National Aeronautics and Space Administration

Megawatt and Beyond, NASA's Electrified Aircraft Propulsion

Dr. Andrew Woodworth
Advanced Air Transport Technology Project, Aircraft Electrification Technical Lead
NASA Glenn Research Center, Materials and Structures Division

IEEE's Third Annual Workshop on Power Electronics for Aerospace Applications (PEASA25) • July 23–24, 2025 • Glasgow, Scotland, UK

The Megawatt Scale

Are EAP Aircraft Viable for 2030–35?

- Work started in 2014
- Concept vehicles
- Set key metrics
- Key component development
- Testbed development

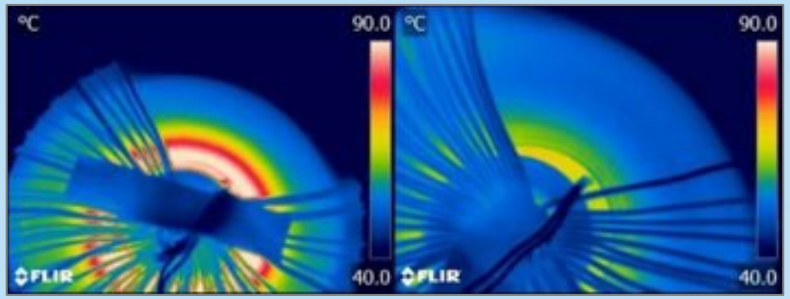
YES, EAP aircraft are viable for 2030–35.

Metrics for 1 kVA or greater power electronics

Performance Metrics	Specific Power (kW/kg)	Efficiency (%)
Minimum	12	98.0
Goal	19	99.0
Stretch	25	99.5

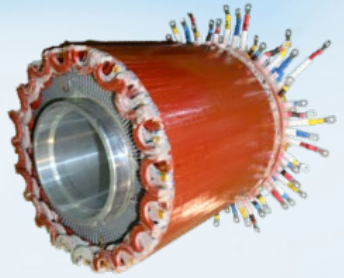
Metrics for MW scale electric machines

Performance Metrics	Specific Power (kW/kg)	Efficiency (%)
Goal	13.2	96.0



Thermal image of a magnetic core made of NASA's soft magnetic materials

NASA Electric Aircraft Testbed (NEAT)



NRA-sponsored electric machine

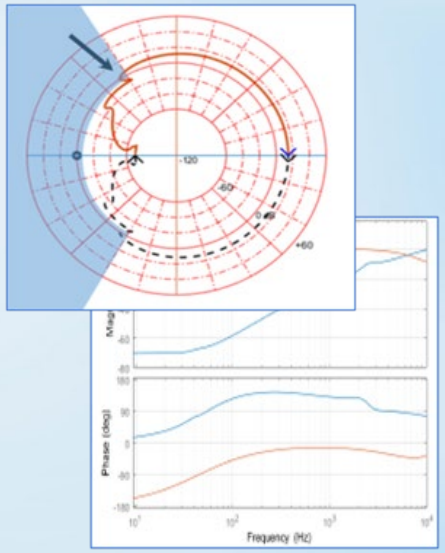
Credit: Kiruba Haran (UIUC)

NASA's STARC-ABL concept vehicle

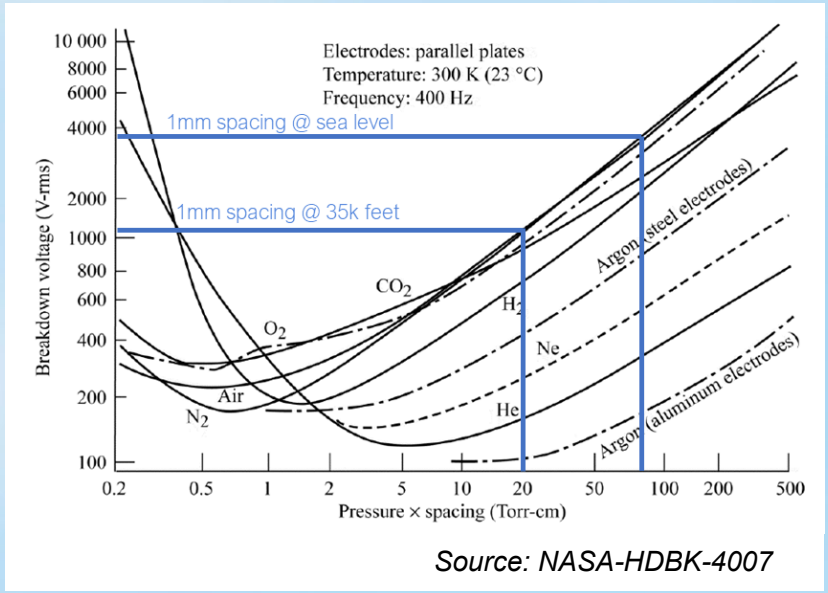
The Megawatt Scale

Can It Fly?

