Airbus ZEROe

Towards the 1st hydrogen-powered commercial aircraft

Cryogenic Engineering Conference

Amanda Simpson, VP Research and Technology, Airbus Americas

AIRBUS

Our **purpose**

We pioneer sustainable aerospace for a safe and united world.

AIRBUS

Airbus ambition

Pioneering Sustainable Aerospace for a Safe and United World

2030
Offer 100% SAF capability on our commercial aircraft

2035
Be the 1st major manufacturer to offer a decarbonized commercial aircraft

2050
Reach aviation* net-zero emission target

*A historical milestone was reached on 7 October 2022 at the 41st ICAO (International Civil Aviation Organization) Assembly: Net Zero Carbon emissions goal in 2050

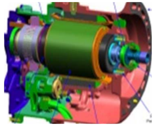
AIRBUS

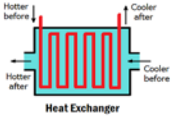
Hydrogen aircraft concept - route to EIS 2035

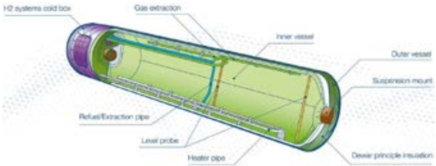
Three main steps at Airbus level, in the route to decarbonisation

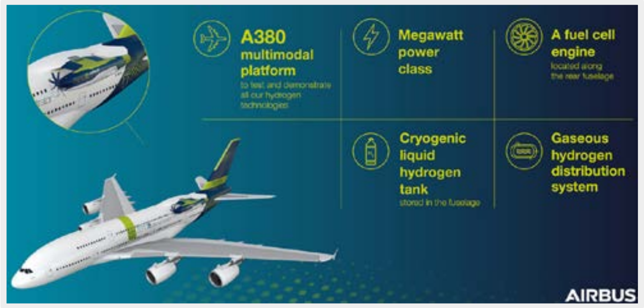
- Sustainable Aviation Fuel
- Next generation aircraft: engine, aircraft, operations
- Disruptive new aircraft: **ZEROe aircraft**

Structured approach involving **technos**, integrated **test benches**, and **flying demonstrators**, to get to **ZEROe final solution**









Airbus state-of-the-art practices, complemented by dedicated activities for defining and maturing the new technos and architectures

Hydrogen technologies overview

Major de-risking required

- Aircraft concepts & configuration
- Safety / Certification
- H2 storage & Distribution
- H2 integrated propulsion system & controls
- Aircraft operations (maintainability, refueling)
- Contrails
- Industrialization

Hydrogen Powered Gas Turbines
(Gas turbines with modified combustion chamber, fuel injectors and fuel system)

Liquid Hydrogen Storage
(in non-pressurised zone behind rear pressure bulkhead)

Power Electronics & Electric Motors
(powered by the fuel cells and injecting energy onto the turbofan shaft)

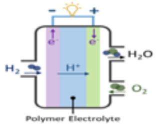
Fuel Cell Systems
(megawatt scale, supplementing the gas turbines with electrical power at very high levels of efficiency)

Different type of propulsion systems under study

H_2 Direct Burn

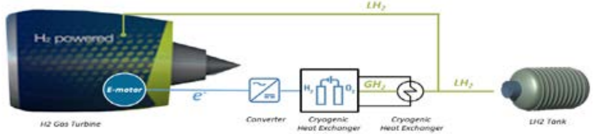
- Same principle as kerosene gas turbine
- Feasibility demonstrated since the 50's (B57)
- New components:
  Combustion chamber, Injectors, Cryo heat exchangers, H_2 pumps...

H_2 Fuel Cells



- Produce electricity to power electric motors
- Water is the only by-product
- High efficiency: 55% to 60%
- Main challenges: Weight, Cooling

H_2 Hybrid architecture



- Combine H_2 Gas Turbine and H_2 Fuel Cells
- Several strategies: Boost in take-off/Climb, Assistance in transient phases.
- Enabler to increase Gas Turbine efficiency
- No power offtakes on gas turbines

AIRBUS

Introducing Airbus ZEROe

Turboprop

<100
Passengers
Passagers

1,000+nm
Range
Rayon d'action

Hydrogen
Hybrid Turboprop
Engines (x 2)

Hydrogène
Turbopropulseur hybride
Moteurs (x2)

Liquid Hydrogen
Storage & Distribution
System

Hydrogène liquide
Stockage et distribution
Système

Blended-Wing Body

Turbofan

<200
Passengers
Passagers

2,000+nm
Range
Rayon d'action

Hydrogen
Hybrid Turbofan
Engines (x 2)

Hydrogène
Turbopropulseur hybride
Moteurs (x2)

Liquid Hydrogen
Storage & Distribution
System

Hydrogène liquide
Stockage et distribution
Système

AIRBUS

Airbus’ ambition is to bring the ZEROe clean commercial aircraft to market by 2035

