FUTure PRopulsion and INTegration
towards a hybrid-electric 50-seat regional aircraft

Thermal Management for HEA: Conceptual Approach

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FUTPRINT 50 Consortium

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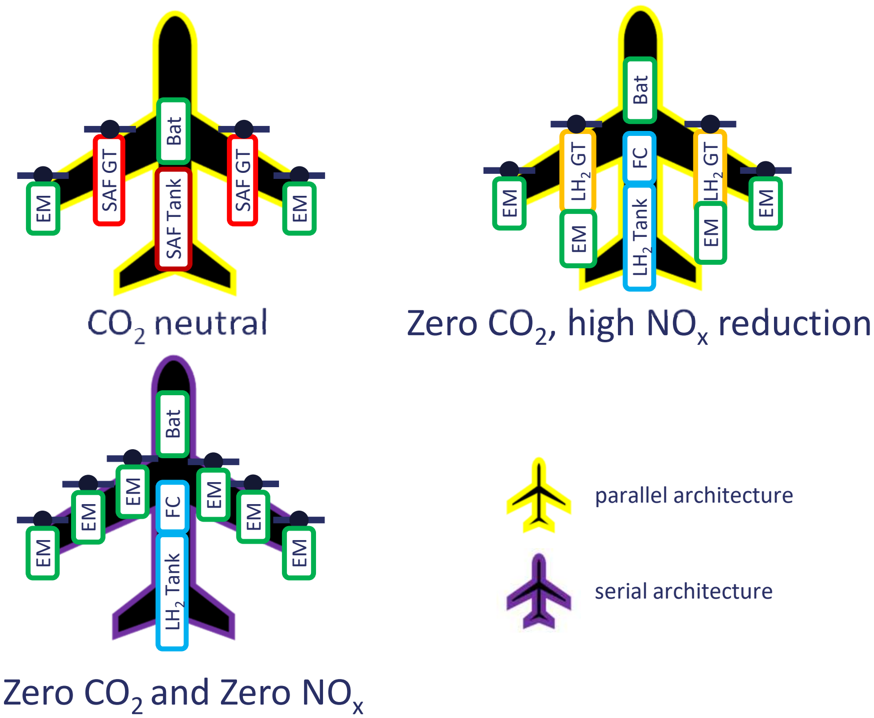
Brief Recap – Research Motivation

- Operational emission goals for aviation.

- Thermal Management System (TMS) is responsible for controlling heat transfer between heat sources and sinks to maintain the temperature of aircraft subsystems in comfort, safe and efficient levels.

- There are many TMS challenges in HEA due to:
  - Electric motors, power electronics, batteries, etc;
  - Condensed electronics compartments;
  - UK-UK (unknowns *unknowns): unknown emergent behaviors due to integration.*



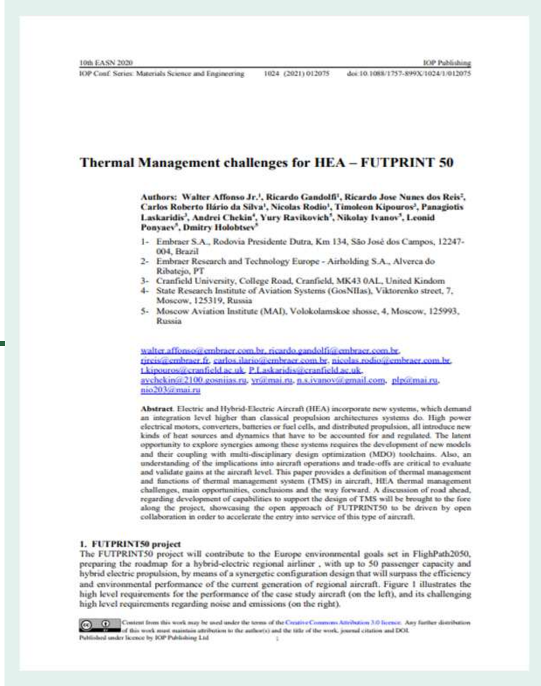
Main Propulsive Architectures Candidates to Prioritization in FUTPRINT50 Project

Brief Recap - Previous Results

- Identification of potential technologies to integrate thermal management system for FUTPRINT50 case study in terms of:
  - Basic operational concepts (high level description of each technology);
  - Current TRL;
  - TRL forecast to 2030.

