IEEE CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), No. 50, October 2021.
Invited presentation J3Or1A-01 given at CEC-ICMC 2021, July 19-23, 2021, Virtual.

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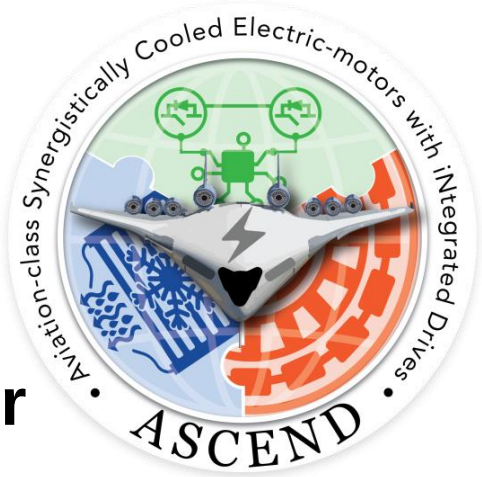
CHANGING WHAT'S POSSIBLE

Superconducting Motor and Cryo-Cooled Inverter Engine: SOARING

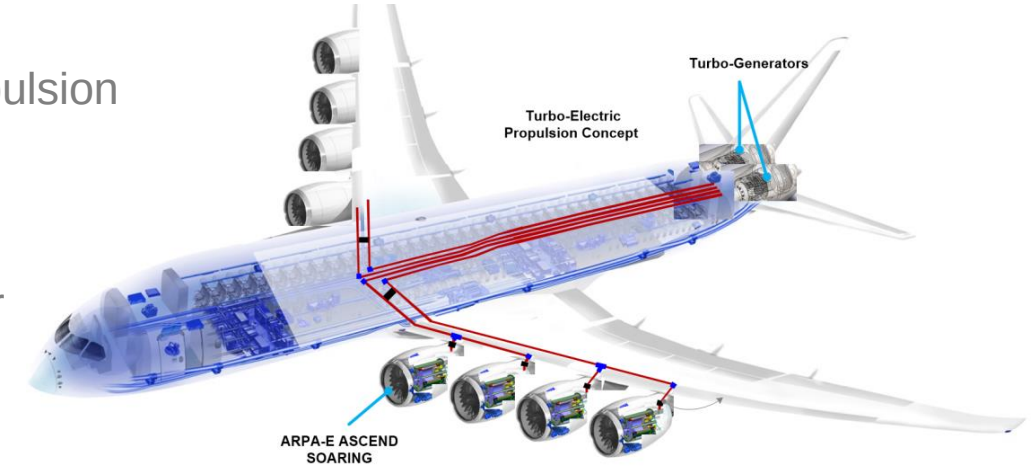
PI: Parag Kshirsagar, Raytheon Technologies Research Center



Project Vision

Disrupting Multi-MW Class Aircraft Propulsion through extreme power density:

