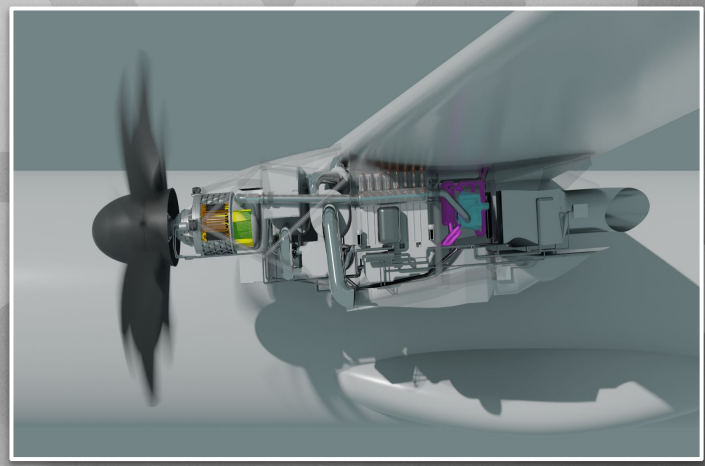
UpNext

Superconductivity & Cryogenics for future electric aircraft propulsion

Dr Ravi Kiran Surapaneni
Technical Lead - CryoProp
Airbus UpNext



ECCE- Europe 2024

04 Sep 2024

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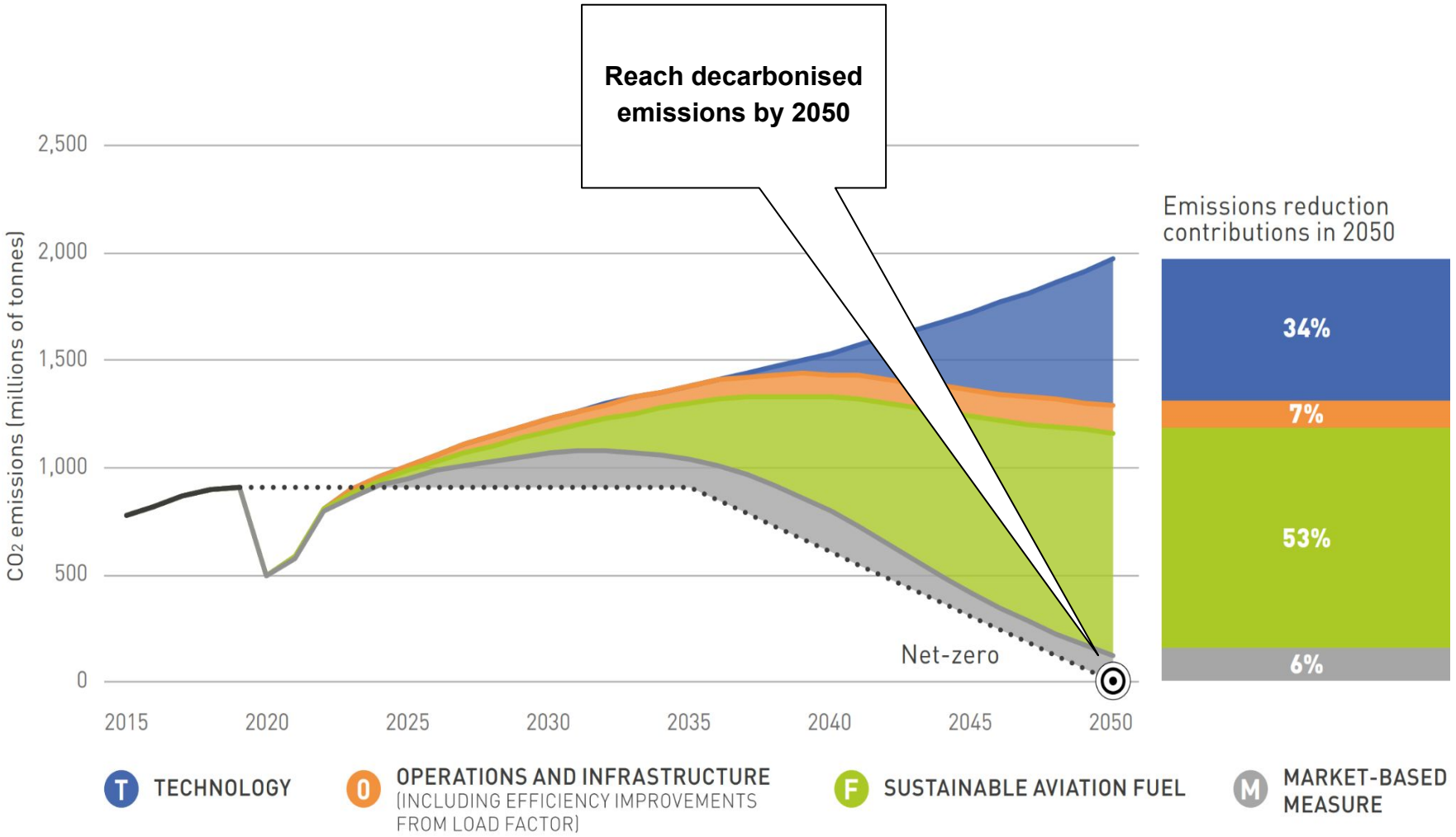
Aviation's next big challenge



Source: ATAG Waypoint 2050 | Scenario 3: aspirational & aggressive technology perspective

Decarbonisation in 2050

Multiple solutions are required

Airbus is leading the journey towards cleaner aerospace

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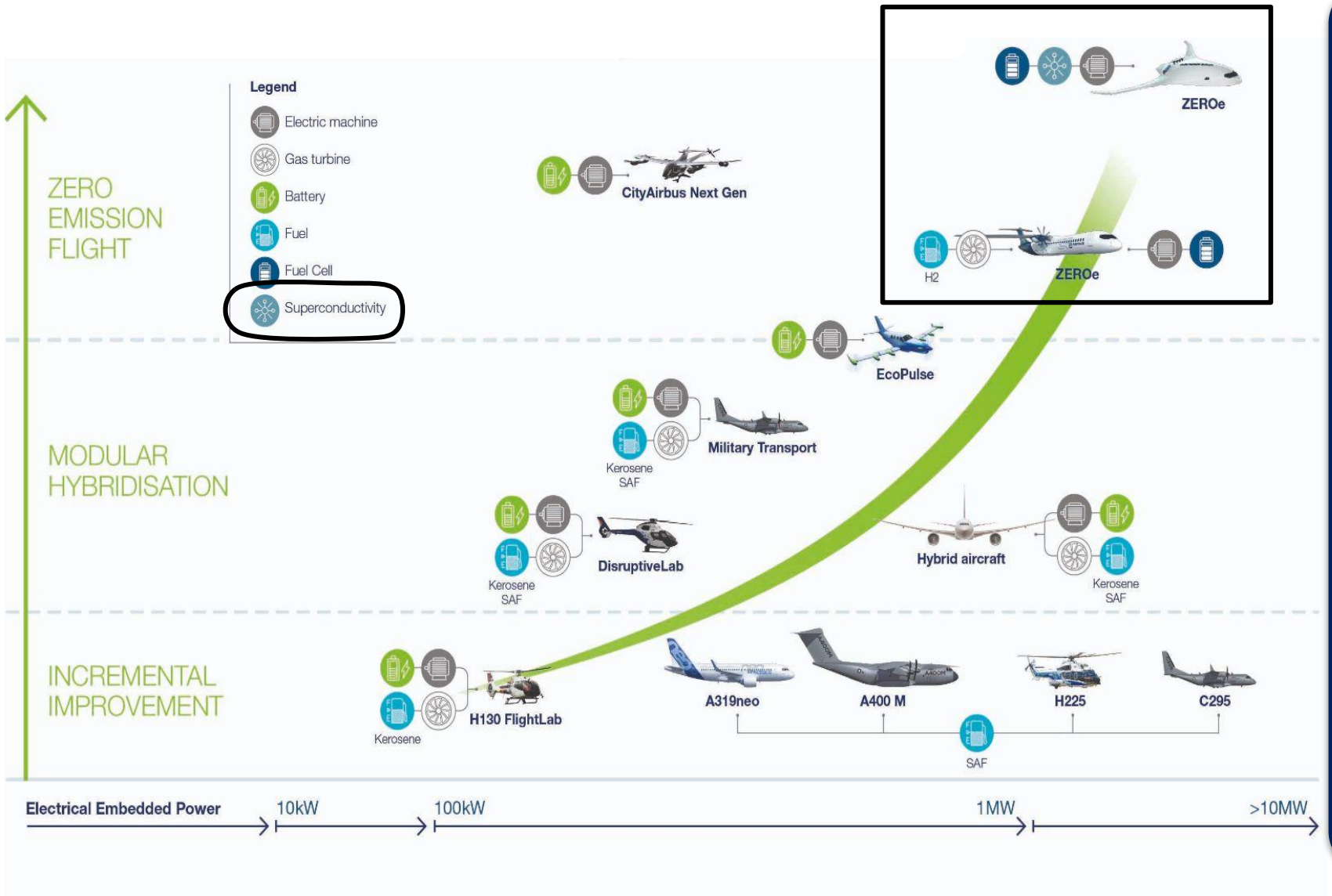
Pathways to decarbonise the AVIATION sector