2018
Project Start

2020
Aircraft Concepts Unveiling

Aircraft Configuration
Technology Maturation
Flight Demonstration
Ecosystem Establishment

2027
Product Selection

Product Development

2035
Entry Into Service (EIS)

ZEROe Hydrogen combustion demonstrator

A380
multimodal test platform
with its capacity to store large hydrogen tanks

Hydrogen combustion engine
located along the rear fuselage

4 liquid hydrogen tanks
stored in a caudal position

Liquid hydrogen distribution system

AIRBUS

Airbus UpNext Blue Condor

Arcus-J Gliders

- One with Jet-A powered engine
- One with H2 powered engine

Chase aircraft to measure emissions for analysis and comparison

AIRBUS

ZEROe Fuel Cell demonstrator

A380 multimodal platform

to test and demonstrate all our hydrogen technologies

Megawatt power class

A fuel cell engine

located along the rear fuselage

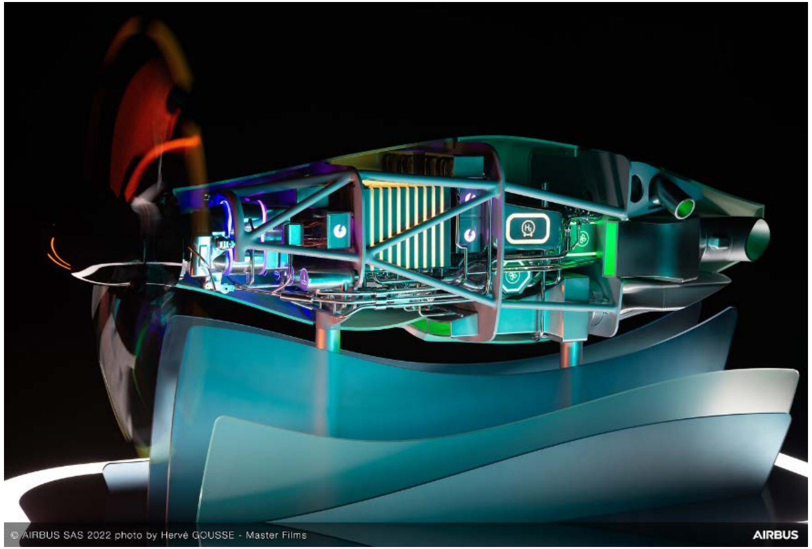
Cryogenic liquid hydrogen tank

stored in the fuselage

Gaseous hydrogen distribution system

AIRBUS

Fuel Cell powertrain demonstrated at 1.2MW



ZEROe Pod Configuration

Stand-alone propeller propulsion system powered by hydrogen fuel

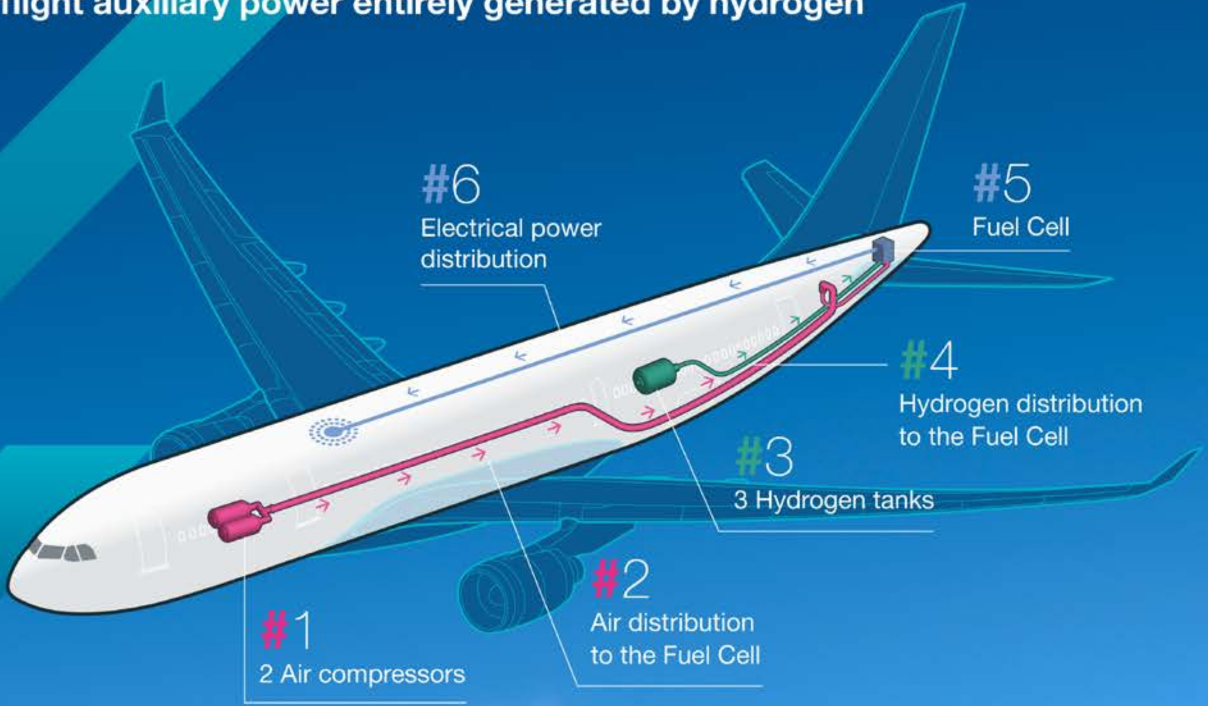
- 8 bladed propeller
- Electric motors
- Fuel cells
- Power electronics
- LH2 tank
- Cooling system
- Set of auxiliary equipment