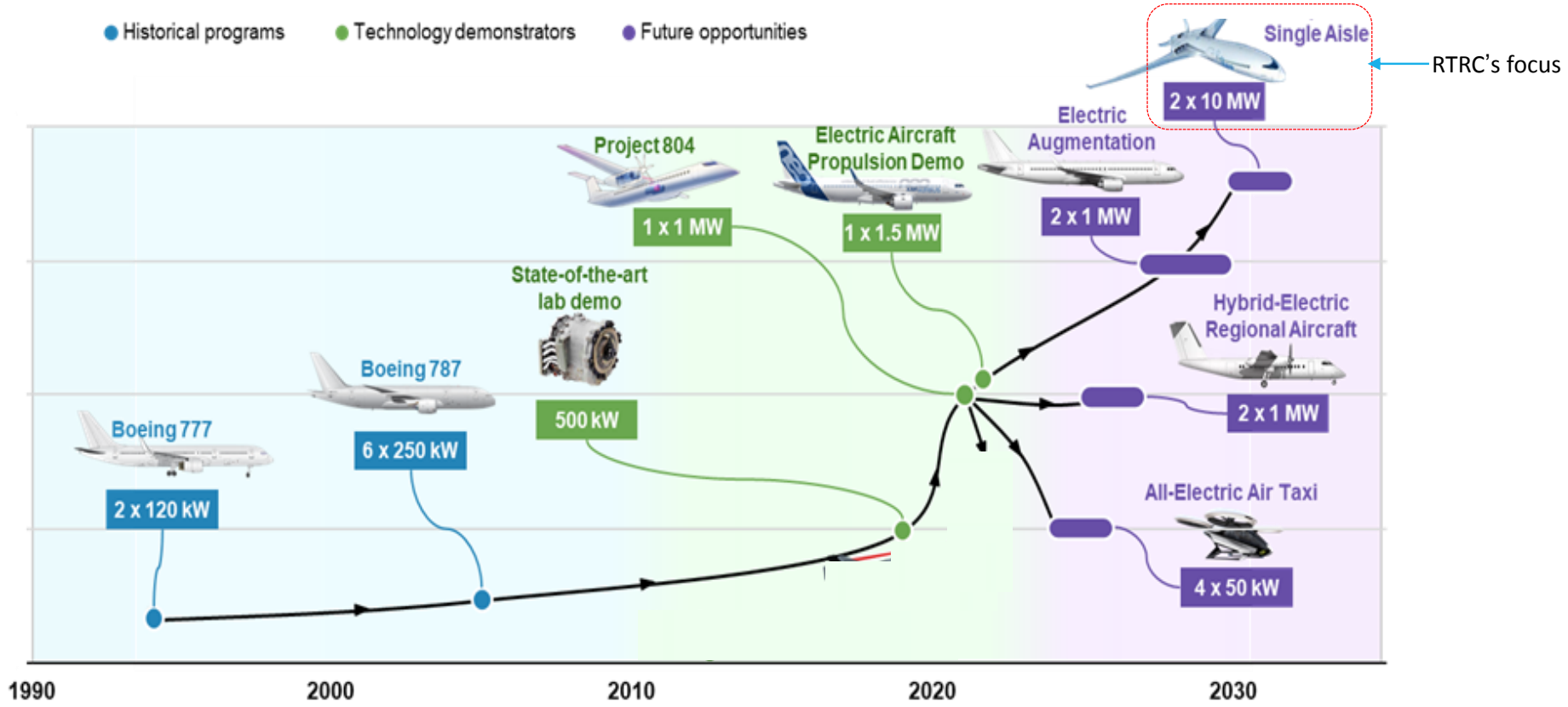
- Fully Superconducting AC motor
- Cryocooled motor drive and
- Adaptive Magnetocaloric Cryo-cooler



Raytheon Technologies
Pacific Northwest National Laboratory
The University of Tennessee Knoxville
Hyper Tech
The Ohio State University

Raytheon Technologies Aviation Electrification Trends

Historical perspective



- *Raytheon Technologies Research Center (RTRC) leading the way on extreme high power density propulsion motor and drive systems through corporate investments and external partnerships*
- *Technologies aligned with aerospace and defense business units*

