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

Thermal Management challenges for HEA FUTPRINT50 aircraft class

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FUTPRINT 50 Consortium

EMBRAER

FutPrInt50

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 875551

European Commission

FUTPRINT50 aircraft class: regional up to 50 pax


FutPrInt50

Future propulsion & integration:
towards a hybrid-electric 50-seat regional aircraft

Milestone 1

Top-Level Aircraft Requirements Defined

Grant Agreement Number: 875551

Project Acronym: FutPrInt50

Project title: Future propulsion and integration: towards a hybrid-electric 50-seat regional aircraft

Starting Date: 01.01.2020

Project Duration: 36 months

Project Officer: Hugues Felix

Project Coordinator: Prof. Andreas Strohmayer (USTUTT)

Author(s): Ricardo dos Reis (EMBRT)

Contributing partners:

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KEY ITEMS

EIS 2035/2040

Up to 50 PAX

Design range: 400Km

Max. range: 800Km

Cruise speed: 450-550Km/h

Take-off length: 1000m

Max. alt: 25 000 feet

-65 % perceived noise vs. 2000

-75% CO_2 / (PAX x Km) vs. 2000

-90% NO_x / (PAX x Km) vs. 2000

A/C taxi : emission free (electric)
Design & Manufacture 4 Recycling

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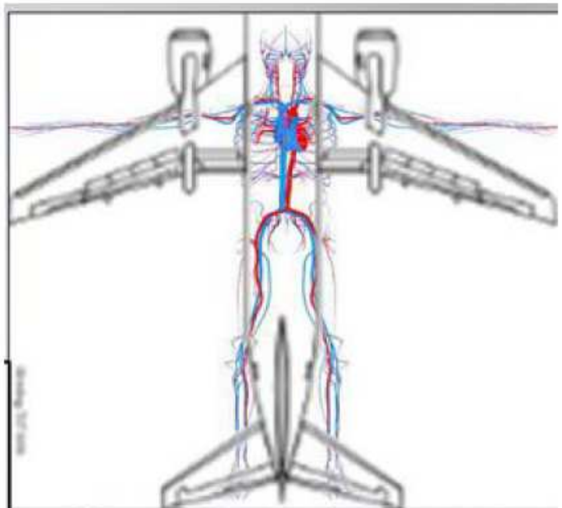
*“Thermal Management is the ability to **manage heat transfer** between heat sources and sinks **to control the temperature of aircraft subsystems/components** in order **to achieve comfort, safety and efficiency**.”*



Human body circulatory system as model for aircraft

NASA

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HEA Thermal Management Challenges

- High heat loads (transients and continuous);
- High power density (electronics miniaturization, *transmission*);
- High condensed electronics compartments;
- May need non-conventional solutions to the aircraft industry (risks on integration and safety aspects);
- TM system should minimize aircraft impacts: drag, power and weight;
- UK-UK (unknowns *unknowns): unknown emergent behaviors due to integration*

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FUTPRINT50 TMS results

- **Advance the state of the art of HEA TMS:**
  - Updated TMS state of the art for HEA;
  - Thermal management architectures for HEA:
    - Improve trade-offs at design stage;
    - New and improved models for simulation;
    - Models Integration (i.e., aircraft performance, propulsion, thermal management, etc.);

- **Roadmap for HEA TMS;**
  - Technologies demonstrators
  - Regulation development support

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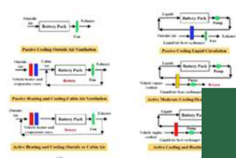
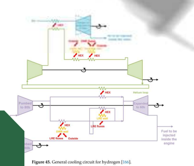
Architectures and systems for HEA TMS

HEAT SOURCES

- BATTERY
- POWER ELECTRONICS
- ELECTRIC MACHINES
- OTHERS





HEAT SINKS

- FUEL
- FUSELAGE
- RAM AIR
- OTHERS

TMS

Our goal: Advance modelling and simulation for HEA TMS

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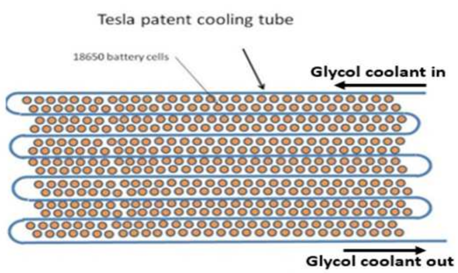
FutPrInt50

