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M3Or2A-02 [Invited]: Electric Aircraft Cryogenic Cooling with Thermo-acoustic Exergy Management

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A key problem with current cryogenic aircraft propulsion systems is the mass burden of cooling the high power electric motors and electronics. The anticipated significant mass addition required for thermal management can nullify the entire benefit of utilizing electric propulsion in aircraft due to the additional induced drag on the aircraft.

Instead, a thermo acoustic-based cooling system is proposed that would use the waste energy from turbo-generators to thermo-acoustically create a pressure wave that is then delivered via routed embedded duct work to pulse-tube coolers located at all components requiring cryogenic cooling in the aircraft. With this approach, cryogenic electric aircraft can be cooled with minimal mass, fuel, and risk.

The complete power system including turbo-generator, distribution, protection, converters, and motors all generate heat that must be dissipated. A number of studies suggest that over half of the losses associated with a full electric power propulsion system is attributed to the thermal management system and as such is likely a key limiting factor to achieving economical flight. Moreover, as the operating temperature is reduced, the power and motor components become flight-weight and more efficient but often at the expense of increased thermal management system mass. In particular, the best system performance is predicted to occur at cryogenic temperatures.

The key to making this technology light-weight and efficient is the creation of an acoustic wave to deliver cooling energy to distal locations through the aircraft. This eliminates the need to deliver energy with electrical, mechanical, or fluid flow- each of which adds mass and complexity. For example, electrical power distribution produces EMI, heating, and requires heavy cables. Mechanical distribution such as distributed torque shafts adds weight and requires lubrication. And pumping a cryogenic fluid requires a large volume of fluid, pumping mechanisms, extensive insulation, and heavy heat exchangers to transfer heat energy.

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