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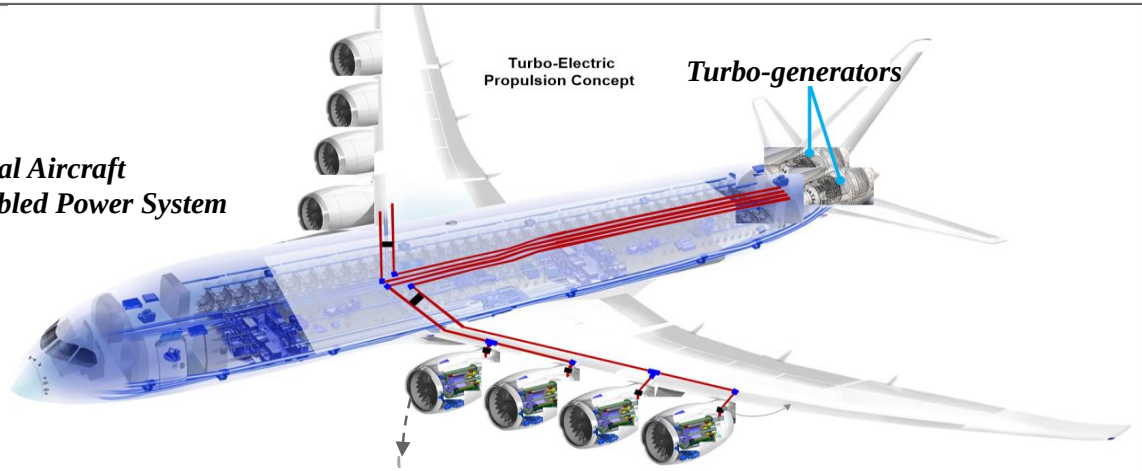
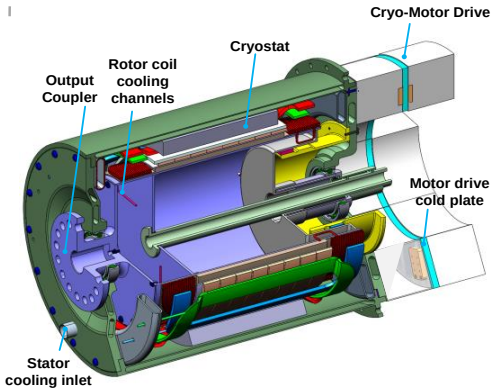
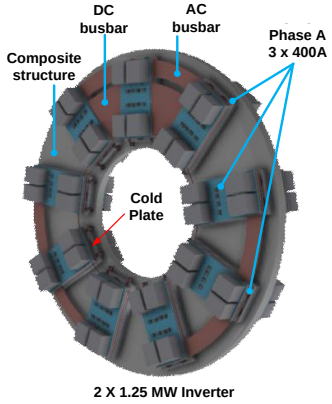
SOARING Overview

20MW Conceptual Aircraft
Cryofuel (Bio-LNG) Enabled Power System

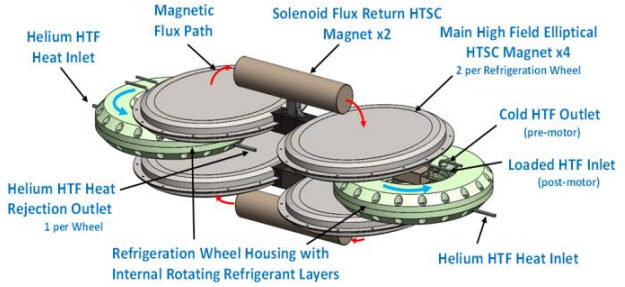




2.5MW, 5000rpm, 20K
Fully Superconducting Motor (ACSYM)



2.5MW, 120K
Motor Drive (CROWN)



Magnetocaloric cryocooler 120K to 20K
(AMAC)

