ZeroAvia's Activities in the Area of Zero Emissions

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EASA
European Union Aviation Safety Agency

Certification Conference

October 24, 2023
Cologne

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AGENDA

01 Background and Solutions

02 H2-Electric Engine: Overview & Roadmap

03 Dornier 228 Flight Test Programme

04 Engine Certification

05 R&D and Future Plans

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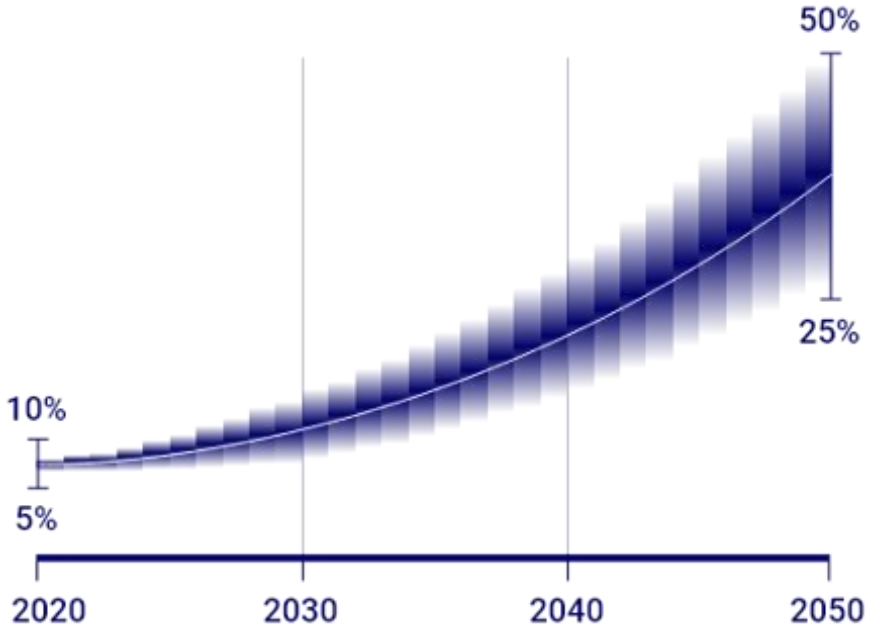
The Need for Zero-Emission Aviation

- Aviation is the fastest-growing source of greenhouse gas (GHG) emissions
- It is expected to account for **25-50% of total human climate impact** by 2050
- Global push by regulators and industry for green aviation and **net-zero carbon emissions** by 2050
- Non-carbon emissions (NOx, contrails, soot, etc…) also have warming effects and account for around two-thirds of climate impact
- A **scalable solution** is needed to reduce carbon and non-carbon emissions



H_2-Electric is the Only Scalable Zero Emission Solution

	Reduction in climate impact: Direct CO_2	Reduction in climate impact: Non-CO_2	Technology scalability	Net impact	Key challenges
H_2-Electric					• Weight of the powertrain • High volume fuel tanks required
H_2 Combustion					• High non-CO2 climate impact • Even higher volume fuel tanks required (efficiency)
Sustainable Aviation Fuels (SAF)					• Feedstock sustainability • High cost of synthetic fuels • Same in-flight emissions
Hybrid-Electric					• Small incremental impact (10-20% max) on both economics and climate

- Source: Market research; analyst reports.