- Identification of possible synergies in thermal management system design of HEA.

These results were captured in our last paper on 10th EASN Conference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Thermal Management challenges for HEA – FUTPRINT 50

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Abstract. Electric and Hybrid-Electric Aircraft (HEA) incorporate new systems, which demand an integration level higher than classical propulsion architectures systems do. High power electrical motors, converters, batteries or fuel cells, and distributed propulsion, all introduce new kinds of heat sources and dynamics that have to be accounted for and regulated. The latent opportunity to explore synergies among these systems requires the development of new models and their coupling with multi-disciplinary design optimization (MDO) toolchains. Also, an understanding of the implications into aircraft operations and trade-offs are critical to evaluate and validate gains at the aircraft level. This paper provides a definition of thermal management and functions of thermal management system (TMS) in aircraft, HEA thermal management challenges, main opportunities, conclusions and the way forward. A discussion of road ahead, regarding development of capabilities to support the design of TMS will be brought to the fore along the project, showcasing the open approach of FUTPRINT50 to be driven by open collaboration in order to accelerate the entry into service of this type of aircraft.

1. FUTPRINT50 project

The FUTPRINT50 project will contribute to the Europe environmental goals set in FlighPath2050, preparing the roadmap for a hybrid-electric regional airliner , with up to 50 passenger capacity and hybrid electric propulsion, by means of a synergetic configuration design that will surpass the efficiency and environmental performance of the current generation of regional aircraft. Figure 1 illustrates the high level requirements for the performance of the case study aircraft (on the left), and its challenging high level requirements regarding noise and emissions (on the right).

Access our last paper through this QR code

Continuing the advances…

- A few technologies were temporarily dismissed because of lack of information.
- Each of these technologies have their own particularities to be considered in design.
- Capturing all these information was essential to learn how to integrate these technologies and propose efficient TMS architectures.
- Cooling technologies assessment sheet:
  - Register qualitative and quantitative data about each technology;
  - Useful to compare them.

Potential TMS Technologies
Liquid Cooling
Forced Air Cooling
Air Cycle Machine
Vapor Cycle System
Magnetocaloric Effect
Absorption Refrigerator
Phase Change Materials
Skin Heat Exchanger
Joule-Thomson Effect
Passive Devices (e.g. heat pipes, thermosyphons, etc)
Vortex Tube

Cooling Technologies Assessment Results

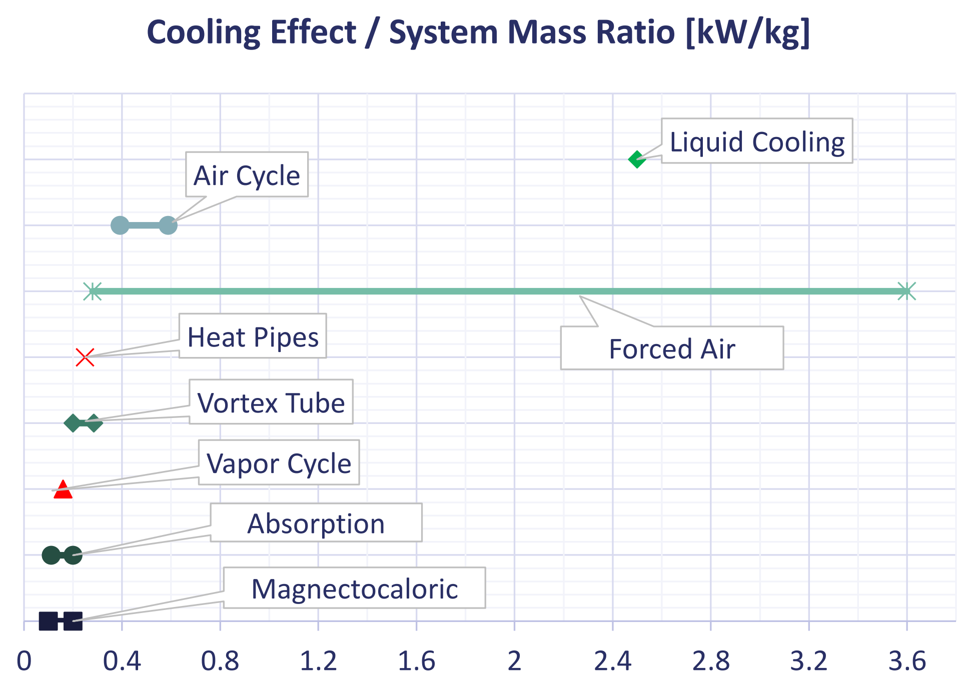
Qualitative Data – Cooling Technologies Assessment