AIRBUS

UPNEXT

HyPower

to experiment in flight auxiliary power entirely generated by hydrogen



A330 to go up to 33.000 ft

Fly the aircraft for 1h and take up to 10kg of gaseous hydrogen

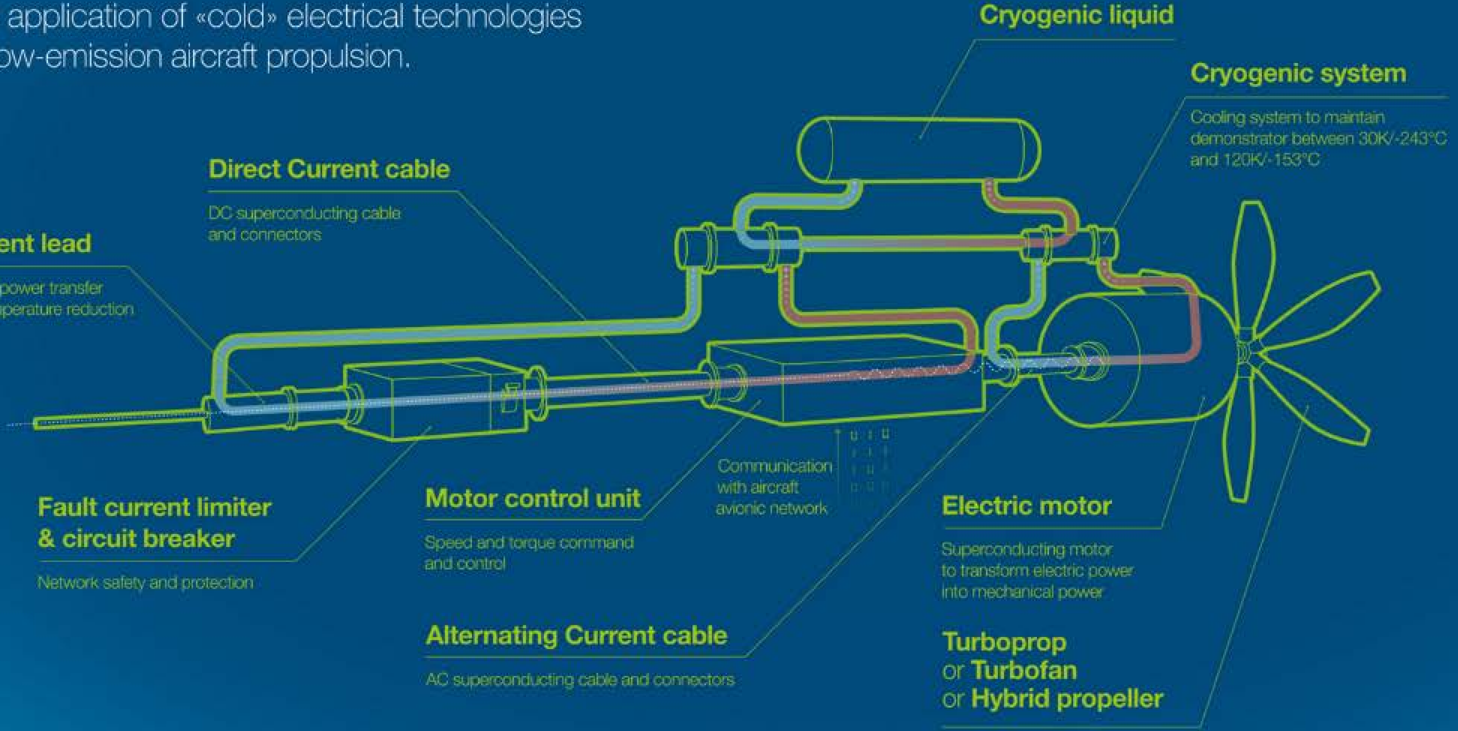
Reducing CO_2, NOX and noise emissions

A new **technological demonstrator**

ASCEND

Advanced **S**uperconducting & **C**ryogenic **E**xperimental powertrai**N** **D**emonstrator

A ground demonstrator to explore the feasibility and application of «cold» electrical technologies for low-emission aircraft propulsion.