OUR MISSION

A Hydrogen Electric Engine in Every Aircraft

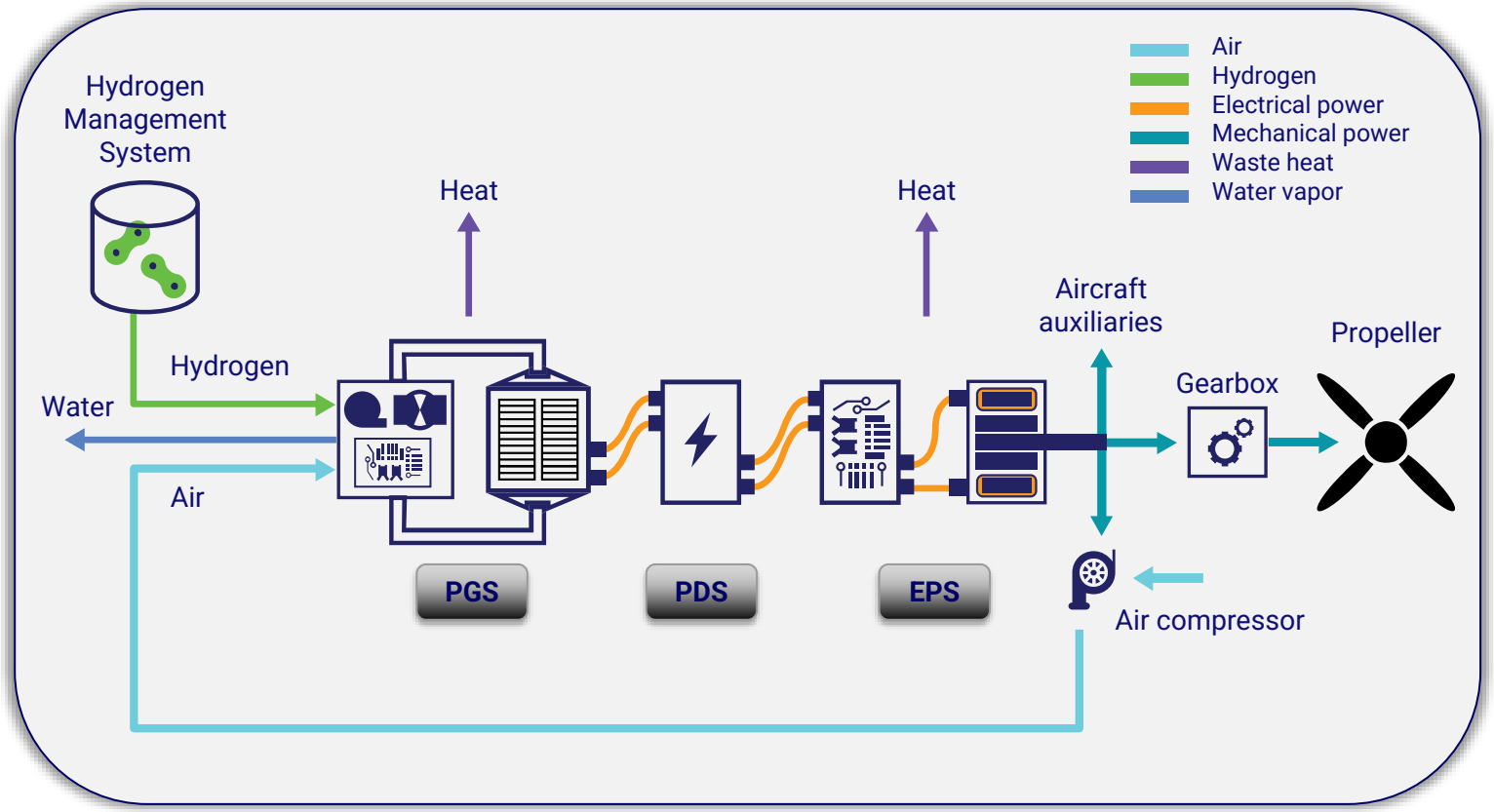
ZeroAvia is Developing a Full Engine Offering

PGS = Power Generation System
PDS = Power Distribution System
EPS = Electric Propulsion System

- **Key Aspects**

- Electric Propulsion System (EPS) with electric motors & inverters
- Power Generation System (PGS) with a fuel cell (FC) system
- FC converts hydrogen and oxygen to electricity
- Hydrogen Management System (HMS) with H2 tank and manifolds
- Air supply to the FC provided by a compressor
- Only emission is water vapour