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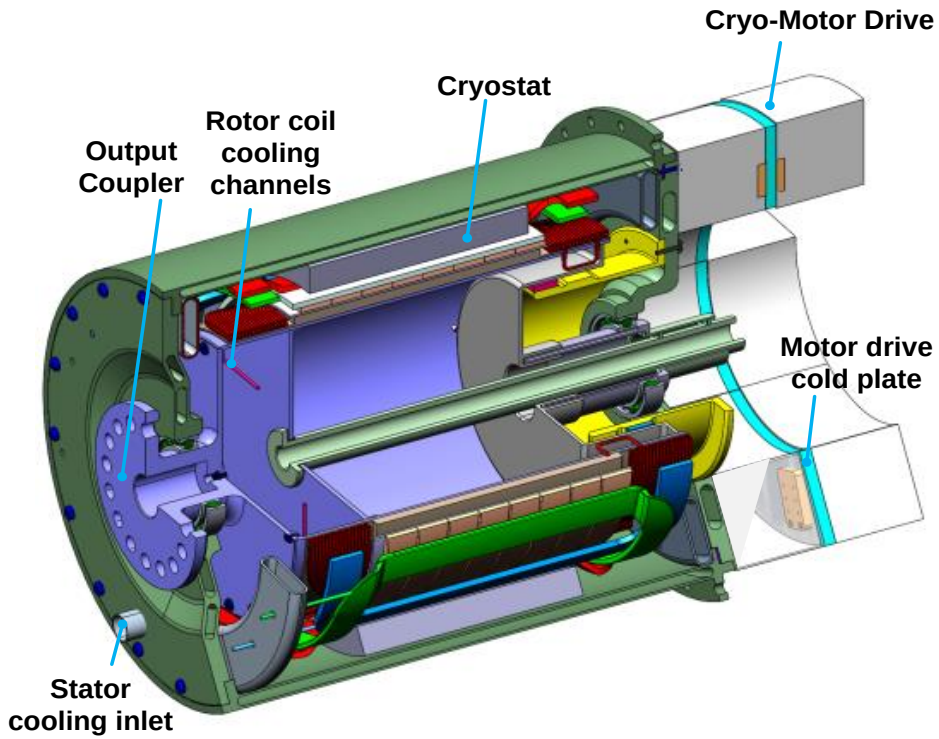
Air Core Superconducting Synchronous Machine (ACSYM)

2.5MW, 5000 rpm

- 2.5MW Fully Superconducting Motor (20K) with AMAC cryocooler and Bio-LNG (120K) as heat sink (Motor power density 2 to 3x SOA)
- High fundamental frequency, low loss AC winding
- Carbon fiber composite structure at cryogenic temperatures
- Integrated Motor Drive Power density > 12.5kW/kg with TMS (no- gearbox), Overall efficiency >93%



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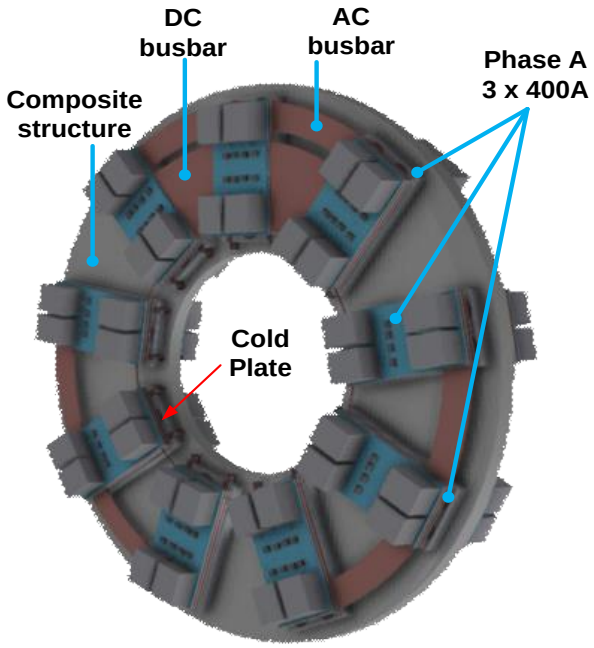
Cryo-cooled Multi-Level Converter (CROWN)