Liquid Hydrogen Cryogenic Temperatures as a **breakthrough** for future electric propulsion system

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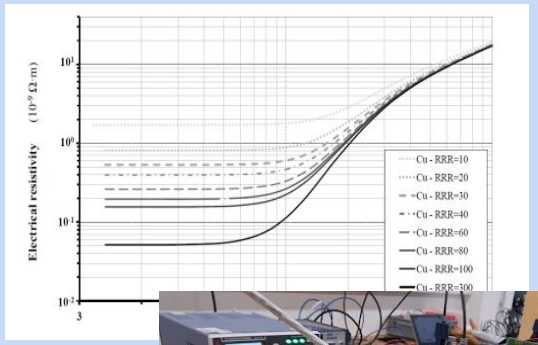
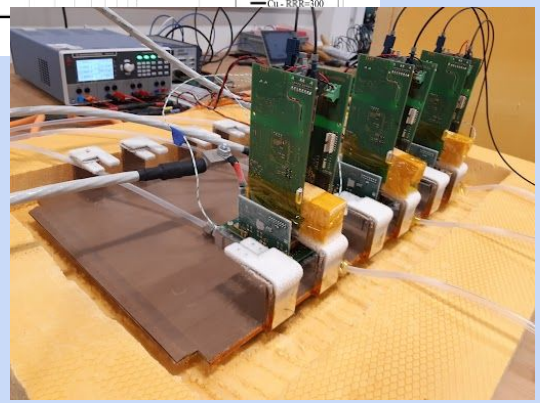
Cryogenic power train: 2 main technologies

Cryogenic e-techno

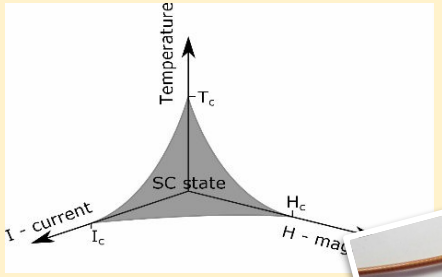
Conventional technologies at low temperatures

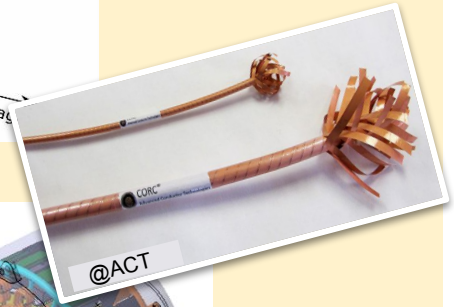


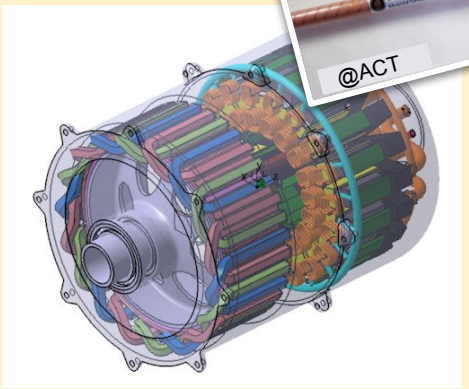


Superconductivity

Specific materials below 3 parameters







Cryogenic technos

- Losses of conductors divided by 10
- Losses of semiconductors divided by 3 to 5