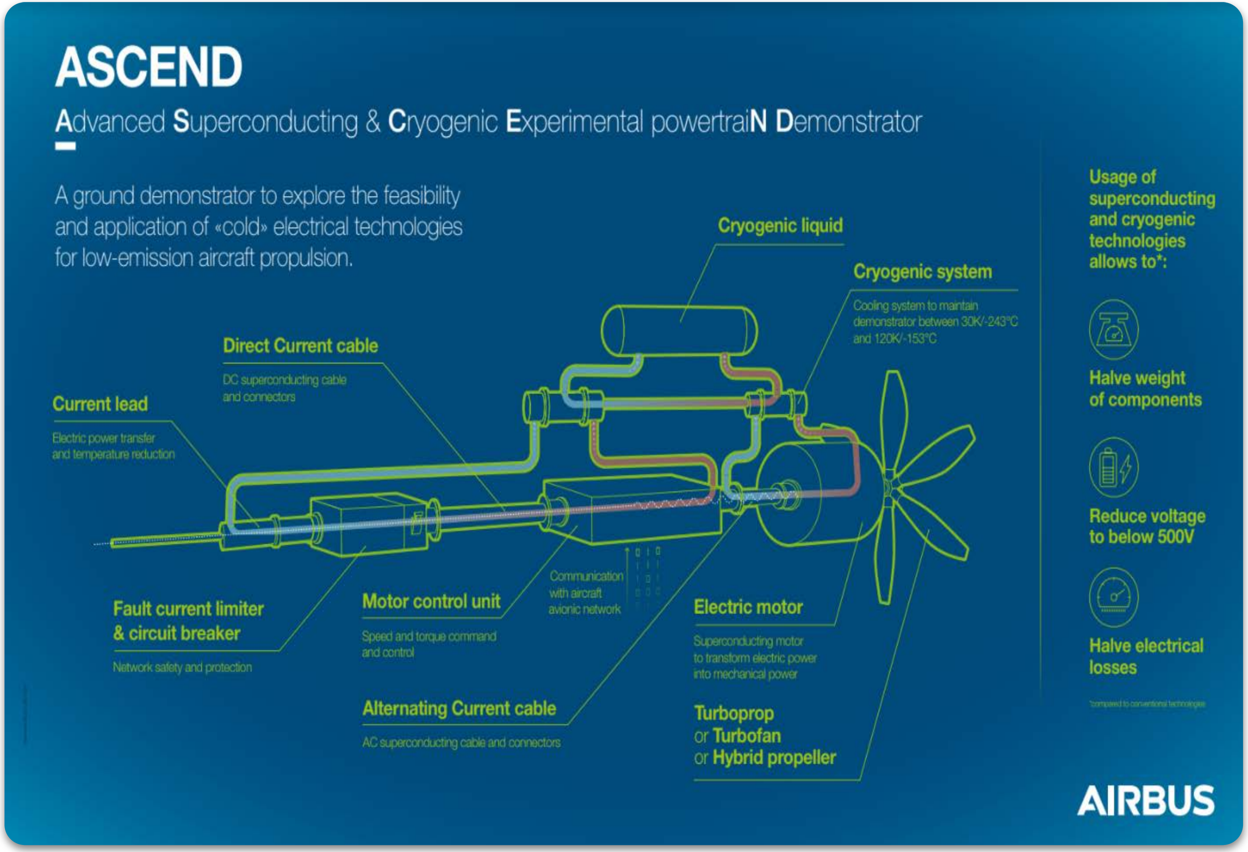
Usage of superconducting and cryogenic technologies allows to*:

- **Halve weight of components**
- **Reduce voltage to below 500V**
- **Halve electrical losses**

