities include improved moveable devices such as flaps and one shot composite 'moveables', with full wing laminar flow or wing morphing further into the future.

Large primary one-shot composites, proof of concept demonstrated. Development of rate capable automated manufacturing is an opportunity for the UK.

Figure 2 – Global TRL levels for aerodynamic structure performance improvements.



The second stream centres on load reduction to optimise design, including passive and active load alleviation, semi aero-elastic hinges, inertia relief, and aero-elastic tailoring. Novel applications of these technologies are TRL 2-3 globally.

Load reduction activities, proof of concept demonstrated. Launched initial development of manufacturing technology strands.

Figure 3 – Global TRL levels for load reduction activities.

UK CAPABILITY

The third stream for development activity is structural optimisation, including novel designs and architectures, such as a truss-braced wing, new leading and trailing-edge architectures, advanced pylon structures, adaptive wingtip, distributed propulsion and biomimicry structures. All of these structural developments are assessed as being at the lower end of the TRL scale globally, spanning TRL 1-4, with the most novel at TRL 1.

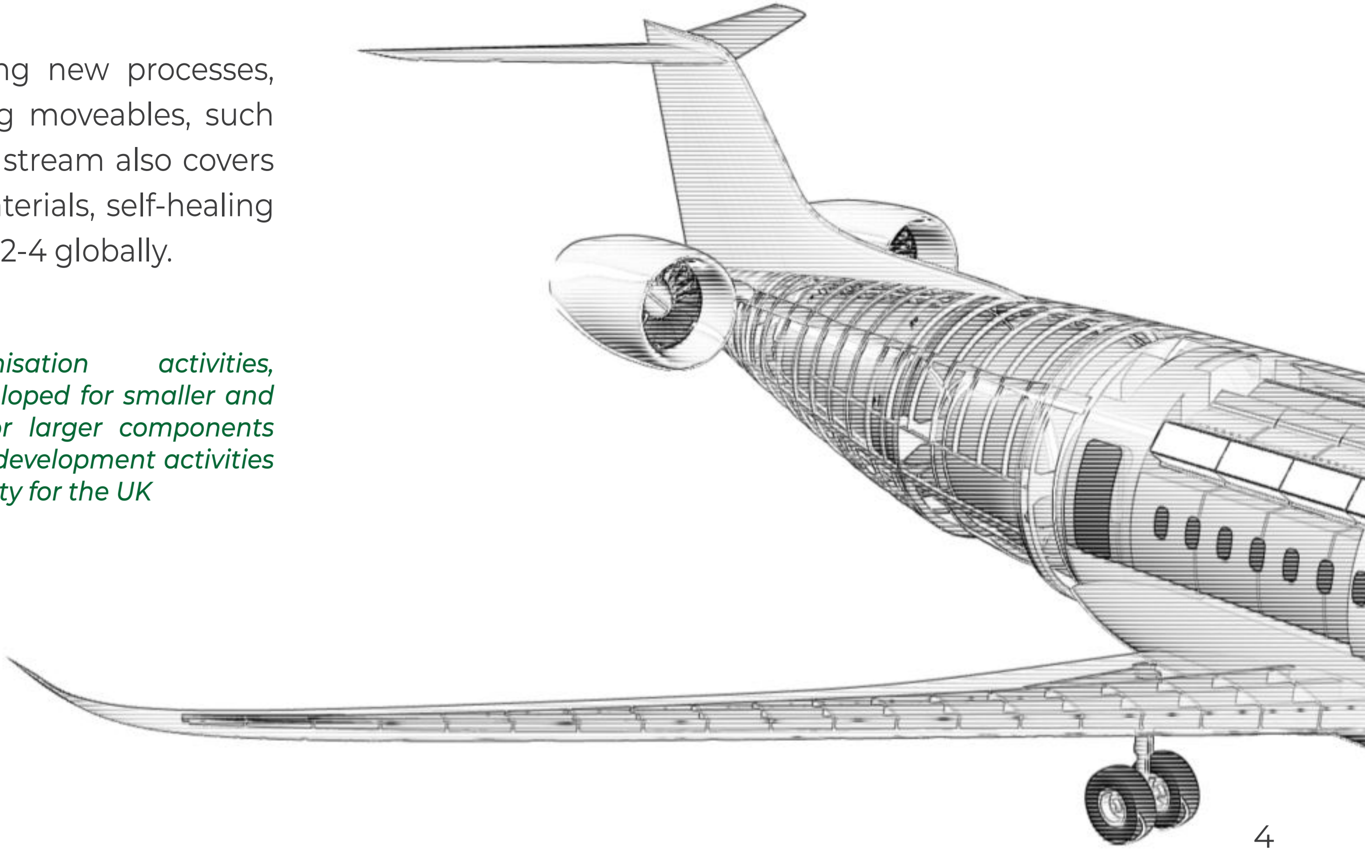
Structural optimisation activities, technology formulation only. Launched initial development of manufacturing technology strands.

Figure 4 – Global TRL levels for structural optimisation activities.

The fourth stream, based around manufacturing optimisation and improvement, including new processes, bonding and joining technologies, out-of-autoclave cure and new processes to create wing moveables, such as spoiler manufacture in a closed mould, is as high as TRL8. This manufacturing-orientated stream also covers the implementation of advanced composites, using programmable or health monitoring materials, self-healing materials for lower maintenance and increasingly sustainable materials. These range from TRL 2-4 globally.

Manufacturing optimisation activities, demonstrations well developed for smaller and subscale components, for larger components the TRL level drops. Rate development activities identified as an opportunity for the UK

Figure 5 – Global TRL levels for manufacturing optimisation activities.