2.5MW, Vdc >1kV

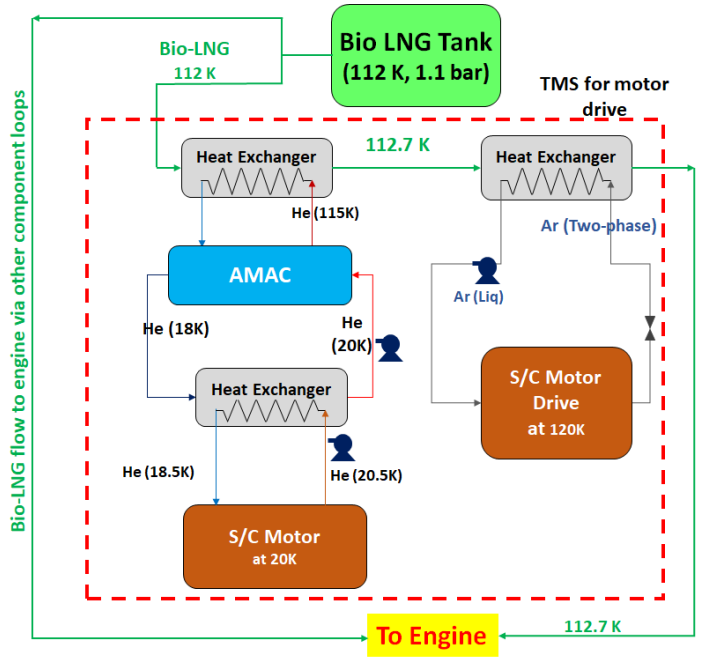
- 2 x 1.25MW Cryocooled Multi-level Motor Drive, (power density 3x over SOA)
- Cryogenically cooled GaN devices (low RdsON)
- Target 0.5% THD in currents without output filters
- Integrated motor drive power density > 12.5kW/kg with TMS (no-gearbox), Overall efficiency >93%