Potential TMS Technologies	Reliability	Operations Impact	Integration Impact	Consortium Experience
Liquid Cooling	High	Low	Significant	Medium
Forced Air Cooling	High	Low	Low	High
Air Cycle Machine	High	Low	Significant	High
Vapor Cycle System	High	Low	Low	High
Magnetocaloric Effect	Medium	Significant	Significant	Low
Absorption Refrigerator	Medium	Significant	Significant	Low
Phase Change Materials	Medium	Significant	Low	Low
Skin Heat Exchanger	High	Significant	Significant	High
Joule-Thomson Effect	High	Significant	High	Low
Passive Devices	High	High	High	Medium
Vortex Tube	High	Significant	High	Low

Research Challenges – Quantitative Data – Cooling Technologies Assessment

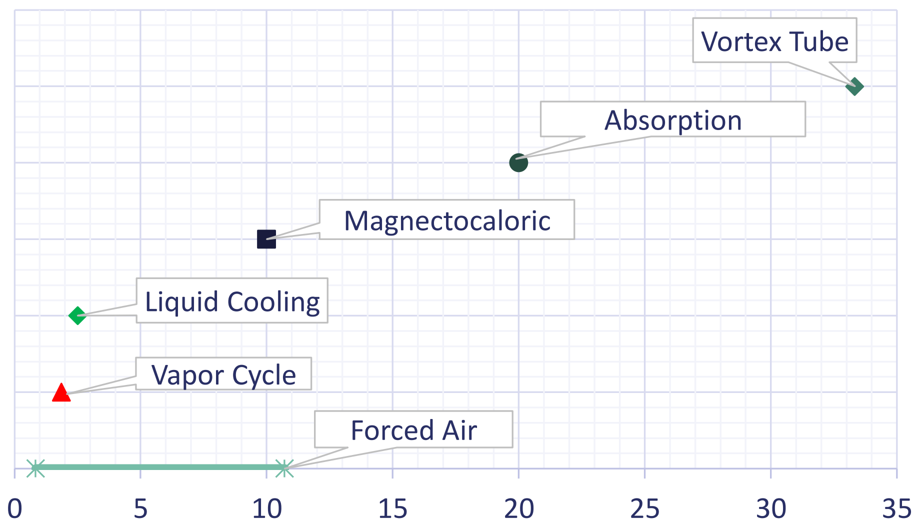
- Low TRL Technologies
  - Limited information available
  - Not implemented on aircraft
  - Using data from different applications can lead to wrong conclusions

- High TRL technologies
  - Some key data are difficult to find because of enterprise strategies