- Work started in 2019
- Technology maturation
  - Altitude compatibility identified as tall pole
- Fault management
  - DC circuit breakers
  - Propulsion controls
  - Power quality
- Thermal management



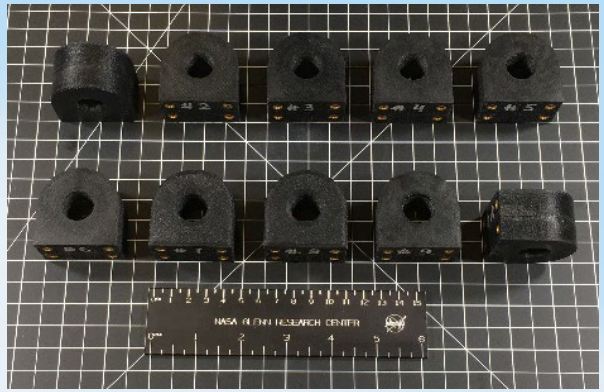
Power quality models



Source: NASA-HDBK-4007

Paschen's curve

NASA 250 kW inverter



Soft magnetic induction filters

Testing at the Megawatt Scale

NASA Electric Aircraft Testbed (NEAT)

- Created for AATT to perform R&D on MW-class powertrains
- Propulsion controls, power quality and stability, system-level effects, characterization and evaluation of new technologies
- Altitude chamber brought online to enable component and systems tests
  - GE MW-scale machine and altitude integration tests, and magniX 650 kW motor and drive
  - NASA ULI program's MW machine with integrated power electronics
  - Partnership with ARPA-E to test ASCEND motors (current test program): Wright Electric and RTX Research

Electrified Powertrain Flight Demonstration Project

- Demonstrators identify gaps in technology, integration, standards and regulation that need to be addressed for commercialization
- Maturing MW-class technology
- Maturing integration of EAP with an airframe
- Addressing standards and regulatory gaps
- Partnered with GE and magniX

Photo credit: NASA, GE, magniX

Yes, it can fly!

High-Power EAP

Systems of >10 MW (beyond mild hybridization)

Possibilities and Hurdles Assessment

Need new vison vehicles studies

- More complicated and more powerful system
- Propulsion controls
  - What will operability look like?
- Fault management
  - What will the new fault modes be?

Component development

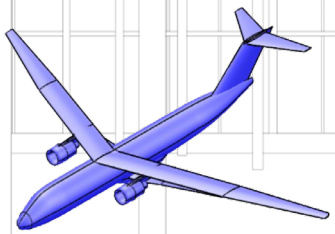
- Power density was a challenge for MW scale. Will that trend continue?
- Can components be efficient enough that thermal management is possible?

NASA Internal System Analysis and Integration

CONCEPT HANGAR

NASA N3-X

NASA STARC-ABL/ST-ABL/
SFC-ABL

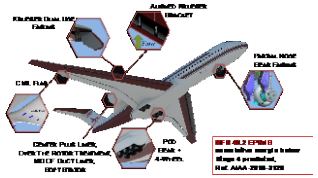


NASA TTBW(s)