Overview of technologies for heat transfer

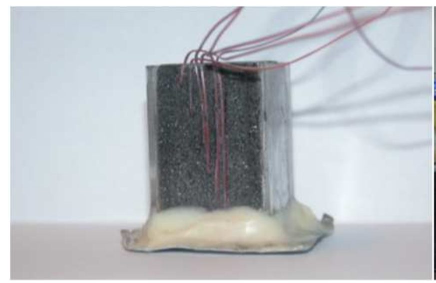
LIQUID COOLING SYSTEMS

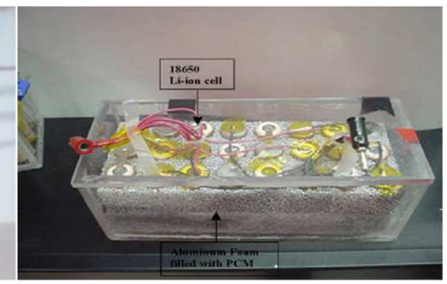
The warm fluid passes through a heat exchanger to be cooled using the ambient as heat sink



THERMAL ACCUMULATORS (E.G., PHASE CHANGE MATERIALS)

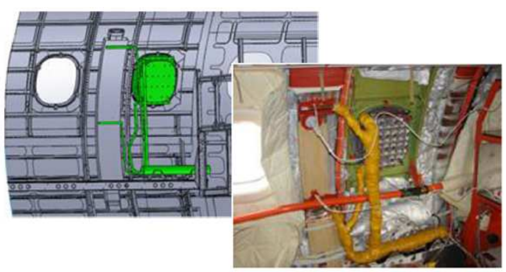
The material reaches its specific phase change temperature

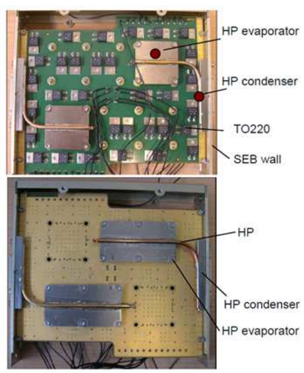




PASSIVE SYSTEMS (E.G., HEAT PIPES, THERMOSYPHONS, VAPOR CHAMBERS)

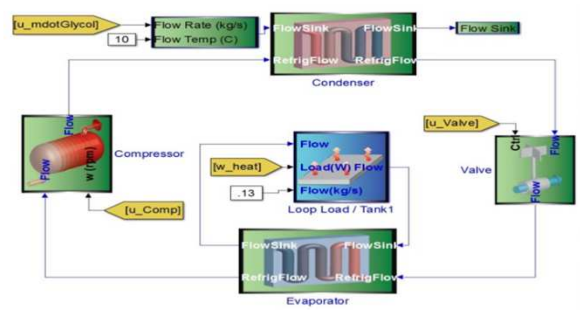
The heat transfer is performed by the evaporation and condensation of the working fluid

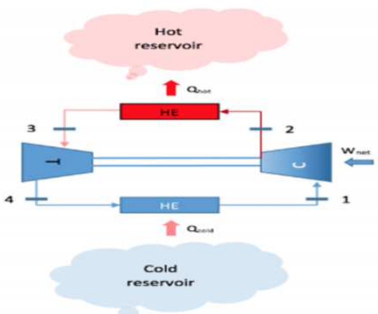




PUMPED TWO PHASE SYSTEMS (E.G., VAPOR CYCLE SYSTEMS, EVAPORATIVE COOLING)

Vapor cycle systems circulate refrigerant fluid via tubing, which absorbs and removes heat from a device and rejects to a heat sink