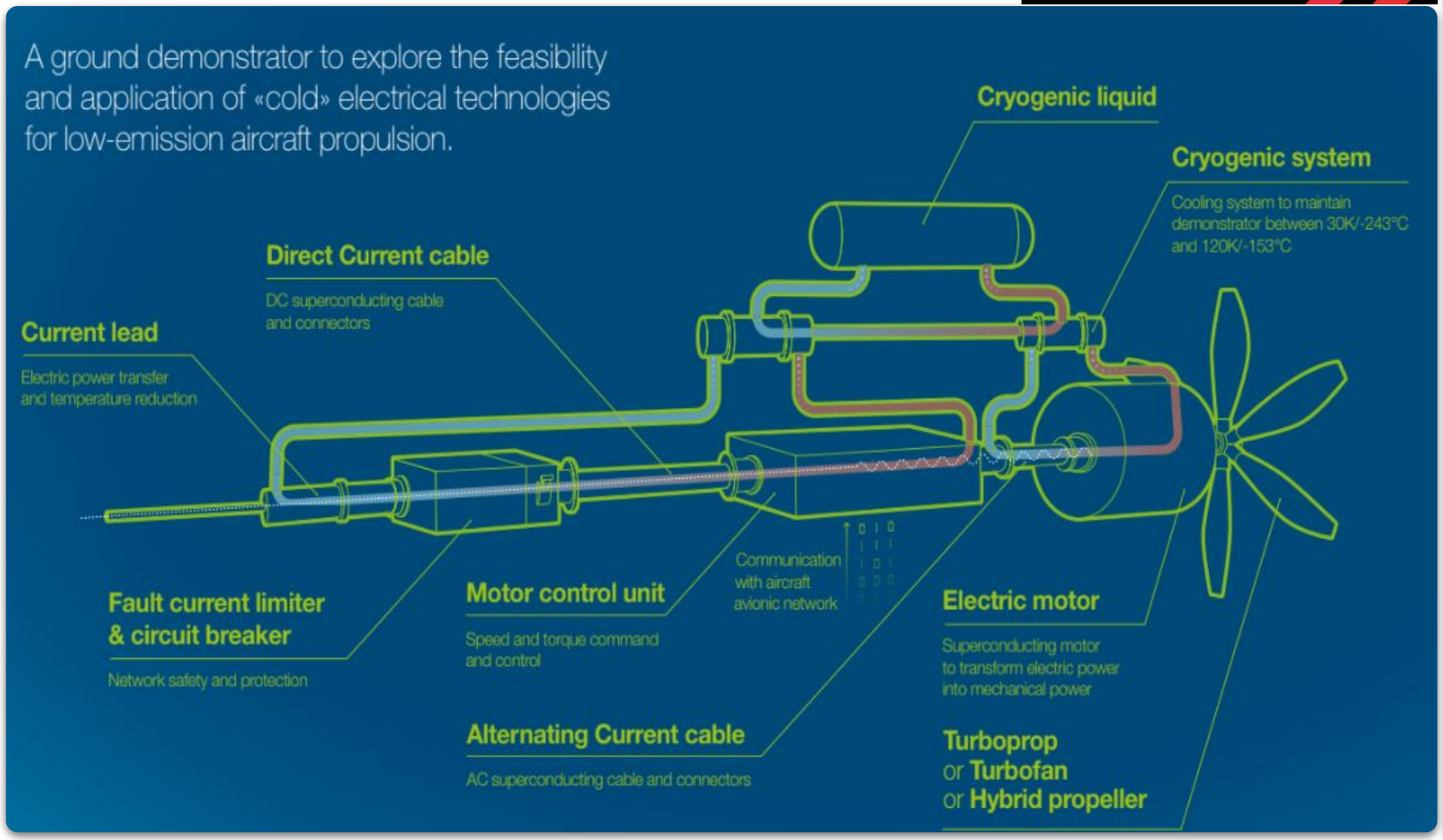
Superconductivity

- no DC losses
- >100x more current density than copper

*compare to conventional technologies

From theory to reality (1/2)

ASCEND Demonstrator learnings



(*) ASCEND Advanced Superconducting and Cryogenic Experimental powertraiN Demonstrator

ASCEND project

Launched in 2021

500kW powertrain with key technos bricks

- Superconducting cables
- Cryogenic power electronics
- Superconducting motors

Successfully tested in EAS facility end of 2023.

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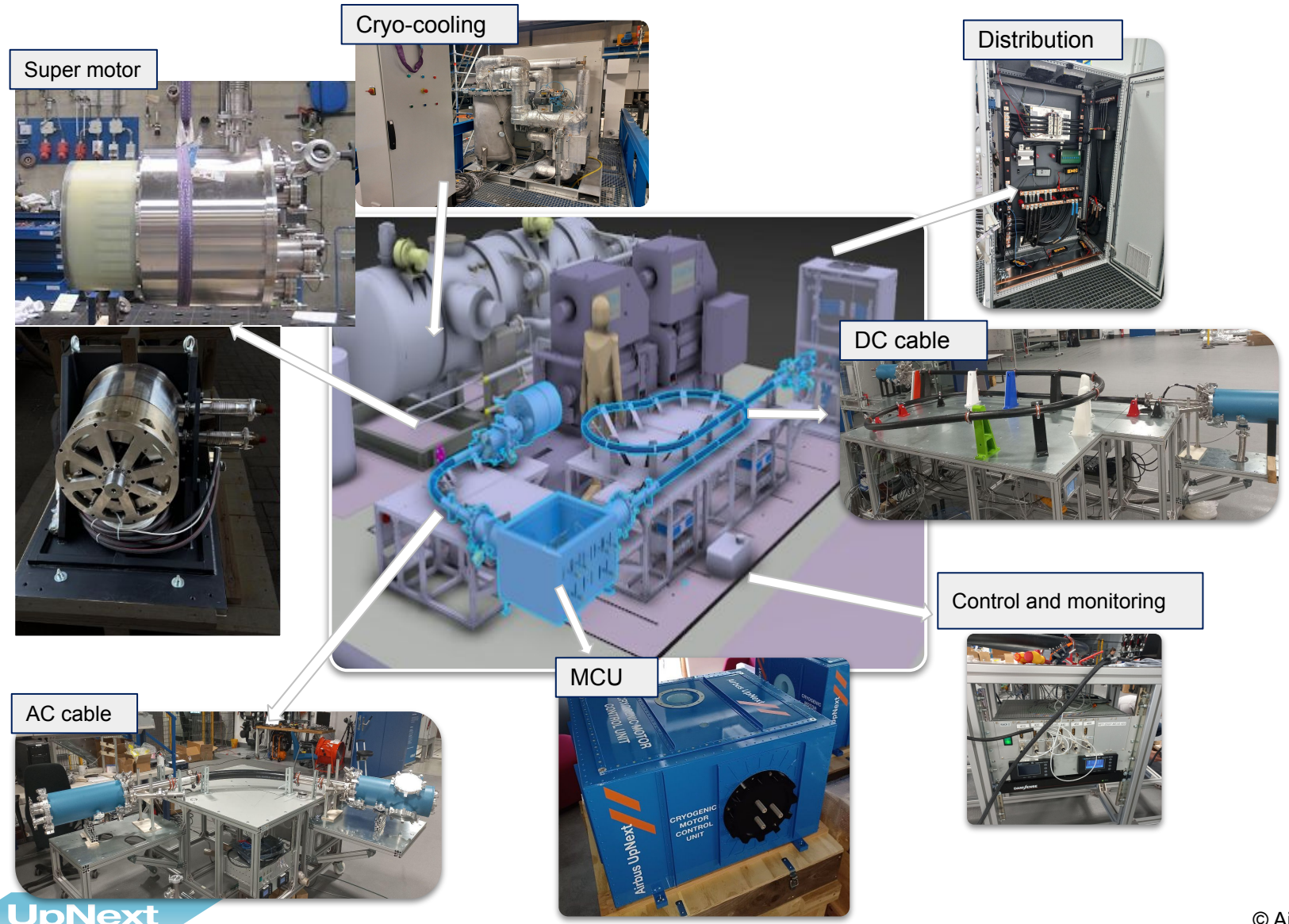
From theory to reality (2/2)



ASCEND project

Successfully tested in EAS facility end of 2023.

- **No showstopper for ground demonstrator**
- **Main learnings**
  - Power density increases with power
  - Efficiency +4-5%
  - New degrees of freedom
- **But**
  - Cryo-technologies not at aero standards yet
  - Mechanical integration
  - Reliability in progress