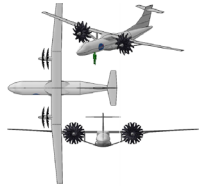
NASA PEGASUS

Over-Wing
Nacelle

NASA EAP Variants
of RJ Baselines



NASA MFN



Open Rotors

NASA D8

Future
Concepts

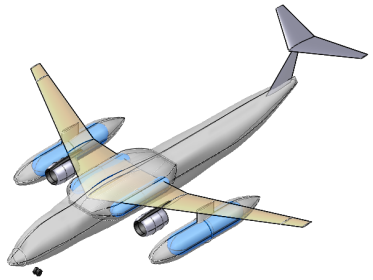
Other NASA Conceptual Studies

SUSAN

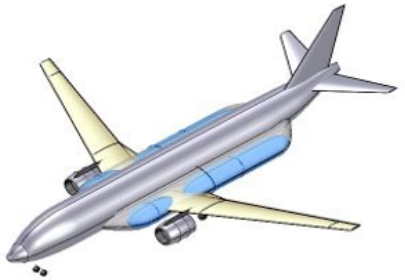
SUbsonic Single Aft eNgine

CH_2ARGE

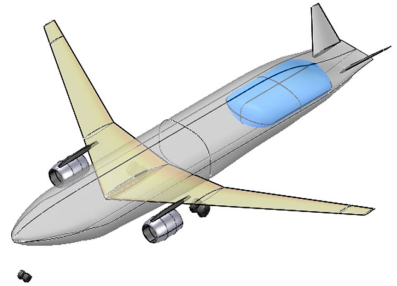
Commercially-viable Hydrogen Aircraft for Robust Growth in Efficiency



"External Tank" LH2 Carriage 150 PAX Aircraft



"Wide Baseline" 150 PAX Aircraft (LH2 Carriage)



Internal LH2 Carriage 150 PAX Aircraft – "HWB"

HETCOF

Hybrid Electric Turboprop Commercial Freighter

NASA External Engagement

NASA SA&I Contracts

Future Scenarios Development

Technology and Subsystem Exploration

- Technology and Subsystem Exploration Trade Studies
- Technology Development Roadmaps

Aircraft Concept Exploration

- Aircraft Exploration Trade Studies
- Detailed Aircraft Description Task
- Aircraft Concept Development Roadmaps

Current Engagement

- Aerospace Systems Design Laboratory (GT)
- Aurora Flight Sciences (a Boeing company)
- Electra.aero
- JetZero
- Pratt & Whitney

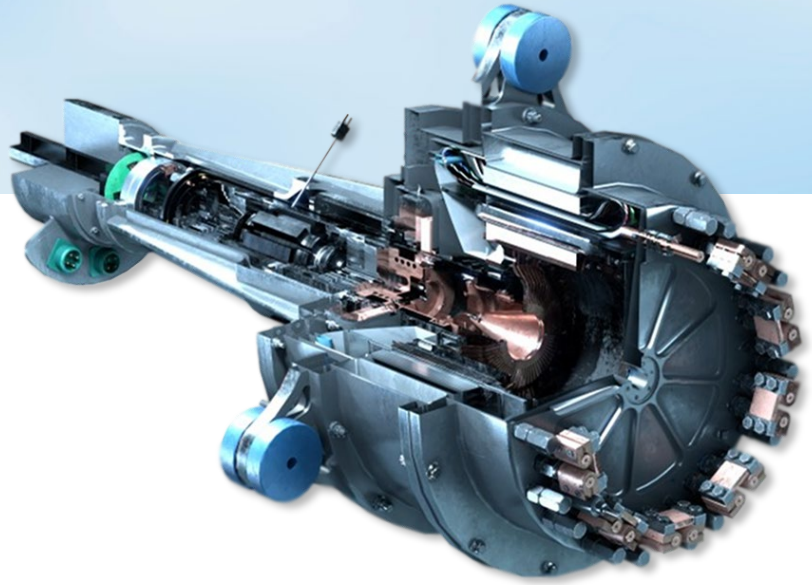
University Leadership Initiative

IZEA (Integrated Zero Emission Aircraft)

CHEETA (Center for High-Efficiency Electrical Technologies for Aircraft)

High-Power EAP Technology

- Draw from conceptual aircraft studies to guide technology development
- Propulsion controls and fault management studies
- Superconducting machine technology
- Compatible power electronics
- Materials



Is superconducting technology ready to contribute?

- An increasing number of concepts utilize superconducting technology
- Significant risk/reward
- The only way to answer the question is to dig into the details of the technology