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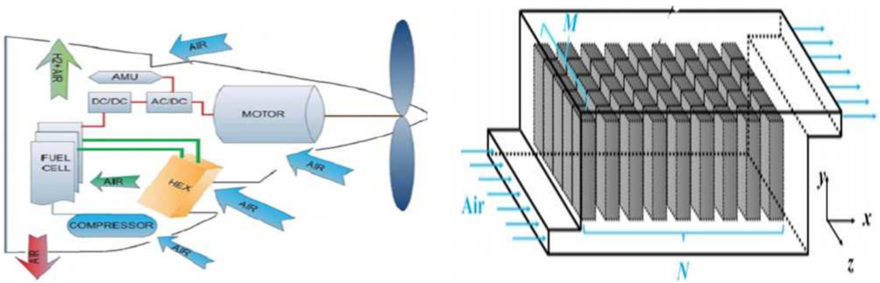
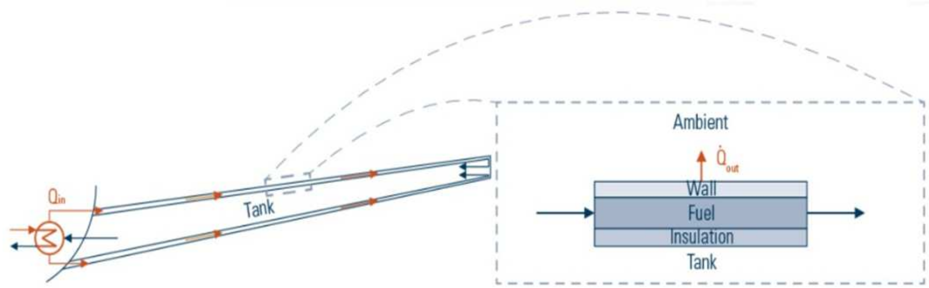
Overview of technologies for heat transfer

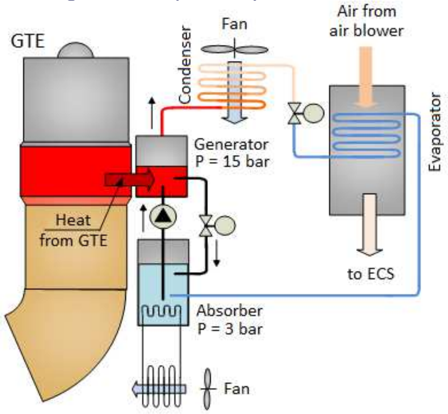
AIR COOLING (E.G., FANS, AIR CYCLE MACHINES, RAM AIR)
Air cooling is accomplished by flowing air around/inside the heat loads



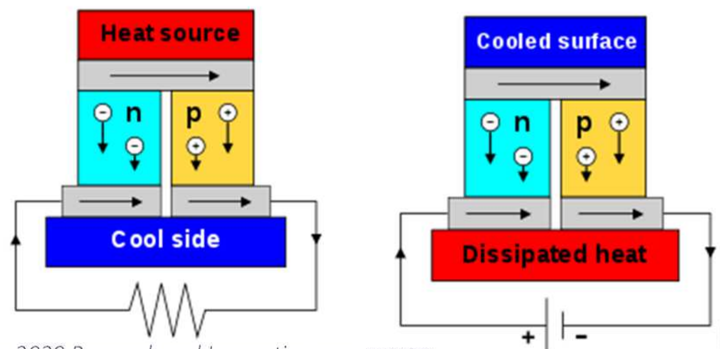
SKIN HEAT EXCHANGERS (E.G., FUSELAGE HEAT EXCHANGERS)
The aircraft skin act as a heat exchanger transferring heat to the ambient air



ABSORPTION REFRIGERATOR
Refrigerant is cooled during its absorption by the absorbent



SEEBECK EFFECT AND PELTIER EFFECT
The build up of an electric potential across a temperature gradient and The energy transfer when an electric current passes through the junction of two dissimilar conductors