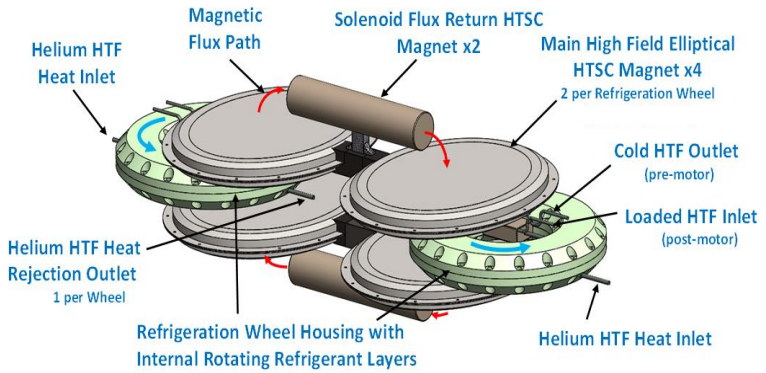
2 X 1.25 MW Inverter

Thermal Management System Details

Cryogenic TMS for 2.5 MW powertrain

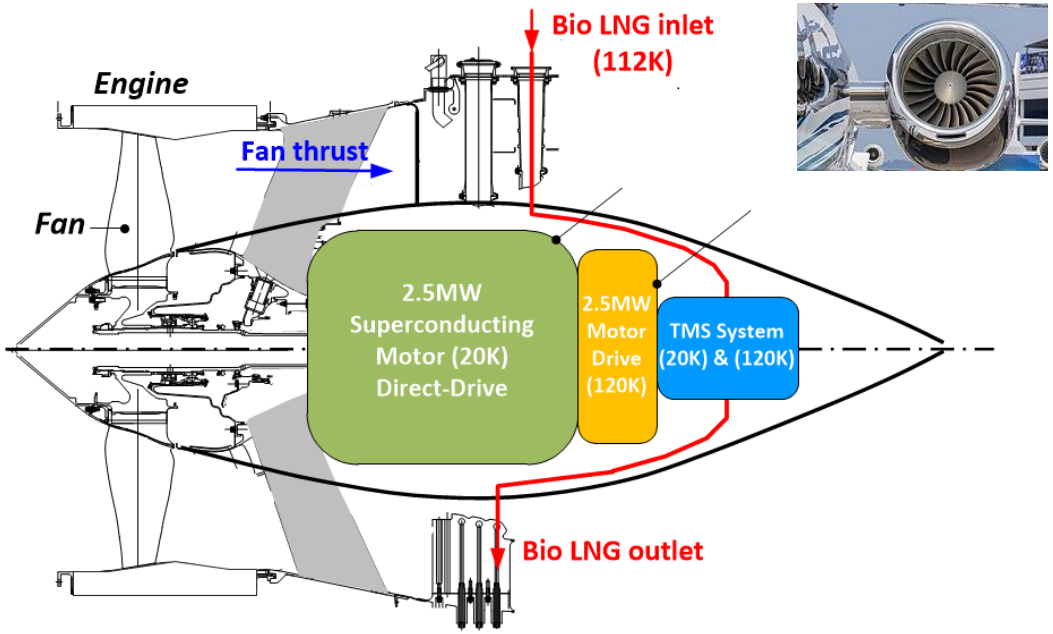


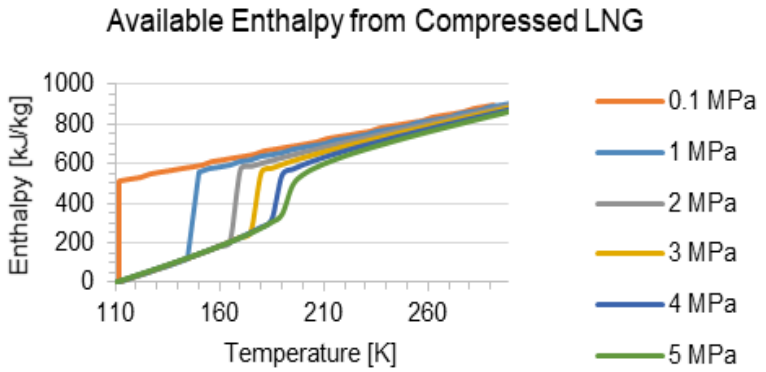
AMAC Cryocooler



- Motor cooled to 20 K by novel Advanced Magnetocaloric Adaptive Cryocooler (AMAC) with COP 3 times better than SOA cryocoolers and cooling capacity (W/kg) 3-4 times SOA. (Pull down from 120K to 20K). Cooling Power > 200W.
- Pumped two-phase loop at 120 K to cool motor-drive electronics through custom-designed light-weight cold plates
- Advanced optimized heat exchangers leveraging existing novel two-phase and single-phase heat transfer modeling tools