*compared to conventional technologies

AIRBUS

ASCEND: A first step toward cryogenic propulsion



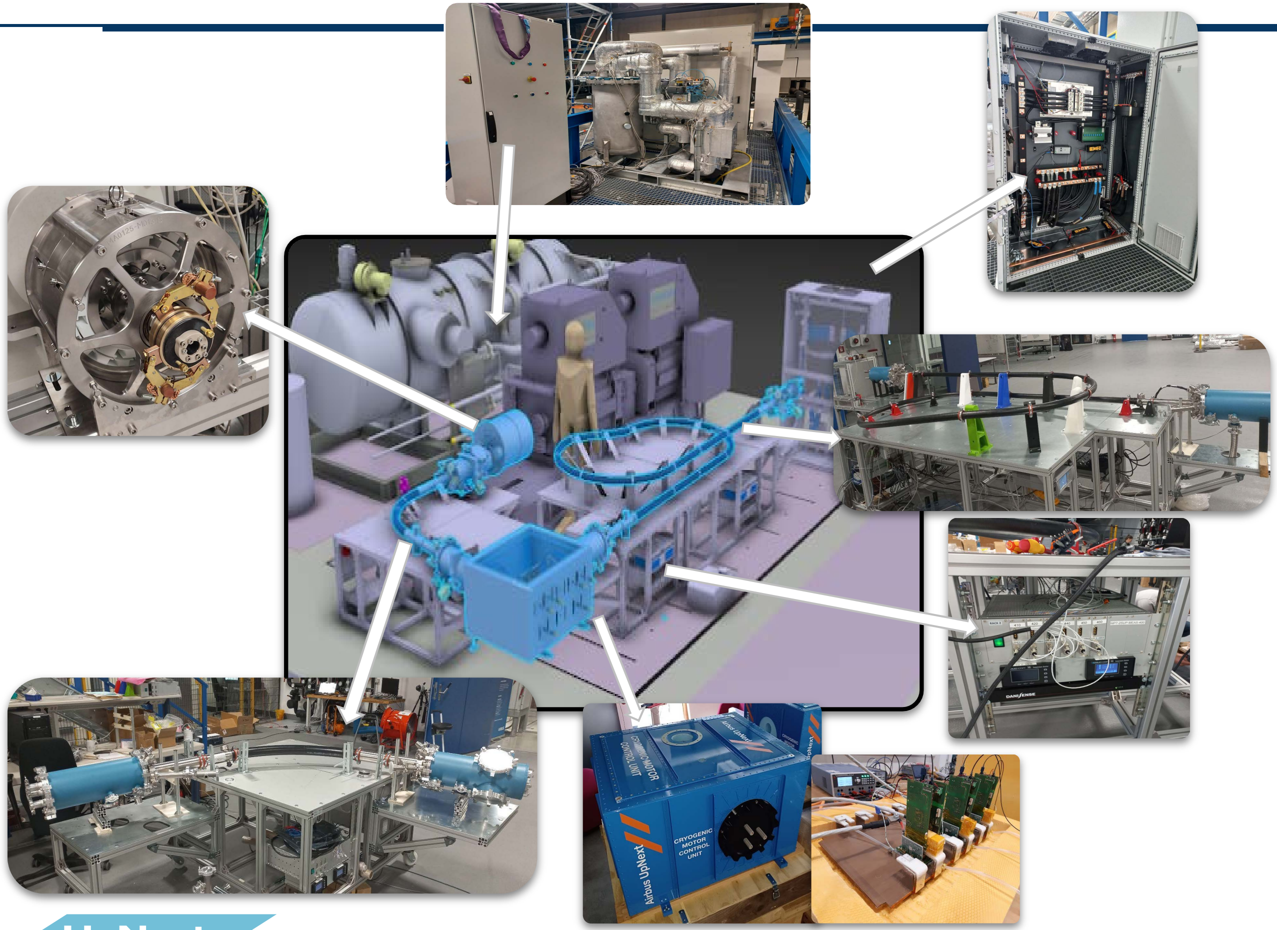
Launched in 2021

500kW powertrain with key technos bricks

- Superconducting cables
- Cryogenic power electronics
- Superconducting motors
- cryo-cooling system

Testing in EAS facility 2022 & 2023

ASCEND Demonstrator



⇨ **No showstopper for ground demonstrator**

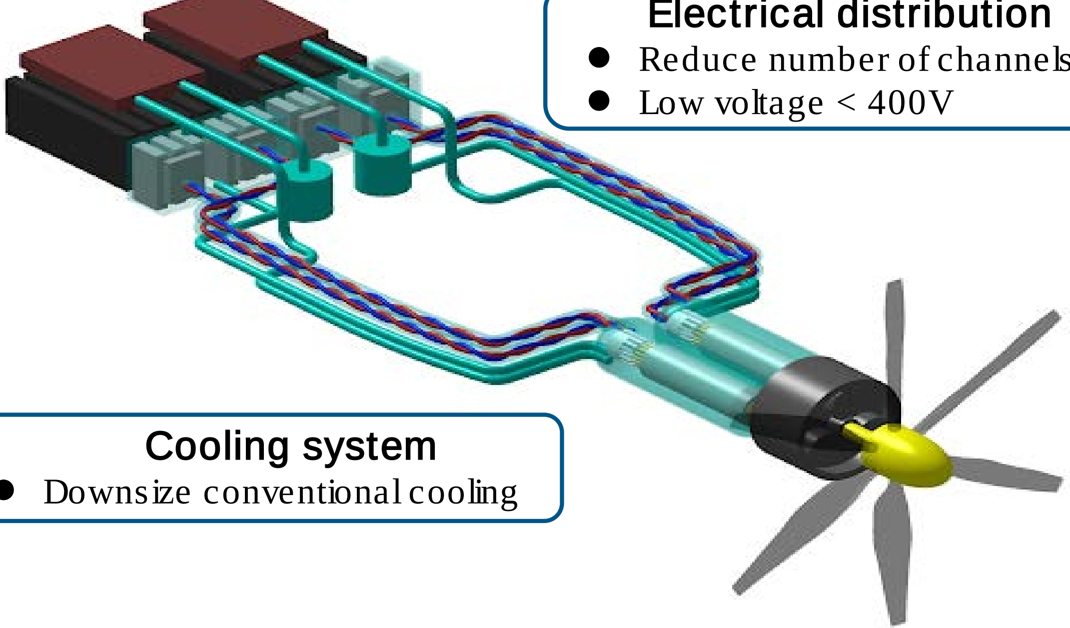
⇨ **Promising performances with available technologies**