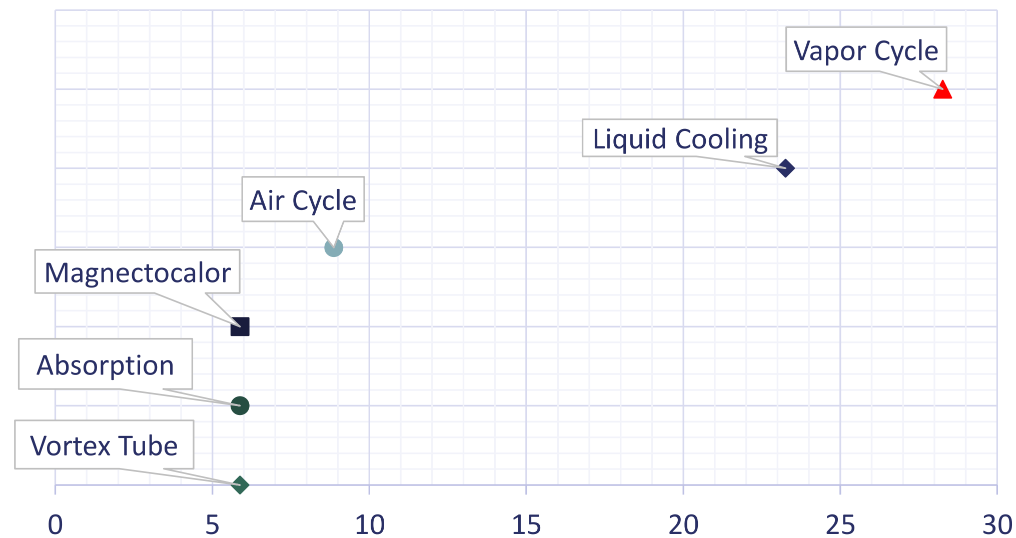


Research Challenges – Quantitative Data – Cooling Technologies Assessment

Cooling Effect / System Electric Power Consumption Ratio [kW/kW]



Cooling Effect / Cooling Air Flow Ratio [kW/ kg/s]



TMS Conceptual Architectures

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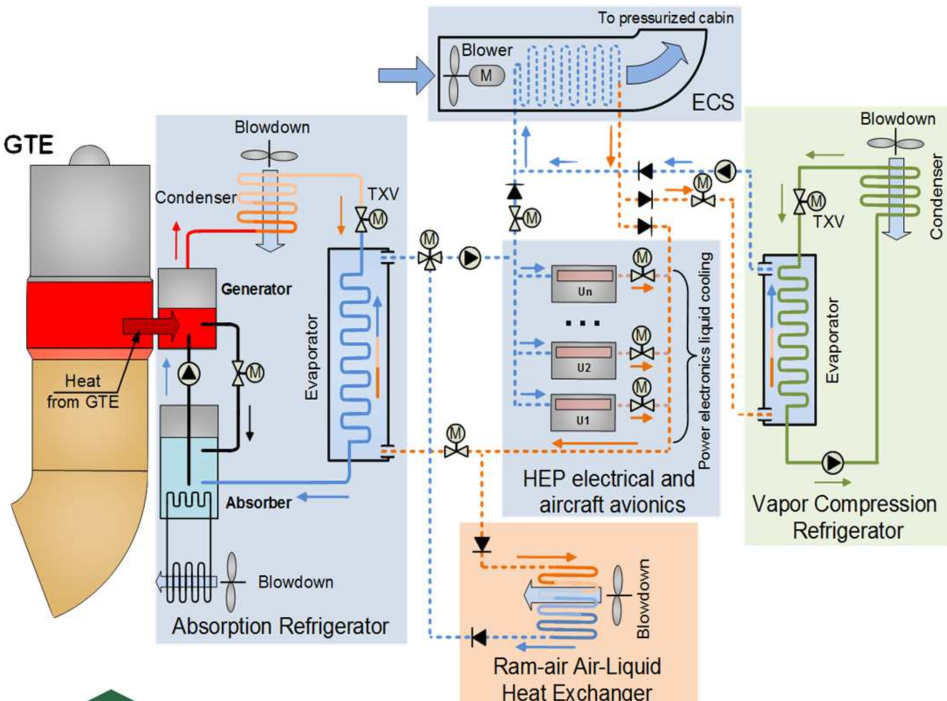
Absorption Refrigerator Architecture



MAIN CHARACHTERISTICS:

- No moving parts – low maintainability;
- No direct emissions.

HAZARDS AND LIMITATIONS:

- Could contain hazardous products;
- Only functional when there is heat generation (no AC on ground, needs GPU);
- No specific aeronautical regulation/AMC and no use in aerospace industry so far but widely used in other industrial sectors.