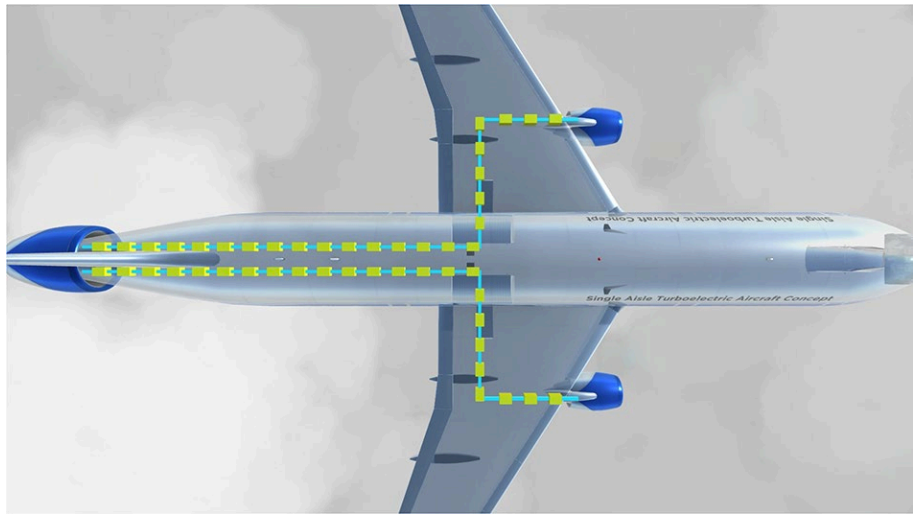
Propulsion Controls

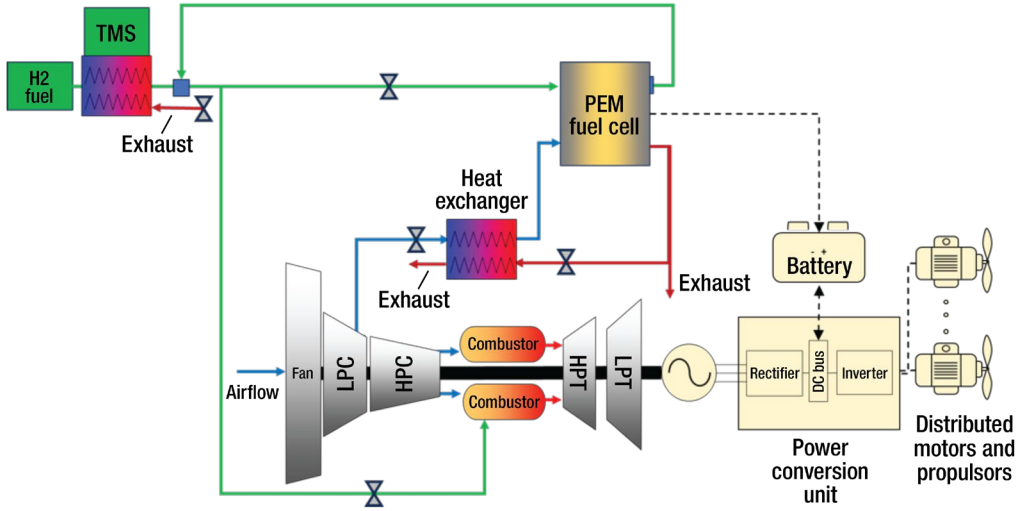
System-Level Control of Flight-Critical Propulsion Controls (first step)

- How to maintain operability during transients throughout the flight envelope?
- Complication: Many more disparate subsystems
  - Turbine, electrical power system, fuel system, energy and thermal management of all systems

Fault Management (second step)

- How to maintain operability of the aircraft if a subsystem fails?
- What redundancy is necessary to maintain operability through a fault condition?