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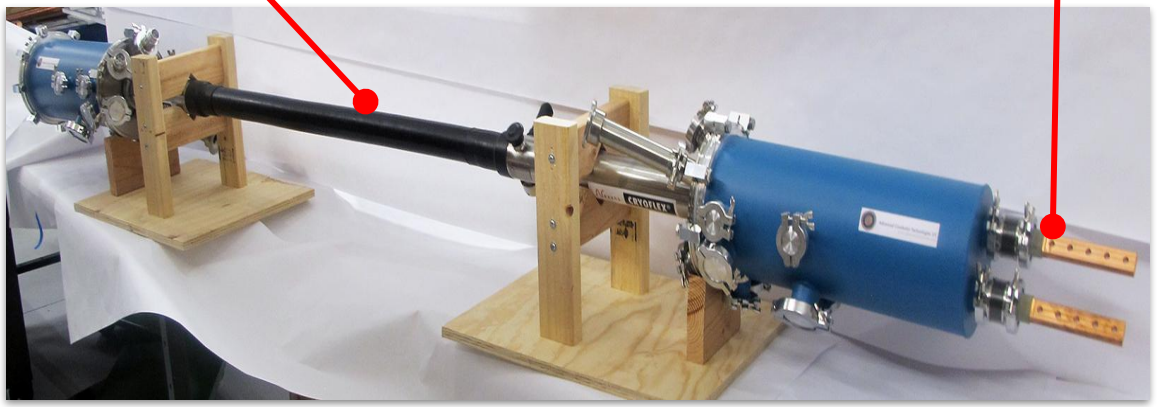
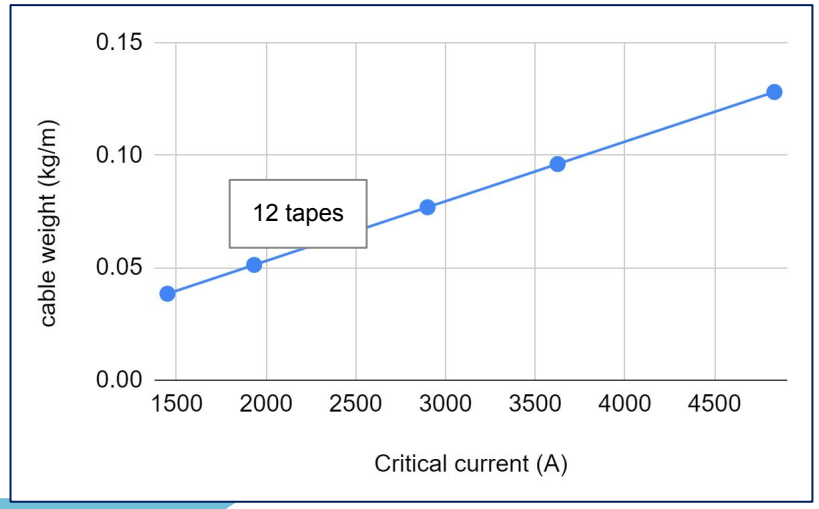
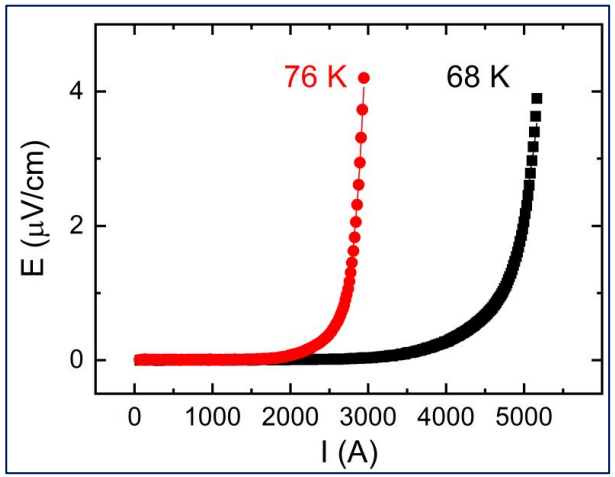
Superconducting Cables







Supra Cable

Cable weight is power independent and lossless

- Weight of “cryostat” and current leads independent of power
- Impact of current is negligible on conductor
  - Adding more tapes
  - Decreasing the T°

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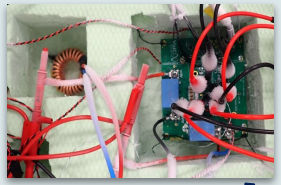
Cryogenic Power Converter

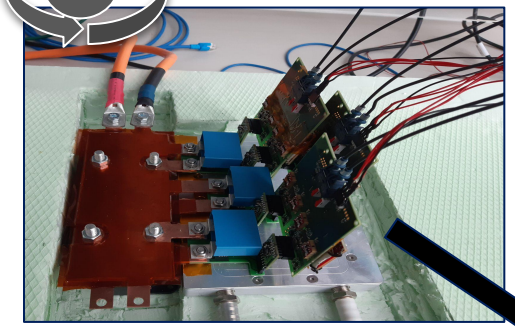
Fail fast approach | >4th MCU generation in less than 3 years

1 Components characterisation

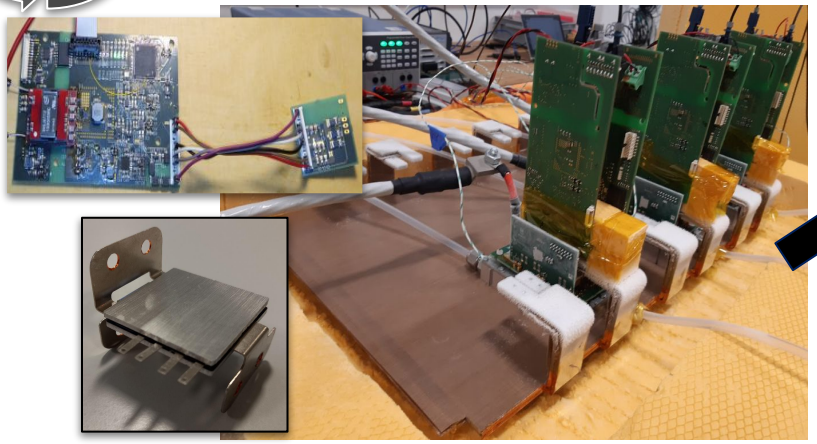


Airbus CRT

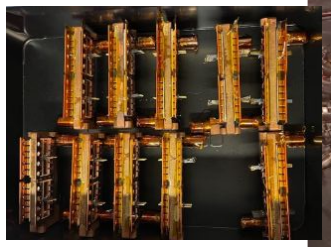
2 First Internal demo (40 kW)