System Overview



All Segments - Starting With 9-19 Seat Regional Aircraft

✓ Done

6 Seat

250kW R&D Prototype

✓ In Testing

19 Seat 600kW

First commercial offering

250+NM range,

EIS 2025

✓ In Development

40-80 Seat 2-5.4MW

Scalable system covering regional A/C

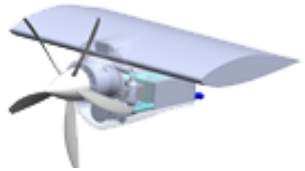
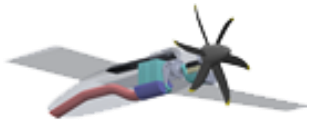
First commercial offering 500+NM range

EIS 2027

✓ Technology pathway

- **to power even larger aircraft**

Product Roadmap

	2025	2027	2029	2032+
				
	ZA600	**ZA2000**	**ZA2000RJ**	**ZA10000**
Shaft Power	500-750 kW	2-4 MW	5+ MW	10+ MW
PAX	10 - 20 seats	30 - 90 seats	30 - 90 seats	100 - 200 seats
Range	up to 500nm	up to 1,000nm	up to 1,000nm	up to 3,000nm
H_2 Storage	Gas	Liquid	Liquid	Liquid
Fuel Cell Technology	LTPEM	HTPEM	HTPEM	HTPEM
Current # of Engines in Circulation	78k	12k	8k + 46k[1]	34k
Retrofit/Linefit	Retrofit & linefit	Retrofit & linefit	Retrofit & linefit	Retrofit & linefit
Airframes (Illustrative Selection)	 D228  Cessna Caravan  Twin Otter  Otto 500L+	 Dash 8-400  ATR 72  EMB NGTP	 CRJ700  E170	 A320  Boeing 737  A220

1. There are 23k business jets globally, equating to a further 46k engines which are not ZeroAvia's immediate target market but will be addressable in the longer term.
Source: FEV; Urban Air Mobility news; Cirium

Dornier-228 Flight Test Programme

10 Test Flights

- Dornier-228 with H2-electric LH engine
- Test flights under UK CAA permit to fly
- Airfield circuits at Kemble Airport
- First flight: Jan 19, 2023
- Last flight: Jul 13, 2023
- Increasing airspeed (up to 150 KIAS)
- Increasing altitude (up to 5000 ft)
- Thrust Asymmetry
- Different Power Settings
- Endurance Testing
- Go-Around

Objectives Achieved

- ✓ Safe flight envelope established (Vmo 150 KIAS, max 5000 ft)
- ✓ Systems operated within established limitations
- ✓ Satisfactory handling and controllability
- ✓ Safety and viability of H2-electric engine demonstrated
- ✓ No in-flight shutdowns or terminated tests

Certification Journey

DOA Approval

Acquire Design Organisation Approval

Airframe STC

Receive a Supplemental Type Certificate for the modification of the launch airframe with the ZA600 Powertrain

Powertrain TC

Receive a Type Certificate for the ZA600 Hydrogen Electric Powertrain

Entry into Service

Certification Plan for Hydrogen-Electric Engine

Certification Plan

- STC for integration, TC for EPS and PGS
- Special Conditions exist for the EPS, with products already certified and operational in the market
- Requirements for fuel cell power and hydrogen management system under development with regulators and industry working groups
- HMS will initially form part of the aircraft STC with future possibility for TSO Approval of some HMS components

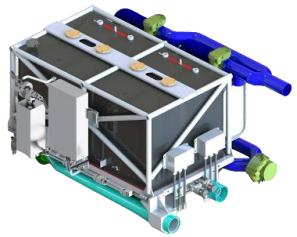
Certified Platform

PGS/PDS
Power Generation & Distribution System
- FC Stack, Balance of Plant
- Special conditions required
- Certified with the load

EPS TC
Electrical Propulsion System
- Motor + Inverter
- Special conditions exist
- Certified under Special Condition to CS-E/Part 33

+

Aircraft STC
Aircraft Supplemental Type Certificate
- Consistent with other major modifications
- Includes fuel system (HMS)