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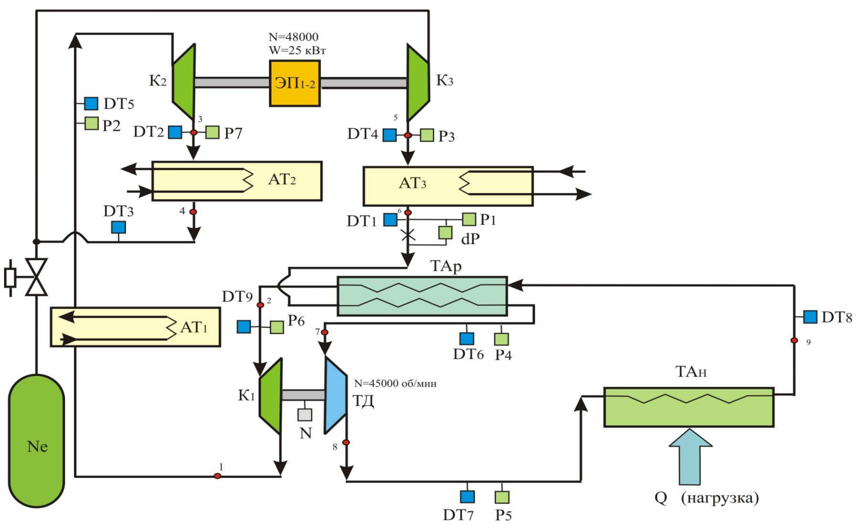
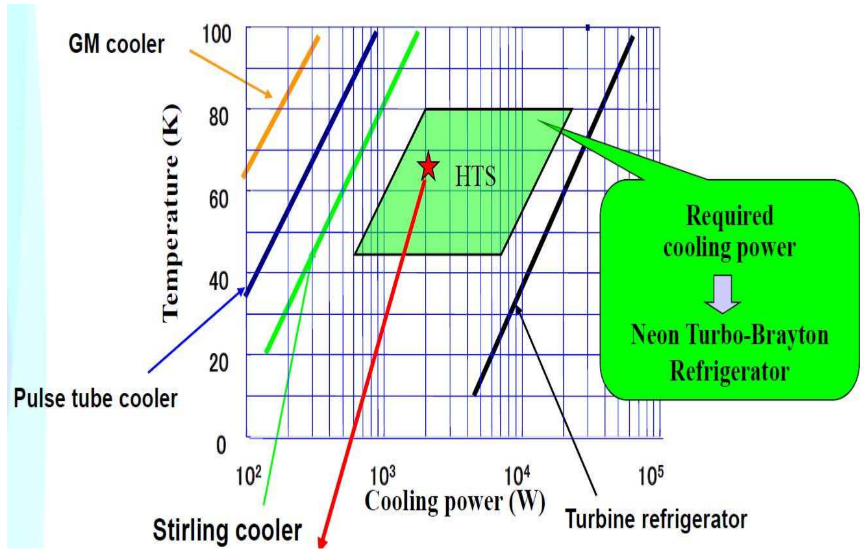
FUTPRINT50

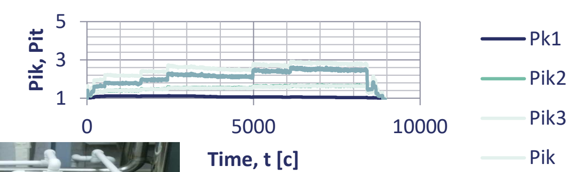
Overview of technologies for heat transfer highlight| Crio





Criogenic Cool Systems can lower electrical losses.
Advances being made to be explored in Futprint50…

…The most promising are CrioRefrigerators using Turbochargers and Turboexpanders based on the Brighton cycle.



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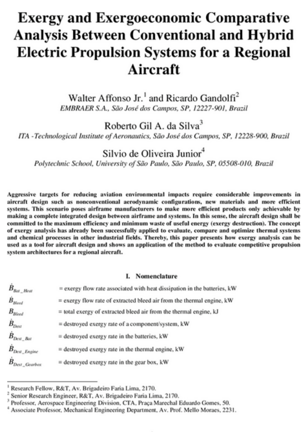
Exploiting synergies: challenges as opportunities (architectures)



Exergy and Exergoeconomic Comparative Analysis Between Conventional and Hybrid Electric Propulsion Systems for a Regional Aircraft

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Aggressive targets for reducing aviation environmental impacts require considerable improvements in aircraft design such as nonconventional aerodynamic configurations, new materials and more efficient systems. This scenario poses airframe manufacturers to make more efficient products only achievable by making a complete integrated design between airframe and systems. In this sense, the aircraft design shall be committed to the maximum efficiency and minimum waste of useful energy (exergy destruction). The concept of exergy analysis has already been successfully applied to evaluate, compare and optimize thermal systems and chemical processes in other industrial fields. Thereby, this paper presents how exergy analysis can be used as a tool for aircraft design and shows an application of the method to evaluate competitive propulsion system architectures for a regional aircraft.