Superconducting Machine Technology

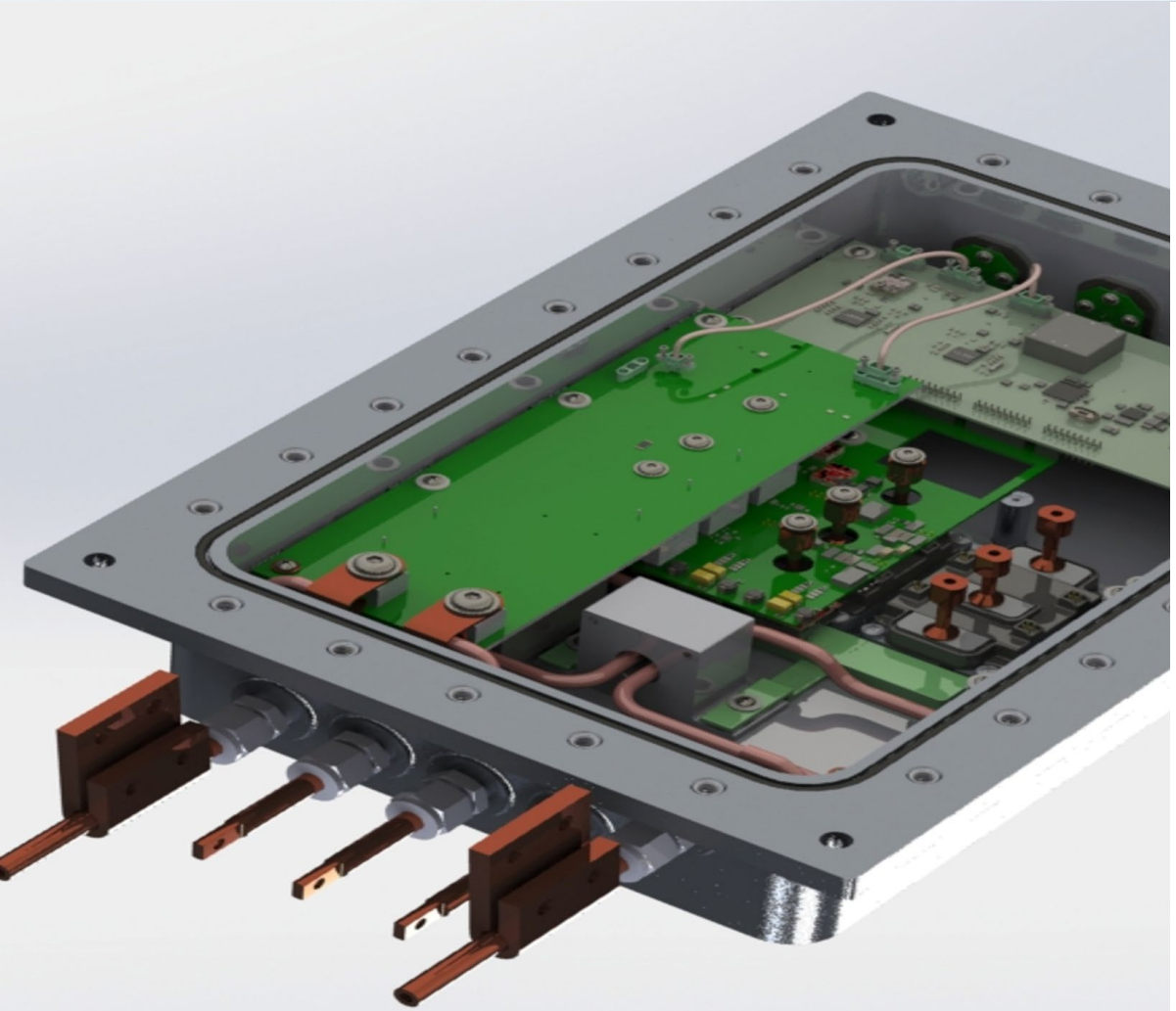
Robust Superconducting (SC) Machine

- Preliminary design for 5 MW machine (capable of driving a fan)
  - Superconducting rotor
  - Low-AC-loss stator winding and thermal management approach
    - Down-select among fully SC and fully cryogenic options
  - Subscale machine and drive TRL 3 demo
- Overall thermal management approach
- Robust cryo-capable 5 MW drive

Key Challenges

- Low-AC-loss stator
- Issues arising from high current
- Safe high-voltage systems
- Weight
- Thermal management
- Power quality and reliability
- Materials and manufacturing

Power Electronics



Compatible With a Cryogenic Stator

- Planning to operate at the cryogenic stator temperature
  - Minimize heat injection to the stator
  - Take advantage of efficiencies at cryo-temperatures
- Low noise and low total harmonic distortion (THD)
  - Electrical noise creates losses in the electric machine
  - THD creates electrical losses in the electric machine

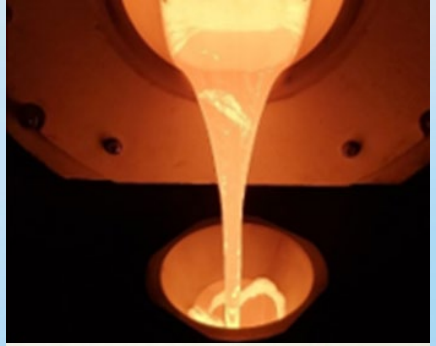
Materials

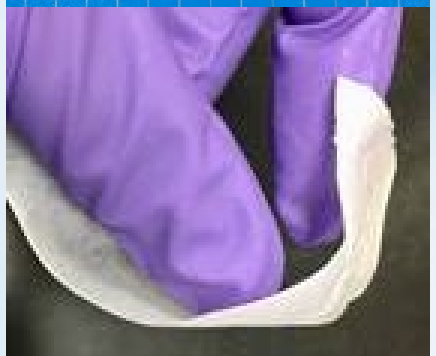
Electric Machine Insulation and Structures