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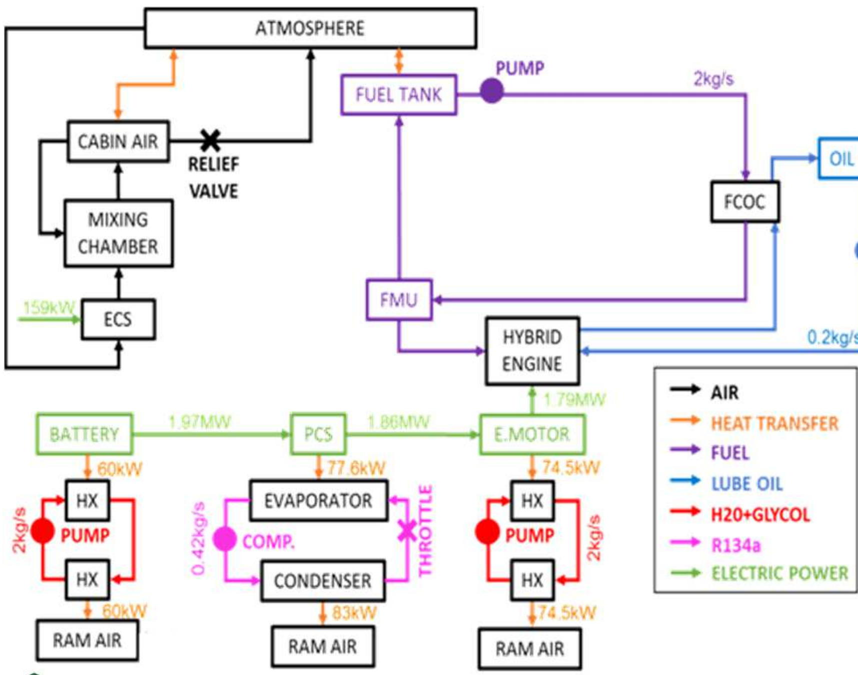
Fuel-Oil Heat Exchanger Architecture



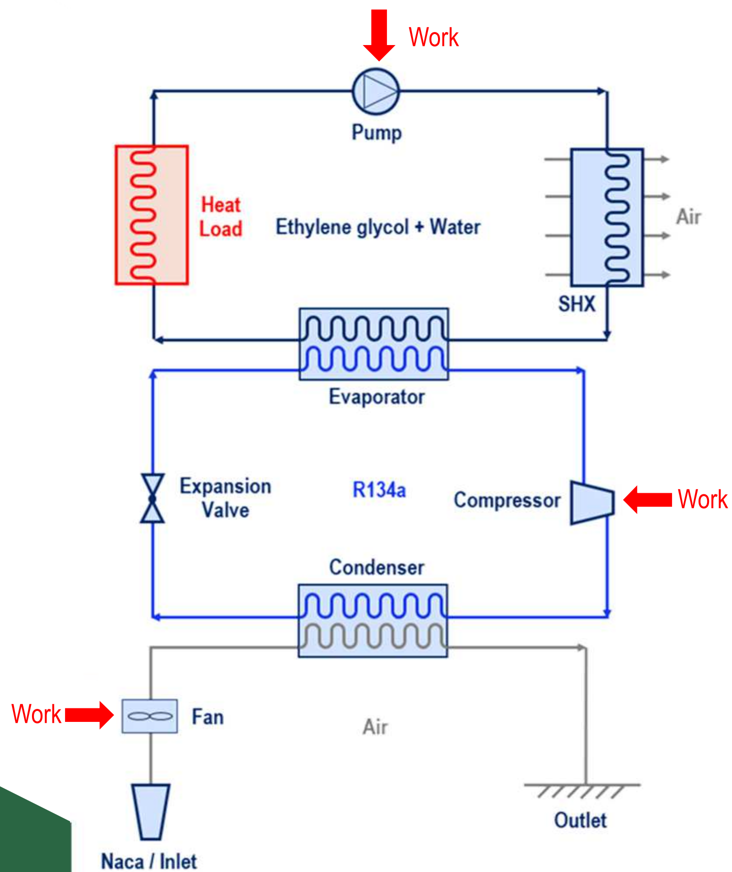
MAIN CHARACHTERISTICS:

- Model for hybrid propulsion;

HAZARDS AND LIMITATIONS:

- Working fluids: R134a and lube oil;
- External work must be provided for the pumps.