I. Nomenclature

$\dot{B}_{Bat\_Heat}$ = exergy flow rate associated with heat dissipation in the batteries, kW
$\dot{B}_{Bleed}$ = exergy flow rate of extracted bleed air from the thermal engine, kW
B_{Bleed} = total exergy of extracted bleed air from the thermal engine, kJ
$\dot{B}_{Dest}$ = destroyed exergy rate of a component/system, kW
$\dot{B}_{Dest\_Bat}$ = destroyed exergy rate in the batteries, kW
$\dot{B}_{Dest\_Engine}$ = destroyed exergy rate in the thermal engine, kW
$\dot{B}_{Dest\_Gearbox}$ = destroyed exergy rate in the gear box, kW

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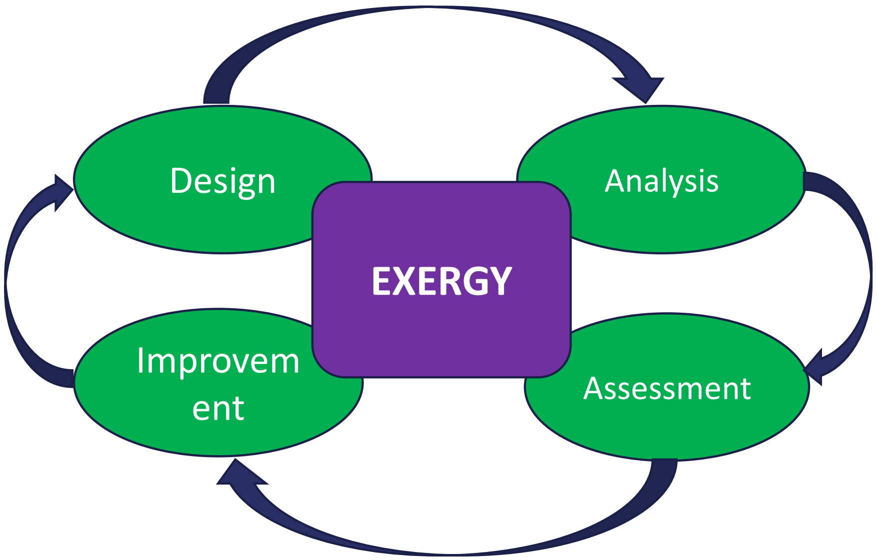

- Explore opportunities in waste heat recovery and energy harvest;
- Perform a more integrated design (aeronautics, propulsion, electric systems, batteries, thermal management systems);
- Perform a mission optimized system design;
- Explore exergy as a figure of merit at aircraft and systems levels.

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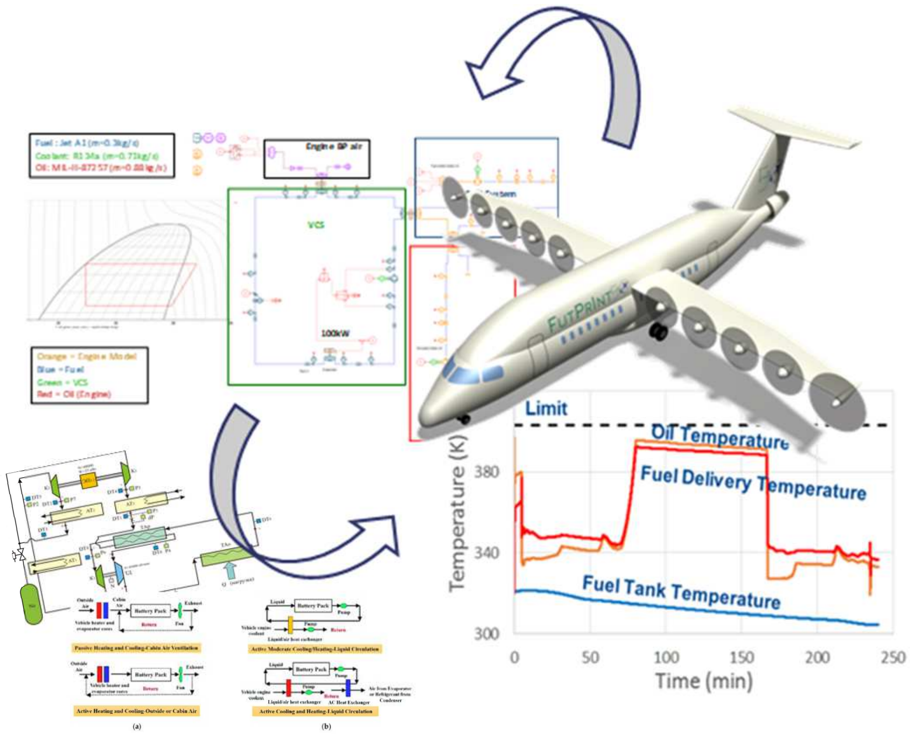
Key message

Integrated design is even more pressing for future HEA



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THANK YOU!

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