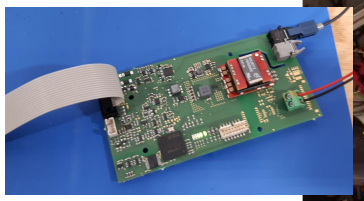
3 500 kW Internal demo

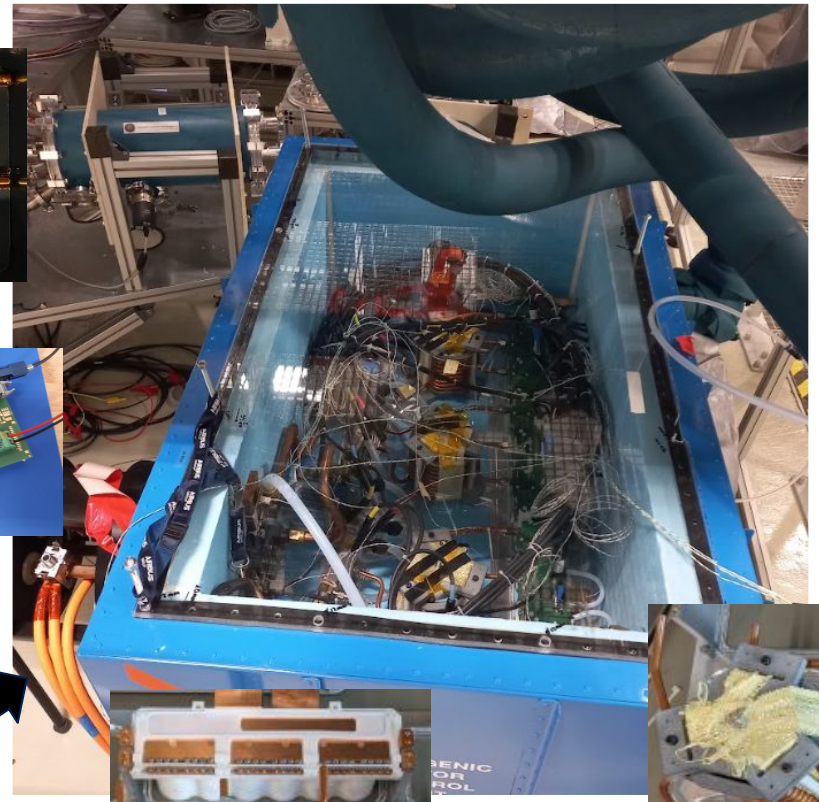


4 Final 500 kW MCU with



Cryo-driver

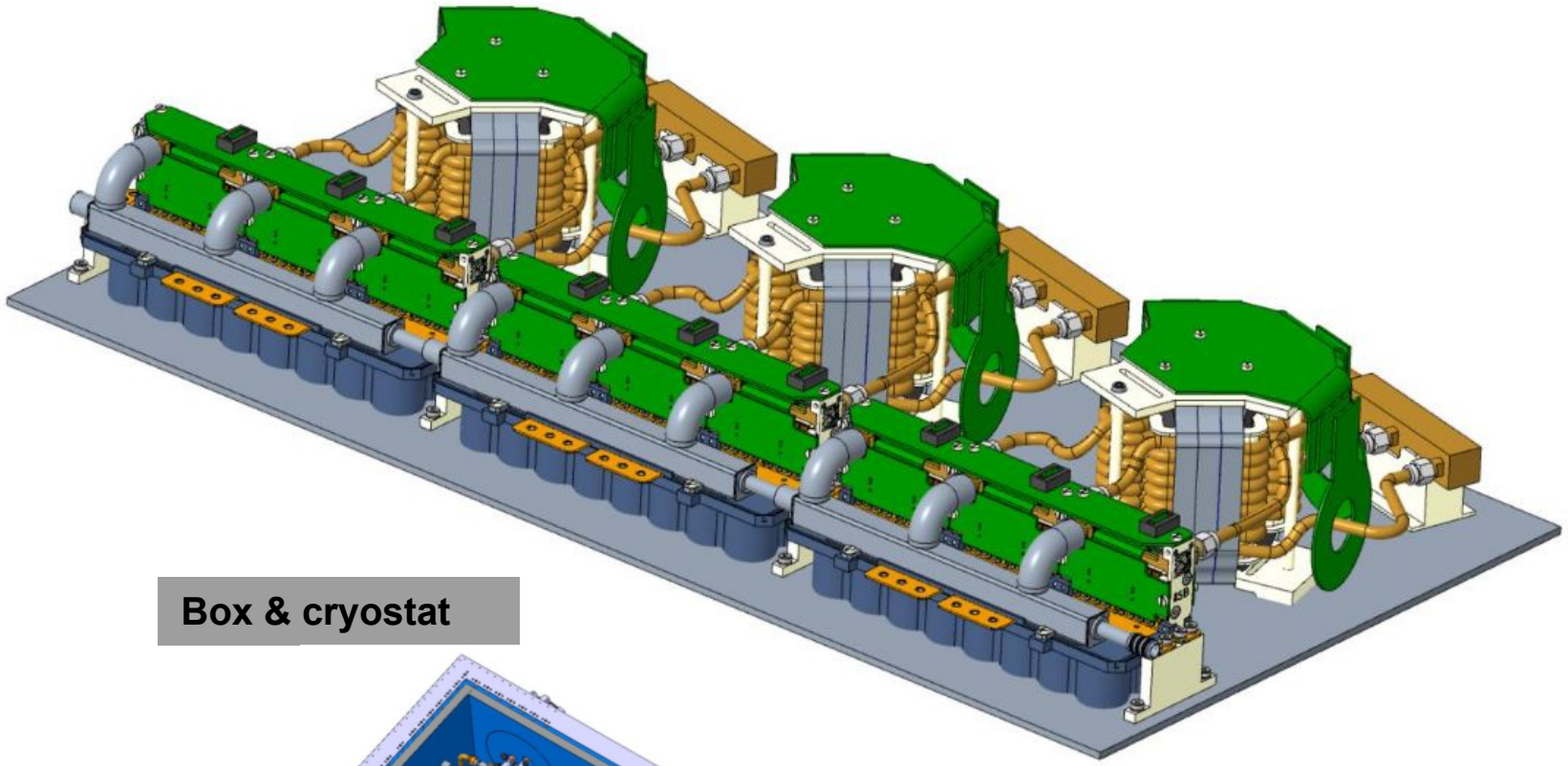




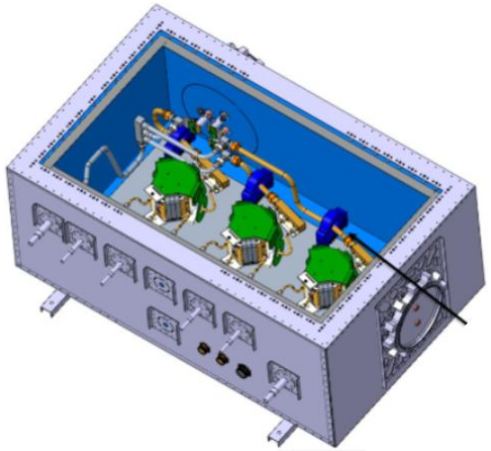
Cryo-Capa

Cryo-inductance

Cryogenic Power Electronics - Main Values



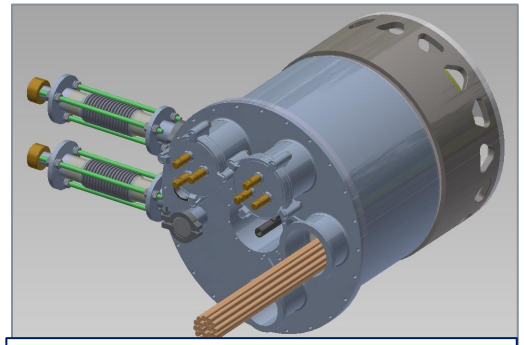
Box & cryostat



Cryo Power Electronics

- ➔ Semiconductor losses **reduced by 50 %**
- ➔ Conduction Losses in bus bars, current leads, and filters **reduced by 80%**
- ➔ Heat flux leak into the superconducting systems can be **minimized (90 to 70 K)**
- ➔ **High current density** design
- ➔ Can **Integrate** into the **superconducting motor and cables**
- ➔ Enclosure for protection and thermal insulation (Extra weight)

Superconducting Motor | Design overview (e-Motor sub-part)



ASCEND e-Motor

- 500 kW @5000 rpm;
- Vrms = 190 V; **η = 99,3%**
- GHe cooling

- **Partial SC motor:**
  - Rotor with Permanent Magnets (PM)
  - Stator with Superconducting (SC) coils

- **Performances:**
  - Nominal power = 500 kW
  - Nominal speed = 5 krpm
  - Polarity of 6
  - Efficiency (@Nominal op.) = 99.3 %
  - Phase-to-phase voltage = 190 Vrms
  - Line current = 1700 Arms
  - Operating temperature = 35 K (average)

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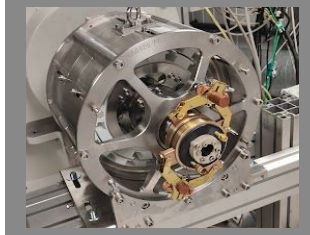

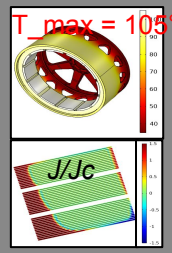

Learn by making: "Airbus homemade demonstrator"