Coupled Liquid Cooling and Vapor Cycle System



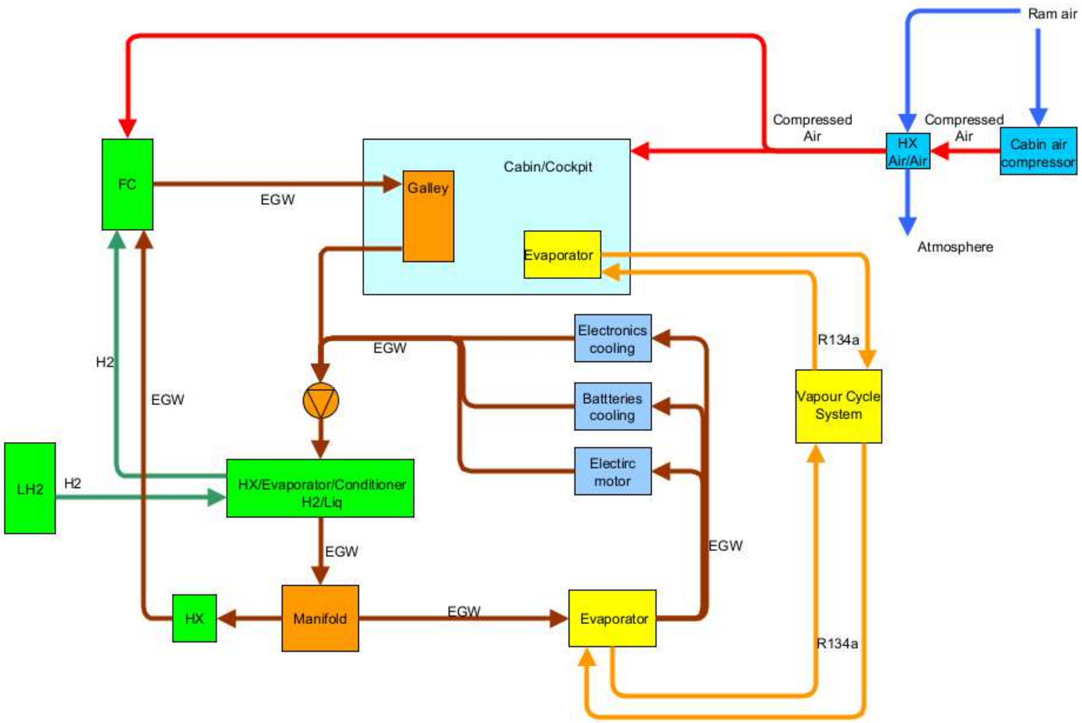
MAIN CHARACHTERISTICS:

- Mature technology;
- Functional if energy can be provided to the pump.

HAZARDS AND LIMITATIONS:

- Working fluid (R134a);
- External work must be applied to the pump, compressor and fan.

Coupled Liquid Cooling and Vapor Cycle System



MAIN CHARACHTERISTICS:

- Model for hybrid propulsion;
- Fuel cell has a restricted operating temperature.

HAZARDS AND LIMITATIONS:

- Working fluid (R134a);
- External work must be applied to the pump, compressor and ram air fan.

Conclusion and Next Steps

CONCLUSIONS

- TMS will be highly dependent on the propulsion architecture;
- Still many unknowns – aerospace applications still emerging, low component/system maturity, transient behaviors are hard to model.

NEXT STEPS

- Prioritize propulsion architectures for analysis;
- Based on chosen propulsions, prioritize TMS architectures, develop their models and understand their limitations and opportunities;
- Develop integrated simulations;
- Keep track of regulatory evolution (special conditions).

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