UK CAPABILITY

The UK has world-leading capability in the design and manufacture of wings and sub-structures. Examples of companies operating in this space include Airbus, Spirit AeroSystems & GKN Aerospace. Sub-tier technology providers, who provide materials, manufacturing and assembly technologies, as well as sub-components for manufacturing, are also dispersed across the country. The UK is increasingly capturing not only assembly, which has traditionally been its strength, but also on-shoring of high technology component manufacture. This is a huge opportunity in the case of both a hydrogen dry wing and conventional wings for aircraft powered by kerosene or by sustainable aviation fuels (SAF). Digitalisation and manufacturing automation technologies coming to market are improving to a point that will allow the UK to compete with lower cost countries. In this space, out-of-autoclave composites are a significant area of development that can potentially significantly reduce manufacturing's carbon footprint.

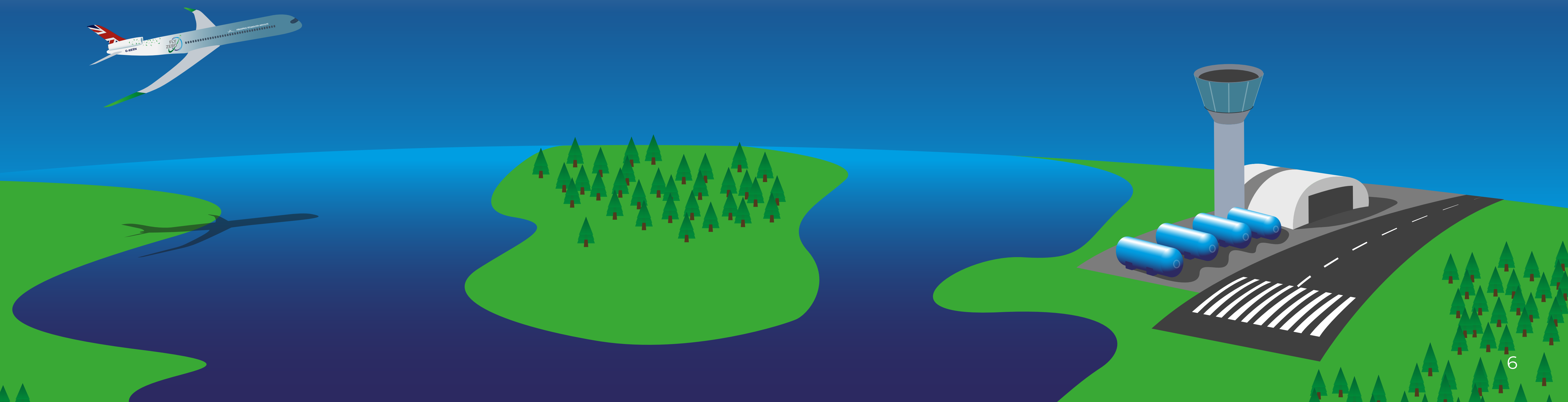
As the use of lightweight composites in structures increases, technologies for recycling also become increasingly important. These are largely at early technology readiness levels (TRL) 2-3 today. In terms of conventional manufacturing, wing manufacture and assembly activities are very mature at TRL 9, and the UK is capable of production at full rate. When considering what a hydrogen aircraft wing may look like, the TRL then drops to between 2-4 with no proven manufacturing rate capability. The High Value Manufacturing Catapult network is active in aerostructures as well as The Welding Institute (TWI). Significant sub-tier developments in this space are still reliant on overseas technology however, such as large-scale composite tooling providers, material development and manufacture.

There are several live projects operating to develop and optimise automated manufacturing. The FlyZero team has engaged with the High Value Manufacturing Catapult network, specifically the NCC and AMRC Cymru, whose work to deploy automated assembly techniques for aerodynamic structures will benefit future aircraft manufacture. Manufacturing of aerodynamic structures forms a significant part of the UK's aerospace footprint.

OVERSEAS LANDSCAPE

Aerodynamic structures capability exists globally, led by countries such as France, Japan, Sweden, Canada and the USA.

In the USA, leading companies include Collins Aerospace, Boeing, Lockheed Martin, Spirit Aerosystems and Triumph Group. SAAB AB, as a large Swedish aircraft manufacturer and Bombardier as a large Canadian manufacturer both have leading aerodynamic structures capabilities. French and German aerodynamic structures capabilities are dominated by Airbus and its supply chain. In Japan, Mitsubishi Aircraft Corporation, Subaru Aerospace and Kawasaki Heavy Industries have the greatest presence in aerodynamic structures.



KEY MESSAGE

The dry wing – a wing without fuel stored within it – is a key differentiator between kerosene powered and liquid hydrogen-powered aircraft. This change presents an opportunity for the UK.

There are several live projects operating to develop and optimise automated manufacturing. The FlyZero team has engaged with the High Value Manufacturing Catapult network, specifically the NCC and AMRC Cymru, whose work to deploy automated assembly techniques for aerodynamic structures will benefit future aircraft manufacture.

Manufacturing of aerodynamic structures forms a significant part of the UK's aerospace footprint. Capability to deliver at rate is a key consideration of airframers when selecting suppliers. Without a funded rate demonstration, the UK is potentially at a disadvantage. French and German organisations are accessing economic development funding to support rate growth; this is a threat to the UK's leading position on wing manufacture.

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**

ACKNOWLEDGEMENTS

Lead authors

Nigel Town
Industrial Supply Chain Architect

Eliot Burrows
Supply Chain Specialist

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.

Department for
Business, Energy
& Industrial Strategy

FlyZero was funded by the Department for Business, Energy and Industrial Strategy.

Front cover & pages 3, 4, & 7 image © ATI, Page 5 image © Airbus

AERODYNAMIC STRUCTURES

UK Capability and Overseas Landscape

FLY ZERO

AEROSPACE TECHNOLOGY INSTITUTE