- Fully S/C 35kW eMotor
- **η = 99%** @1000 tr/min

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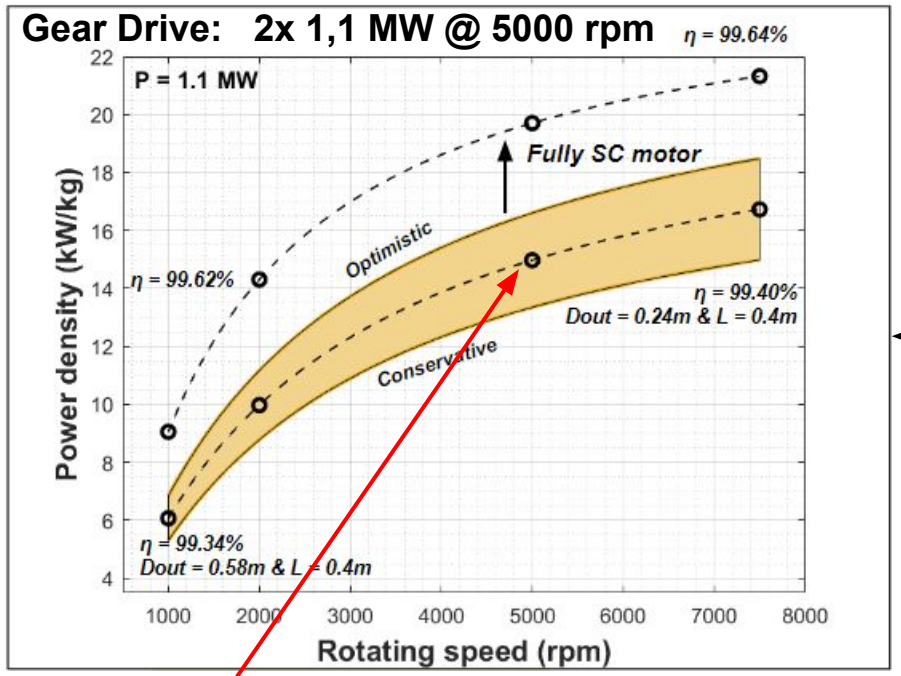
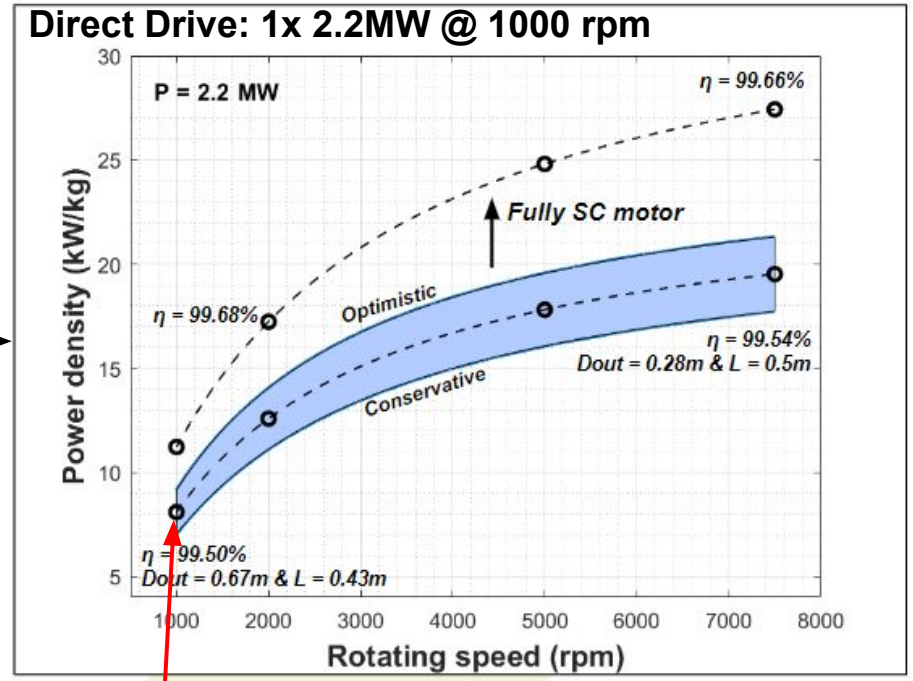
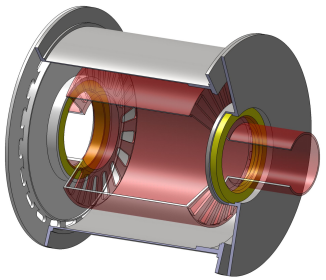
Superconducting Motor | Potential



Based on
ASCEND nominal motor
+
Mid-term mitigations

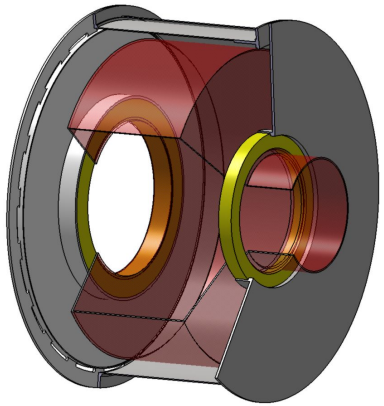




Short-term objective
@5000 rpm

Short-term objective
15 kW/kg / **99.5%**

Mid-term objective
20 kW/kg / **99.5%**



Long-term objective
Direct Drive (1000 rpm)