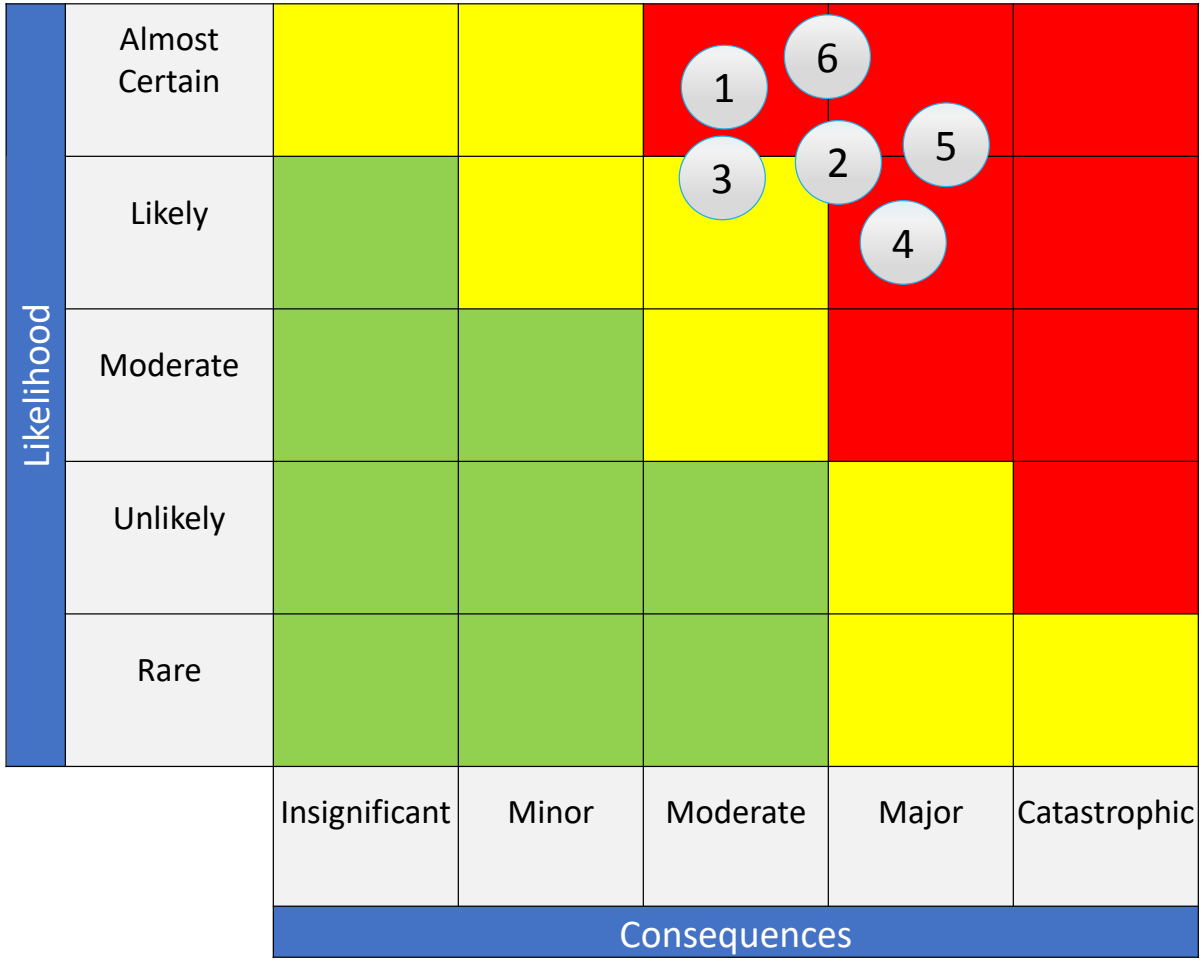
System Integration Details





- Bio-LNG, with latent heat of evaporation of 511 kJ/kg, Boiling point of 112.7 K at 1.1 bar, provides a formidable heat sink
- Ultra-light Cryocooler to pull down temperature from 120K to 20K
- Extreme high power density > 12.5kW/kg and efficiency >93% of the power train

Initial Risk Assessment



Risk	#
Manufacturing, support and cooling of the SC coils	1
Effectiveness of the seals at cryo temperatures	2
High lead losses between motor and drive	3
Weight of AMAC	4
High strength DC magnets for AMAC	5
Cost of the SOARING system	6