- Reduce thermal stress in the application
- Must endure thermal cycling while maintaining properties
- Enable thermal management solutions

Nanocrystalline Soft Magnetic Materials for Induction Filtering Applications

- Currently capable of creating engineered filters from nanocrystalline material
- Update standards for inductive components
  - Standards currently insufficient for systems utilizing advanced power electronics
- Refine in-house testing of induction filters
  - Produce widely meaningful and relevant publicly available data
- Improve inductive component modeling to better inform complex circuit models



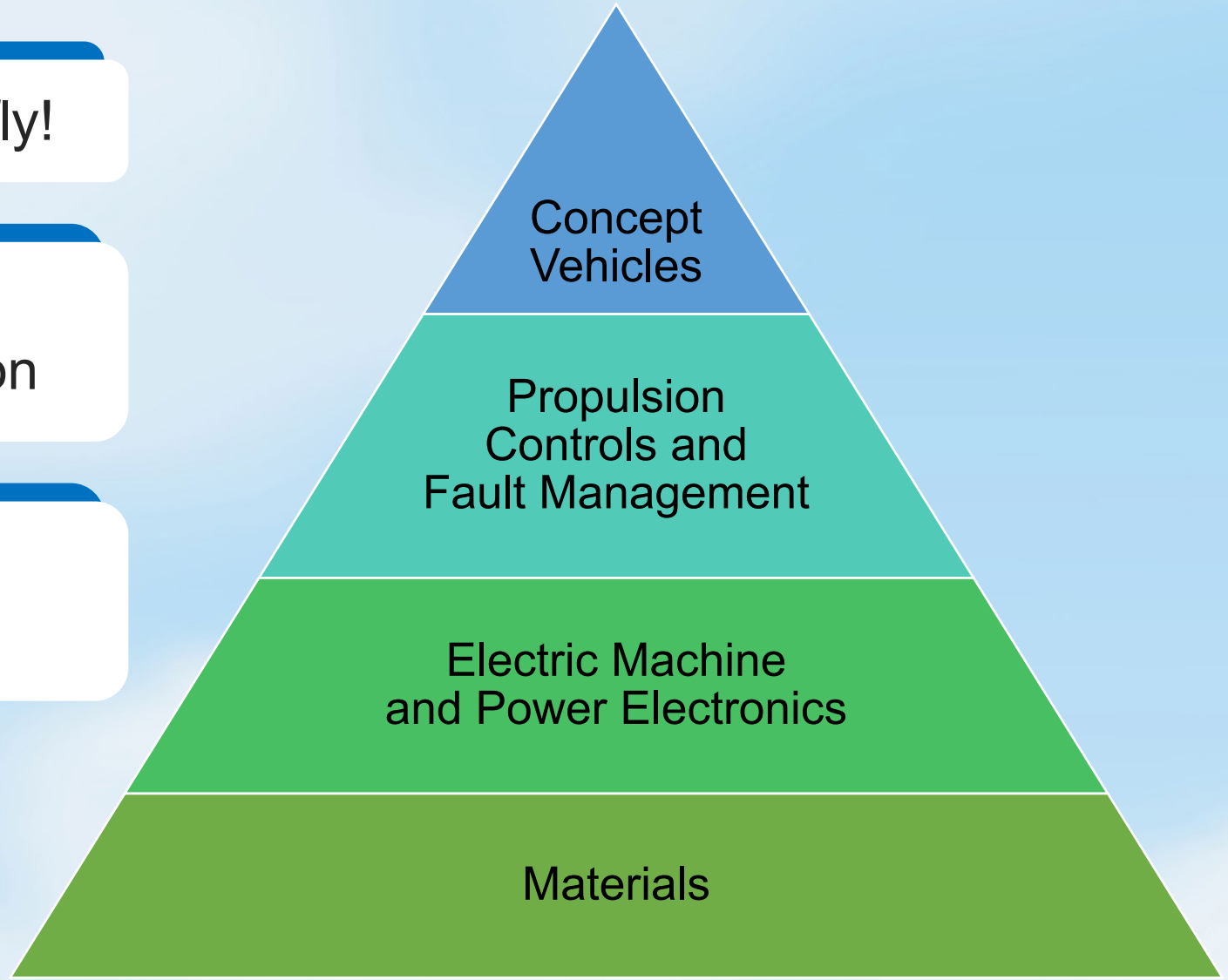