- Efficiency +4-5%
- higher specific power
- New degree of freedom
  - current density, torque

⇨ **Challenges**

- Weight of cryogenics
- Reliability
- Operation

ASCEND Architecture



Power generation
- Downsize Fuel Cell max power

Electrical distribution
- Reduce number of channels
- Low voltage < 400V

Cooling system
- Downsize conventional cooling

Gear Box
- Lower speed

Higher efficiency

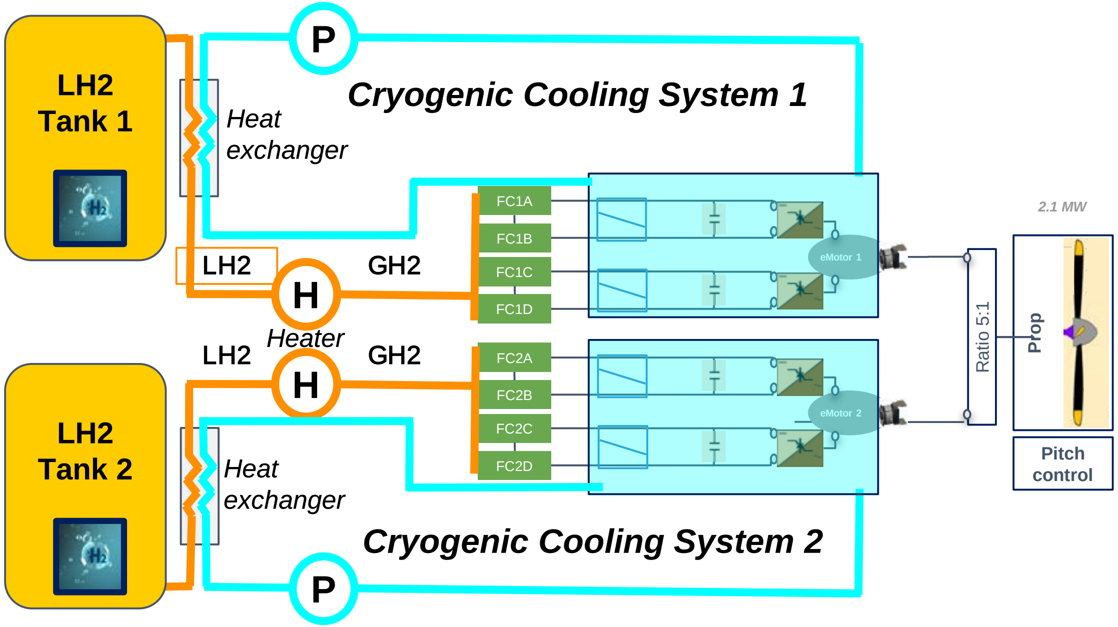
+

New degrees of freedom

(High torque motor & High current)