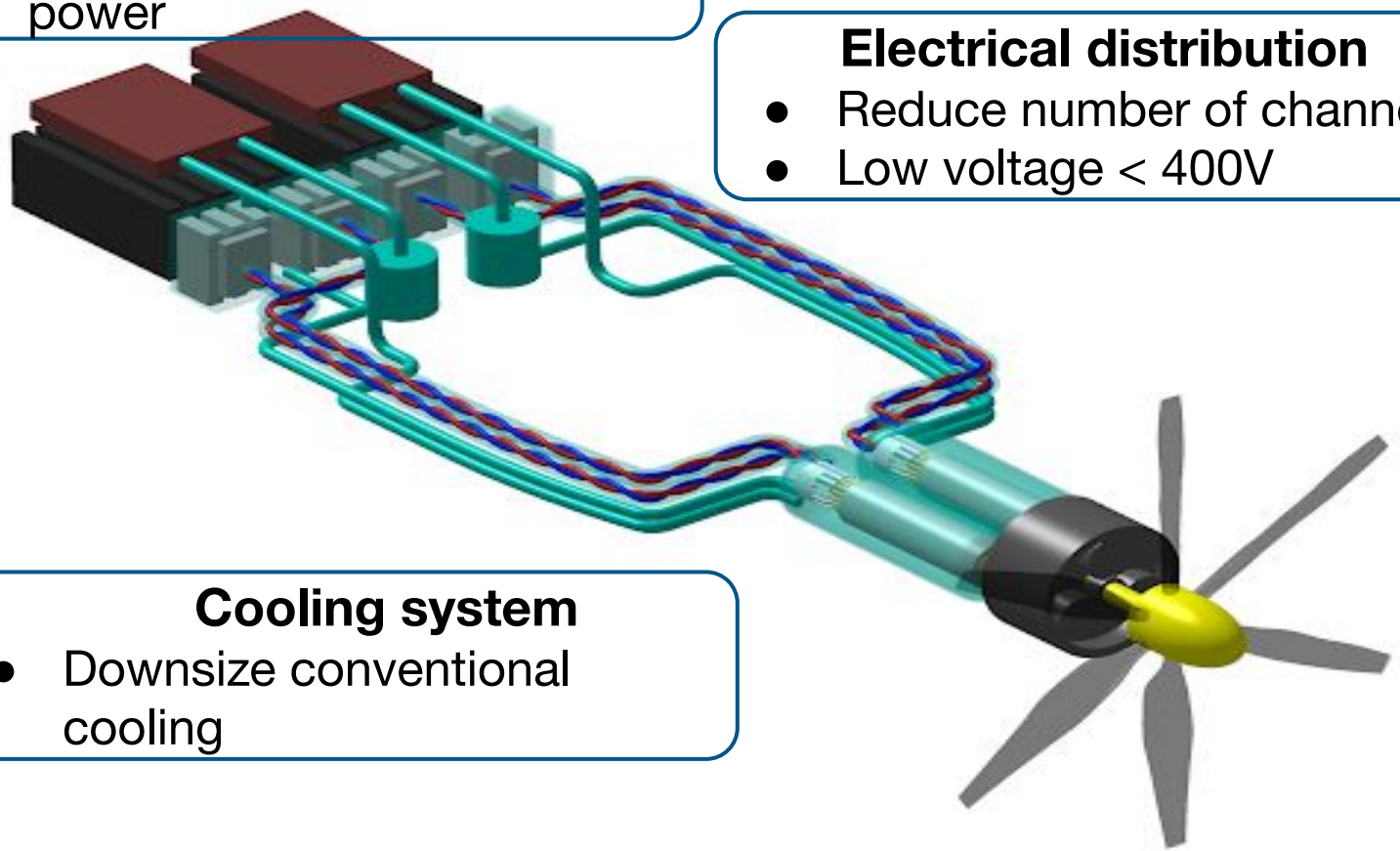
Mid-term objective
8 kW/kg / **99.5%**

Long-term objective
12 kW/kg / **99.5%**

Conclusion : electric propulsion system

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

A game-changer for electric propulsion on LH2 aircraft

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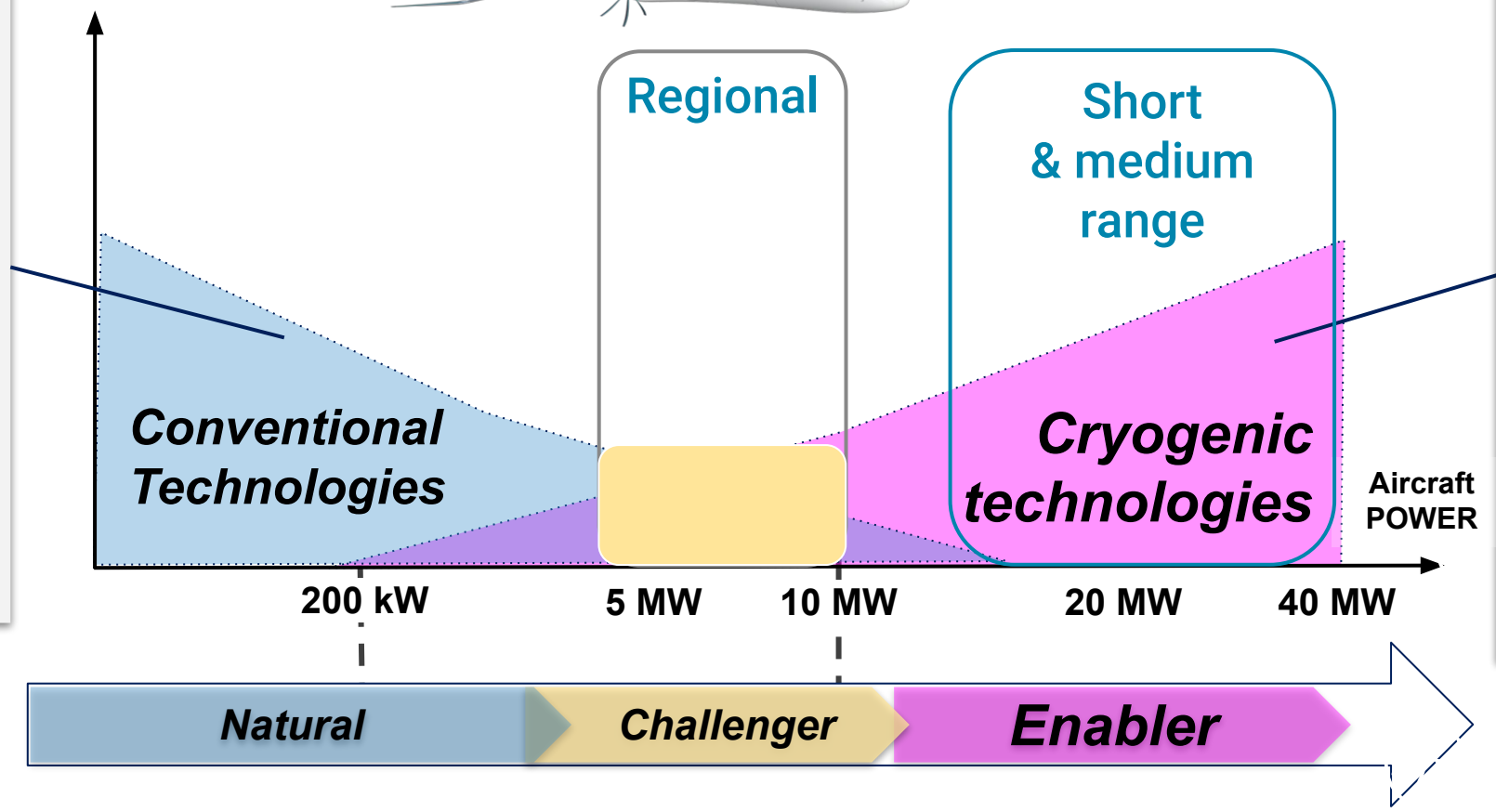
Conventional