Final Thoughts

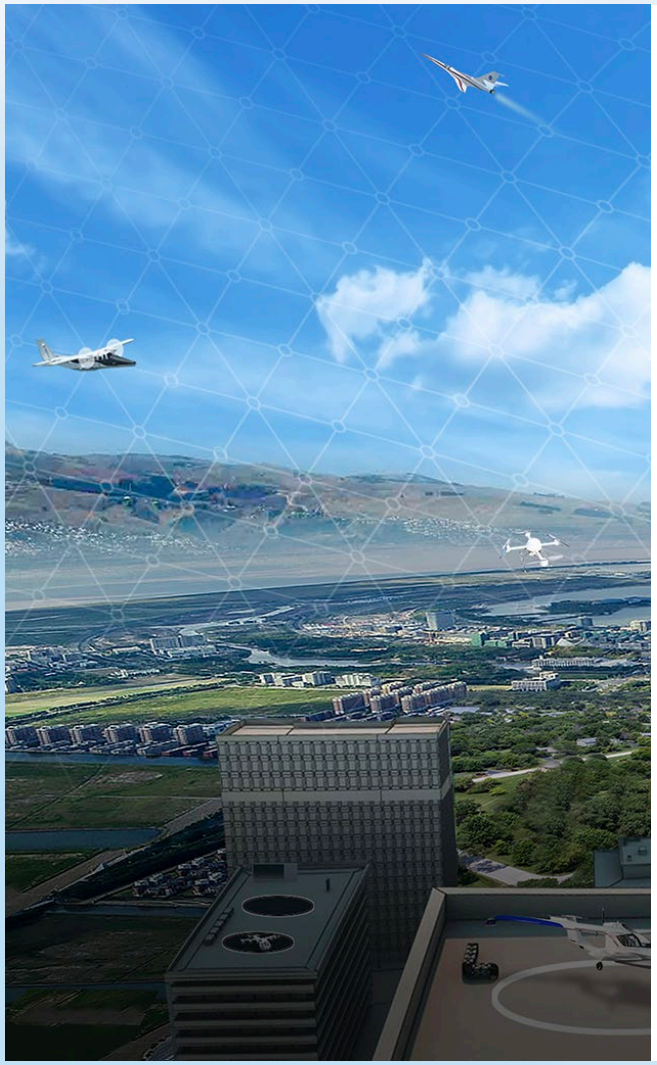
Yes, MW is viable and it can fly!

But…MW scale only gets partial propulsion electrification

Need systems capable of >10 MW (High-Power EAP)



NASA Stakeholders



Advanced Air Vehicles Program

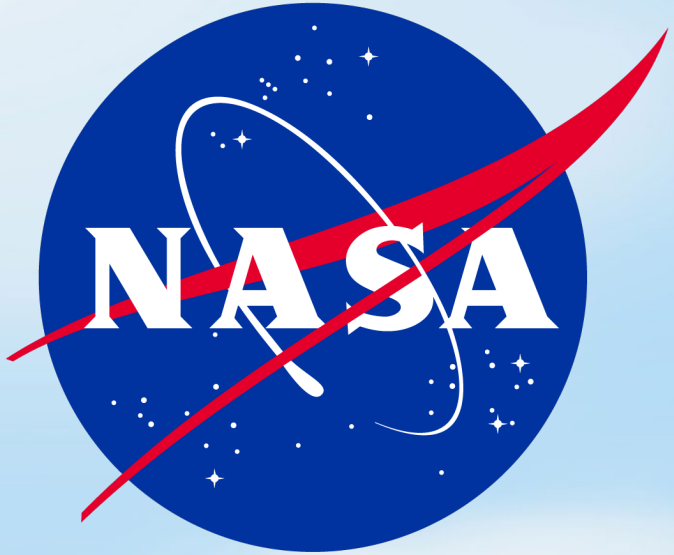
- Advanced Air Transport Technology Project
  - Aircraft Electrification Subproject
- Hybrid Thermally Efficient Core Project

Integrated Aviation Systems Program

- Electrified Powertrain Flight Demonstration Project

Transformative Aeronautics Concepts Program

- Transformational Tools and Technologies Project
- University Innovation Project


NASA