- Downsize components
- Simplify architecture
- Reduce LH2 consumption

ASCEND Architecture



→ **2 cryogenic cooling loops for redundancy**

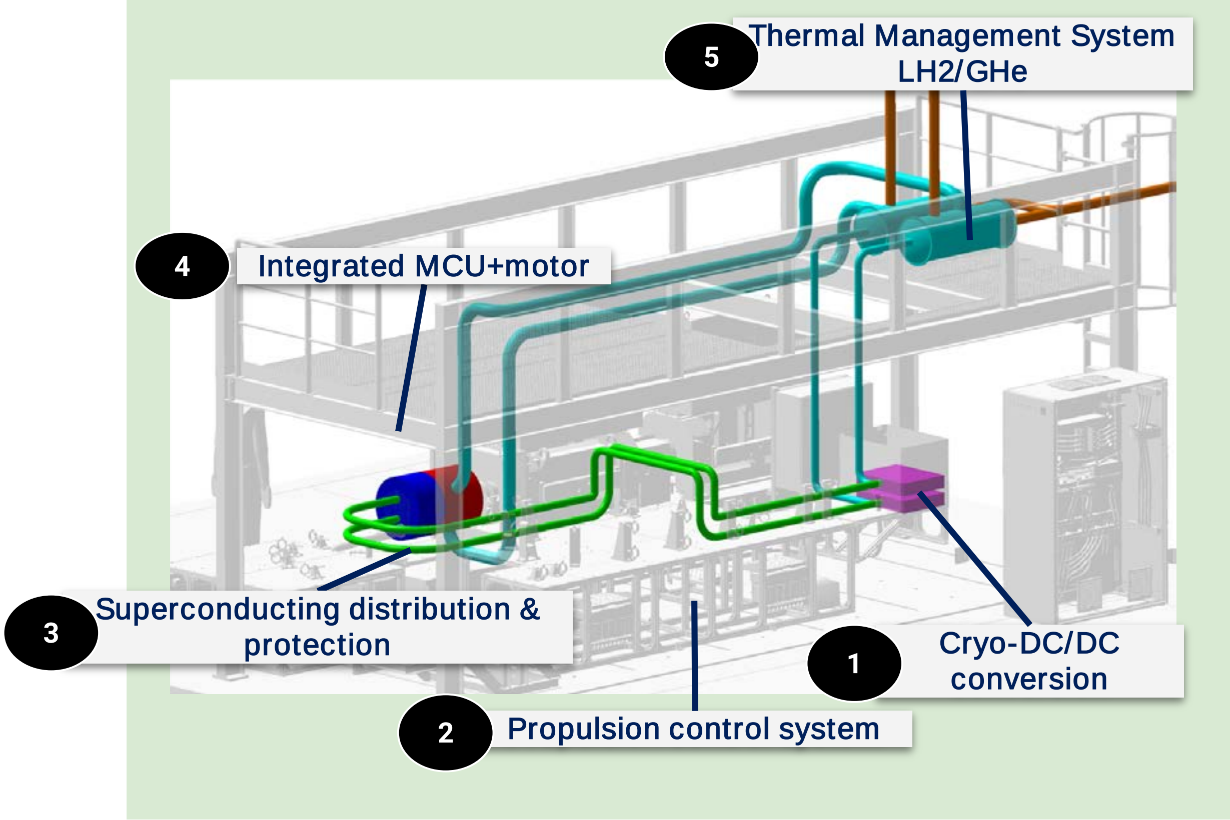
→ **Gaseous Helium coolant**

- Good thermal characteristic
- Neutral gas (safety)
- Lightweight

→ **Chosen temperature to minimize LH2 flow rate needed**

- eMotor : 30 to 40 K
- DC cables : < 70 K
- MCU DC/DC : 80 to 150 K

Next Phase in 2024 with a new demonstrator



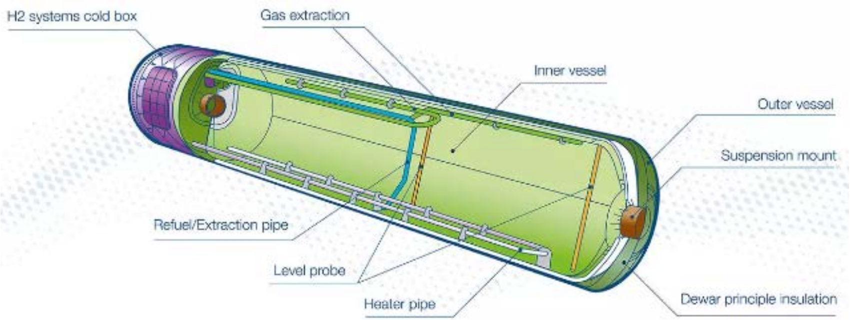
1MW powertrain with a modular approach

- LH2/GHe cooling system
- Integration
- Maturity: Component TRL3/4

Need to develop ecosystem
to mature & accelerate technologies for the next hydrogen aircraft

LH2 Storage challenges

- Maintain 20K during operations & endure 20000 take-offs & landing
  - Design and manufacture from structure to control system
  - H2 distribution from caudal storage to Pod consumption
- Produce for 20+ tanks per month (Build Rate ~10 aircraft / month)
  - Define and mature Industrial system
- Shape new ecosystem for Structural parts, Insulation, cryogenic equipment, Pipes distribution, Feedthrough...