Hydrogen Management System

R&D and Plans

Technology Breakthroughs and Plans…

- ✓ **H_2-Electric aircraft** technology demonstrated
- ✓ Completed **powerplant design** for 600kW engine
- ✓ Developed world's largest fuel cell compressor, supporting FC systems up to 900kW
- ✓ **HTPEM fuel cell technology** with record power density of 2.5kW/kg, 3+kW/kg in development
- ✓ ~2MW **electrical motor in testing**
- ✓ Created EPS test facility for **~2MW+ powertrain**

Abbreviations List

- **BOP:** Balance of Plant
- **CO2:** Carbon Dioxide
- **CS**: Certification Specifications
- **DOA**: Design Organisation Approval
- **EPS**: Electric Propulsion System
- **FC**: Fuel Cell
- **GHG**: Greenhouse Gas
- **H2**: Hydrogen
- **HMS**: Hydrogen Management System
- **HTPEM**: High Temperature Proton Exchange Membrane
- **LH**: Left-hand
- **LTPEM**: Low Temperature Proton Exchange Membrane
- **NOx**: Nitrogen Oxide
- **OEM**: Original Equipment Manufacturer
- **PAX**: Passengers
- **PDS**: Power Distribution System
- **PGS**: Power Generation System
- **STC**: Supplemental Type Certificate
- **TC**: Type Certificate
- **TSO**: Technical Standard Order
- **VMO**: Maximum Operating Speed
- **VTOL**: Vertical Take-off and Landing

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Thank you!

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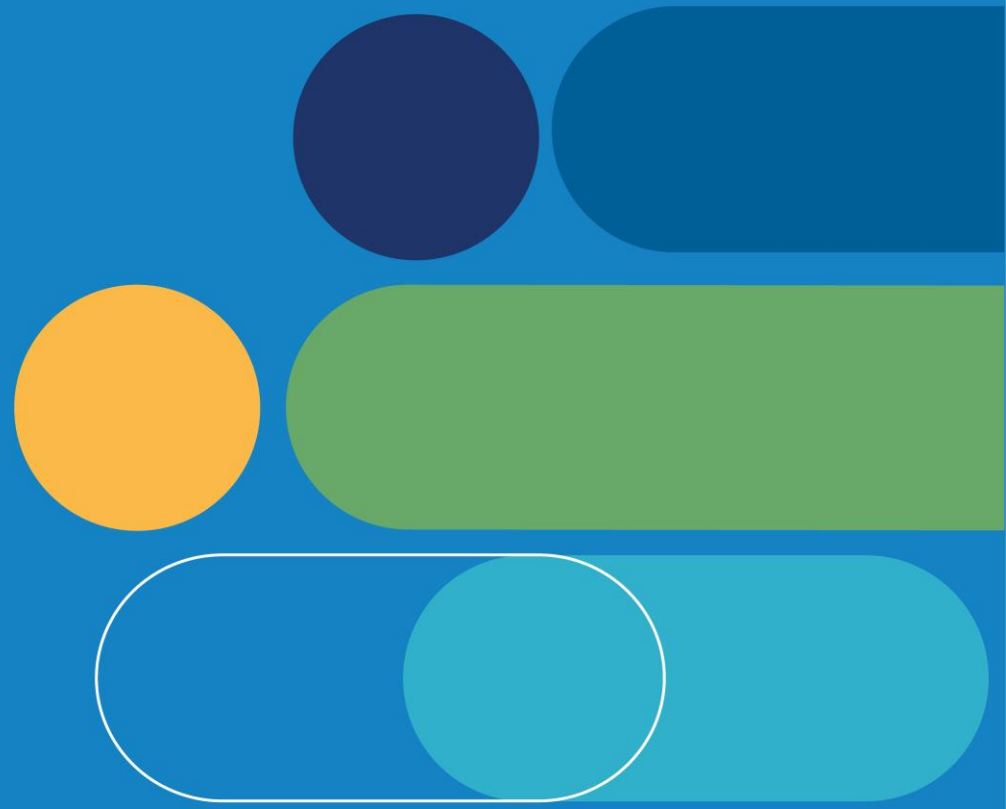

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