Lower potential

But

Less risky & more mature



Cryogenics

High potential

But

more risky and need to be matured

CRYOPROP

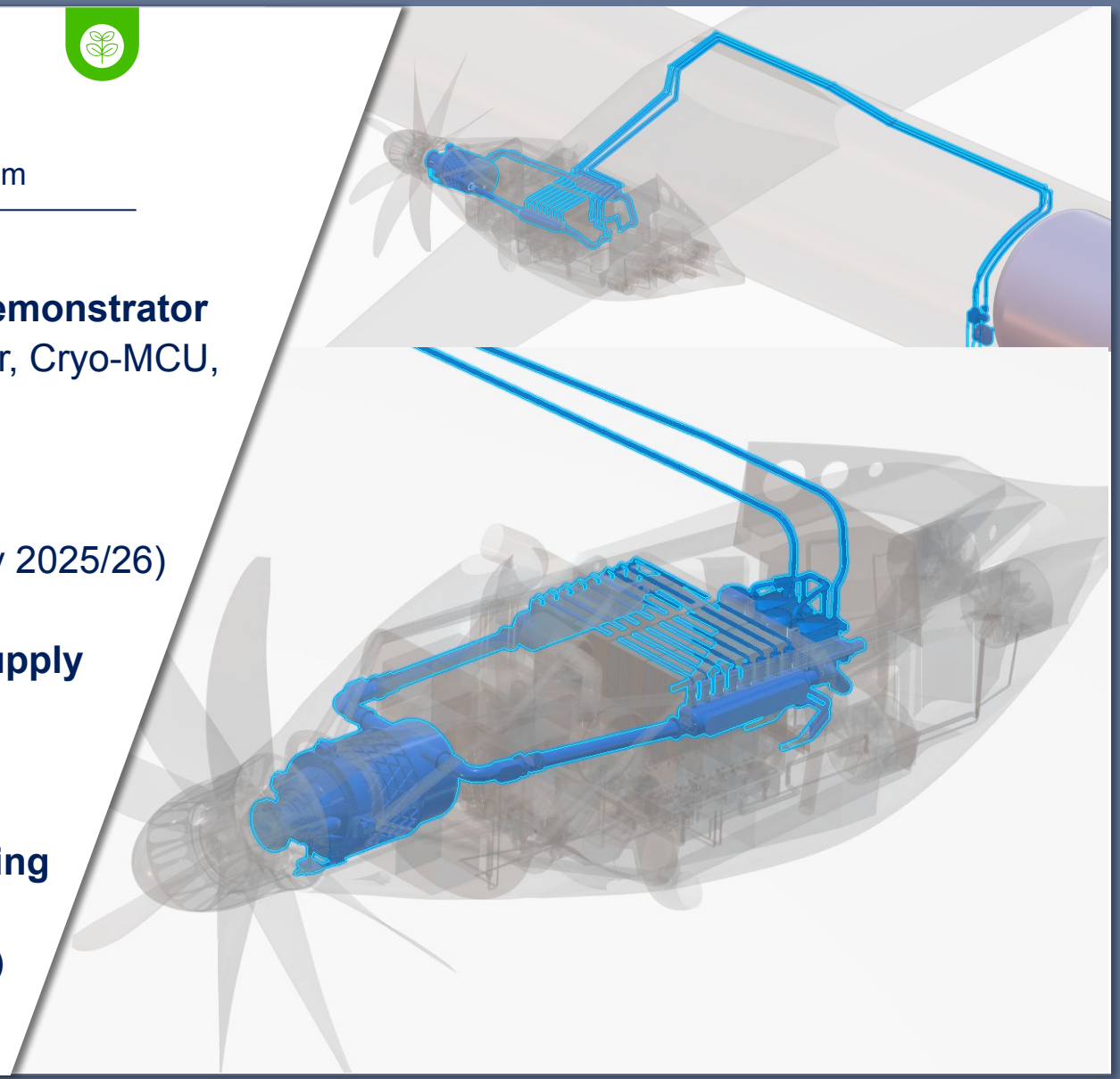
Mature & develop a supply chain for a Cryogenic propulsion system

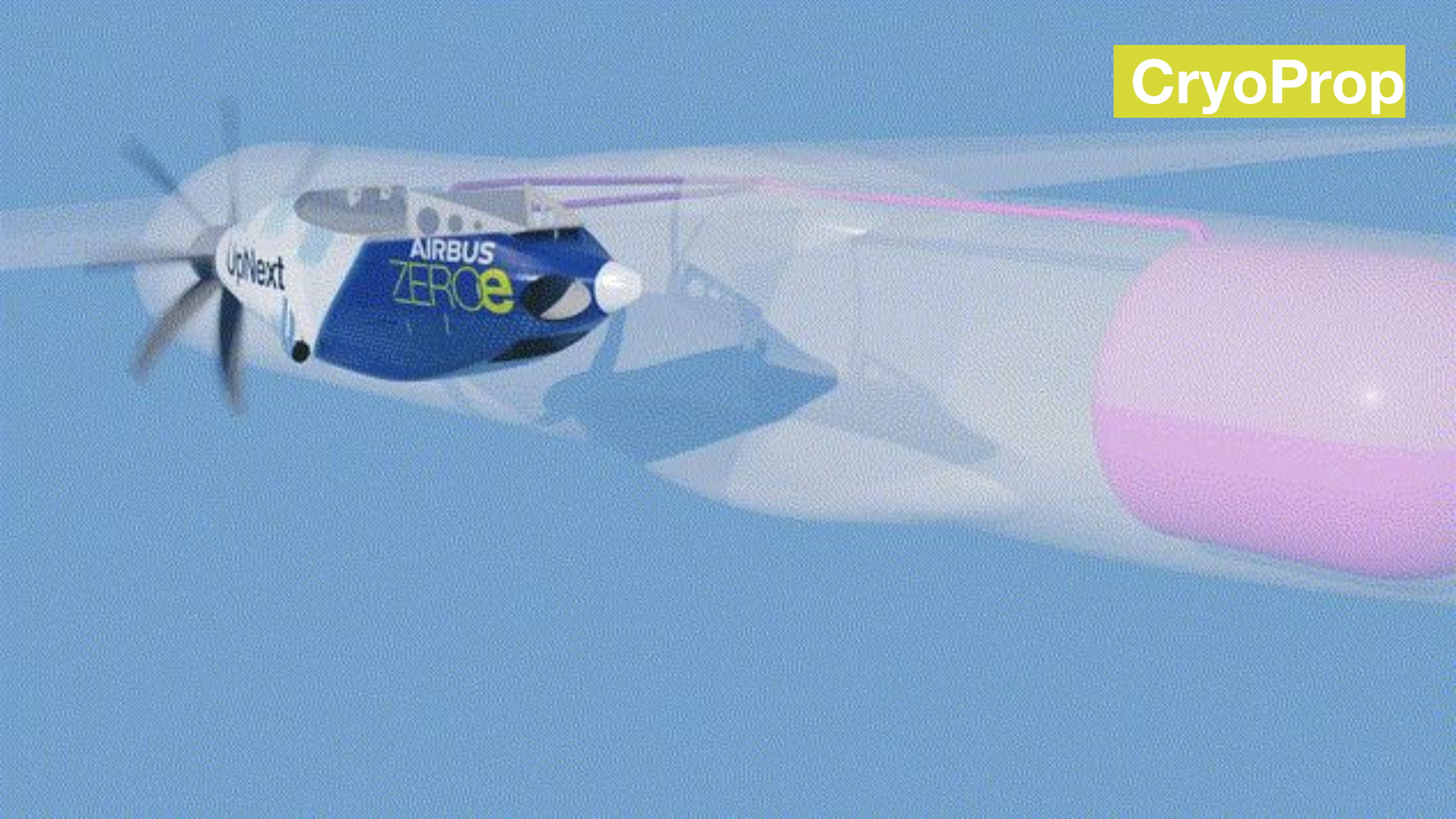
Develop a MW-class cryogenic powertrain demonstrator with LH2 / GHe cryo-cooling system, S/C eMotor, Cryo-MCU, DC cables, PCMS

Maturity for ZEROe Program needs (TRL4 at Component & TRL3 at System level by 2025/26)

Develop a Cryogenics & Superconducting supply chain (building strategic partnerships in line with Airbus Core/Non-Core Strategy)

Foster skills on Cryogenics & Superconducting technologies (pool of experts + collaborative framework with AIRBUS CoCs & ZEROe teams)

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ZEROe

Summary

1. Cryogenic electric propulsion feasibility demonstrated on ground
2. Value for liquid hydrogen aircraft: at least a game changer and an enabler at high power
3. Now focussed on Reliability, operation, maintenance, Safety and … supply chain

The amazing CRYOPROP team

\+

AIRBUS/ZEROe team

\+

Worldwide partners

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Become a partner of CryoProp
Academic: Emelie Nilsson
Industrial : Reda Abdouh

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