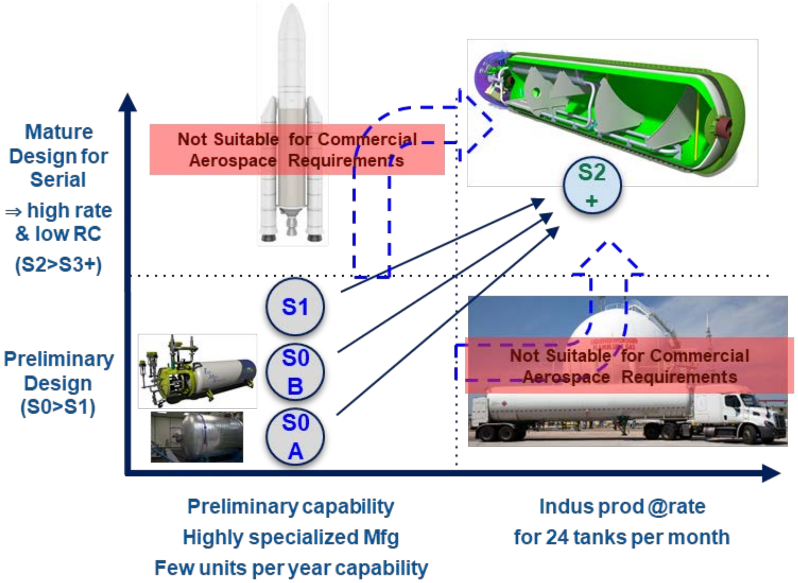


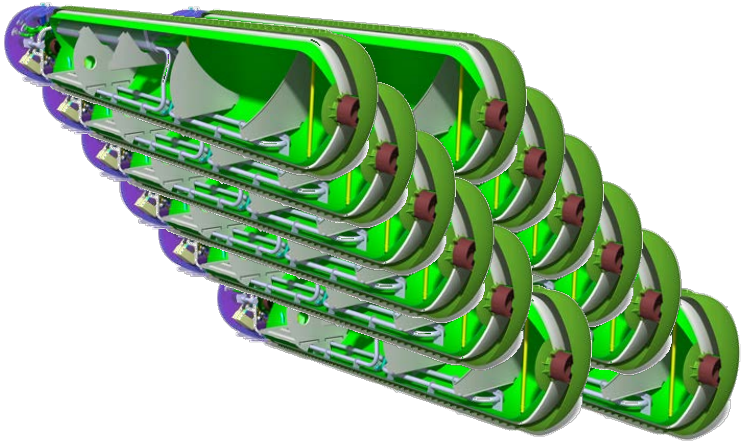
Performance

- Storage volume of ~35 m3 of LH2 separated in 2 tanks ⇒ **~17 m3 tank, with Diameter < 2 m**
- Dormancy time of min 12 hours ⇒ **double walled tanks with insulation and vacuum**
- Contained weight for gravimetric index ~40% ⇒ **Aluminium 2219 tanks**
- Capsule ⇒ **High density of system** (Valves, fueling, venting, pump, …)

ZEROe A/C is disruptive triggering technical and industrial challenges

LH2 Aviation Tank Industrialization





S0: first demonstrators => Exploration

S1: first FLIGHT demonstrators

S2: first INDUSTRIAL demonstrators

S3: first SERIAL configuration

R&T phase — Development phase

2023 | 2024 | … | 2028

Airbus is exploring options to progressively move to the upper right of the graph

ZEROe Liquid hydrogen production at large airport

Air Liquide · GROUPE ADP · AIRBUS

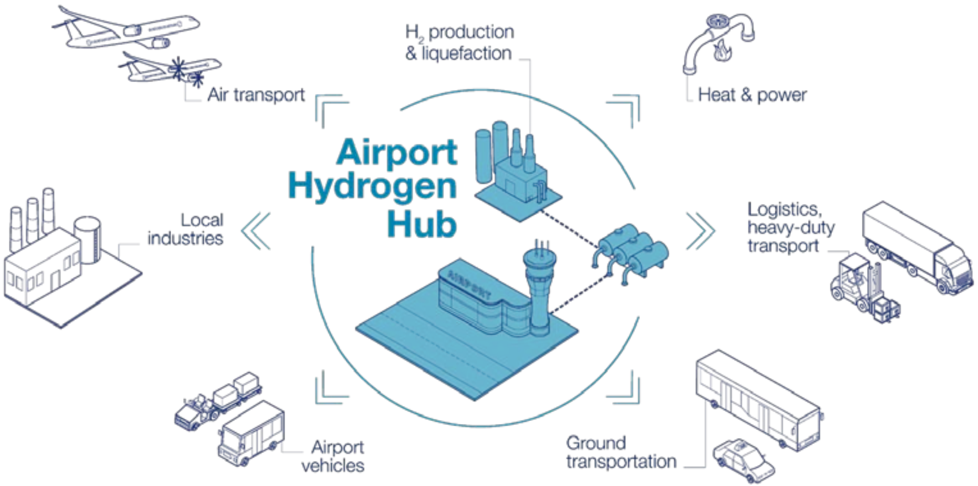
Hydrogen Hubs at airports

Hydrogen Hubs at airports will:

Prepare regulations and standards for the handling of H_2 at airports

Ensure that a large number of airports worldwide are supplied with liquid H_2 by 2035

Foster efficiency improvements and cost reductions in hydrogen liquefaction, storage and distribution



AIRBUS

The Ecosystem Multi Parties Strategic Partnerships

Airlines

Airport Ecosystem

Regulatory Bodies

Energy Providers and Non-Aviation

As of 01/06/2023

AIRBUS

Our path to ZEROe

Exploring various technology pathways & aircraft configurations

Targeting all aspects: climate impact, aircraft design, safety, maintenance, industrialisation, operations, market, infrastructure, ecosystem, etc.

Collaborating with all stakeholders to drive down costs & grow the ecosystem

Together we are sustainable

AIRBUS

Thank you

AIRBUS