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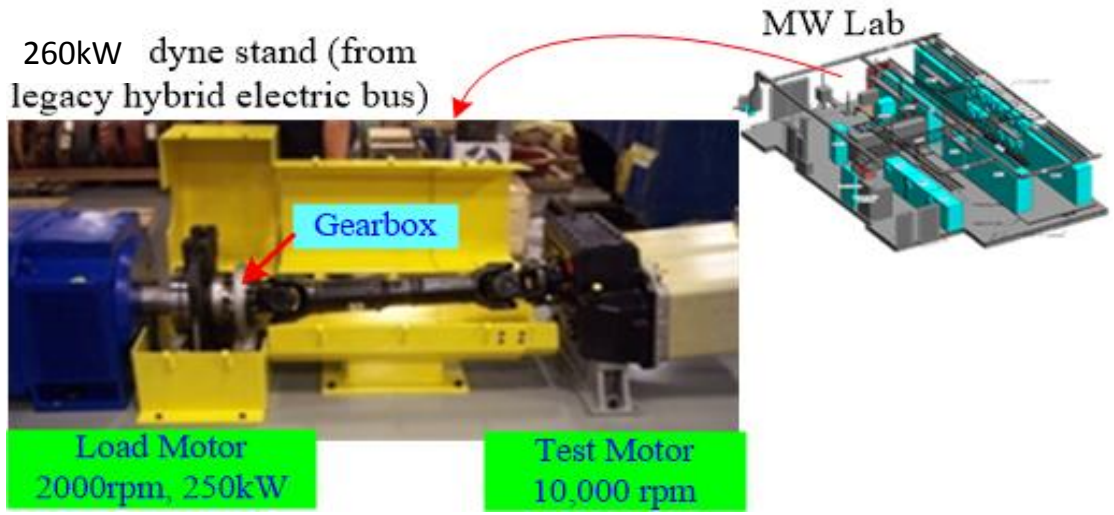
Task Outline & Technical Objectives

Phase 1

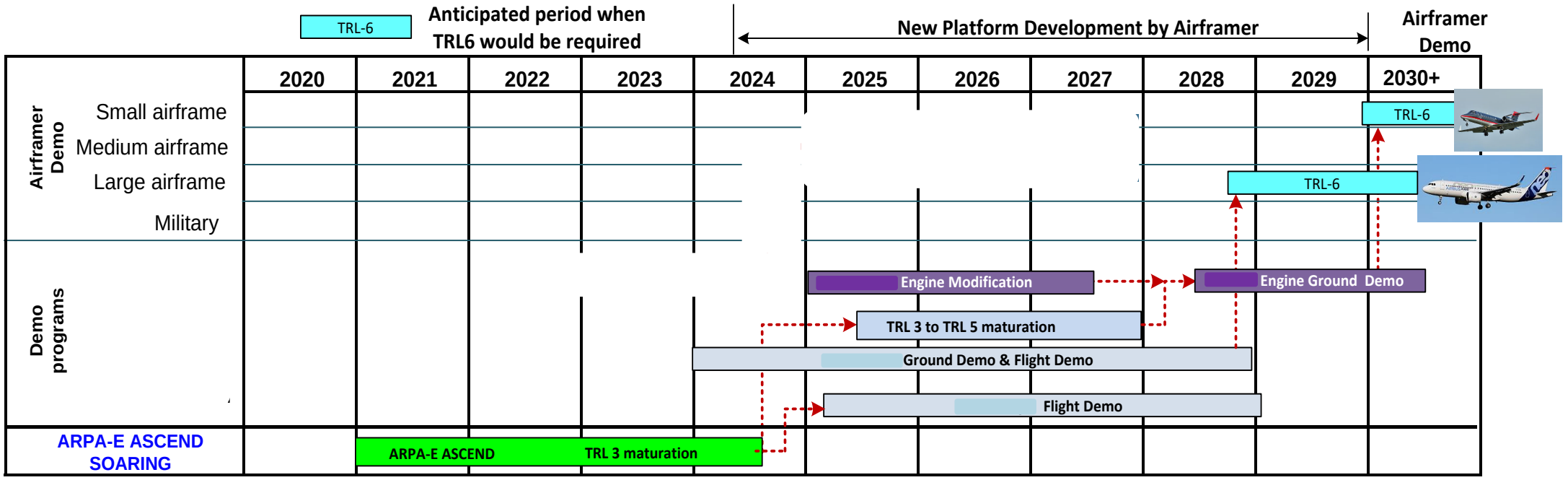
- Conceptual design of 2.5MW SOARING concept to meet FOA targets
- Demonstration of scaled down version of AMAC

Phase 2

- Detailed design of scaled down 260 kW demonstration.



Technology-to-Market Approach



Large demo programs will need partnerships with Govt. agencies (ARPA-E, NASA, Cleansky, UK ATI, etc.)

Q & A

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