



NASA AERONAUTICS

NASA Power and Thermal Technology Overview

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Dayton, OH

The Aviation Carbon Reduction Challenge



- By 2050, an estimated 10 billion passengers will fly each year a distance of 22 trillion revenue passenger kilometres.
- With today's fleet and operational efficiency, this activity would require over 620 megatonnes (Mt) of fuel and generate close to 2000 Mt of CO₂.
- Imagine enabling the same level of demand while reducing net CO₂ emissions to zero by 2050.



Aviation Pillars for a Sustainable Future

National Aeronautics and
Space Administration



Global Aviation Industry GOAL: net-zero carbon emissions by 2050

TECHNOLOGY



NASA = Primary Role

SUSTAINABLE
AVIATION FUEL



NASA = Supporting Role

OPERATIONS
AND INFRASTRUCTURE



NASA = Primary Role

NASA EAP REPRESENTATIVE ACTIVITIES

National Aeronautics and
Space Administration



NASA has executed a plethora of EAP activities over the last 10 years and is in the process of advancing the future of sustainable flight. Work spans from fundamental research to flight demonstrations.



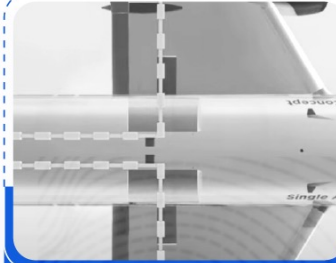
X-57, 100kW class flight demo of all electric distributed propulsion.



Revolutionary Vertical Lift Technology Studies of Electric, Hybrid, Turboelectric Concepts and Technology.

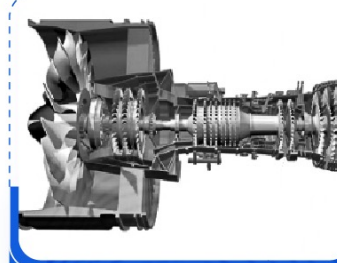


Electrified Powertrain Flight Demo – ground & flight demonstration of integrated MW-class powertrain.



Advanced Air Transport Technology/Propulsion & Power Subproject - powertrain technology

Transformational Tools & Technology – EAP materials & modeling.



Hybrid Thermally Efficient Core (HyTEC)

Advanced turbine engine technologies in a high-power-density core.



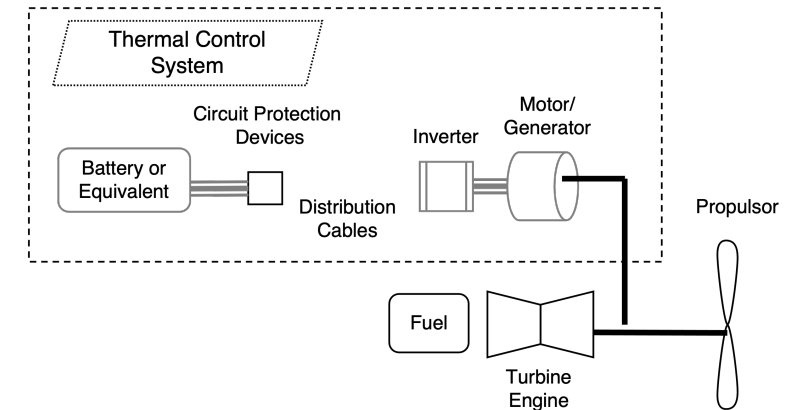
SUSAN – A 20 MW hybrid-electric aircraft concept study featuring a single aft engine with distributed wing-mounted propulsors.

NASA Electrified Powertrain Flight Demonstration

National Aeronautics and
Space Administration



- Electrified Powertrain Flight Demonstration (EPFD) project:
 - Partnership with U.S. industry to establish and demonstrate integrated megawatt-class powertrain systems.
- EPFD Goals:
 - Accelerate US industry technology readiness and competitiveness
 - Facilitate new aviation industry S – Curve for electrification
 - 2030-2035 Entry Into Service: Next generation thin haul, regional and Single-Aisle markets
- Regulations and Standards will play a large role:
 - NASA is partnering with industry to identify the regulatory and standards gaps that may exist for the highest priority electric technologies and gather data to support future regulations and standards development.





NASA has selected two U.S. companies to that will rapidly mature Electrified Aircraft Propulsion technologies through ground and flight demonstrations.

GE Aviation, \$179M

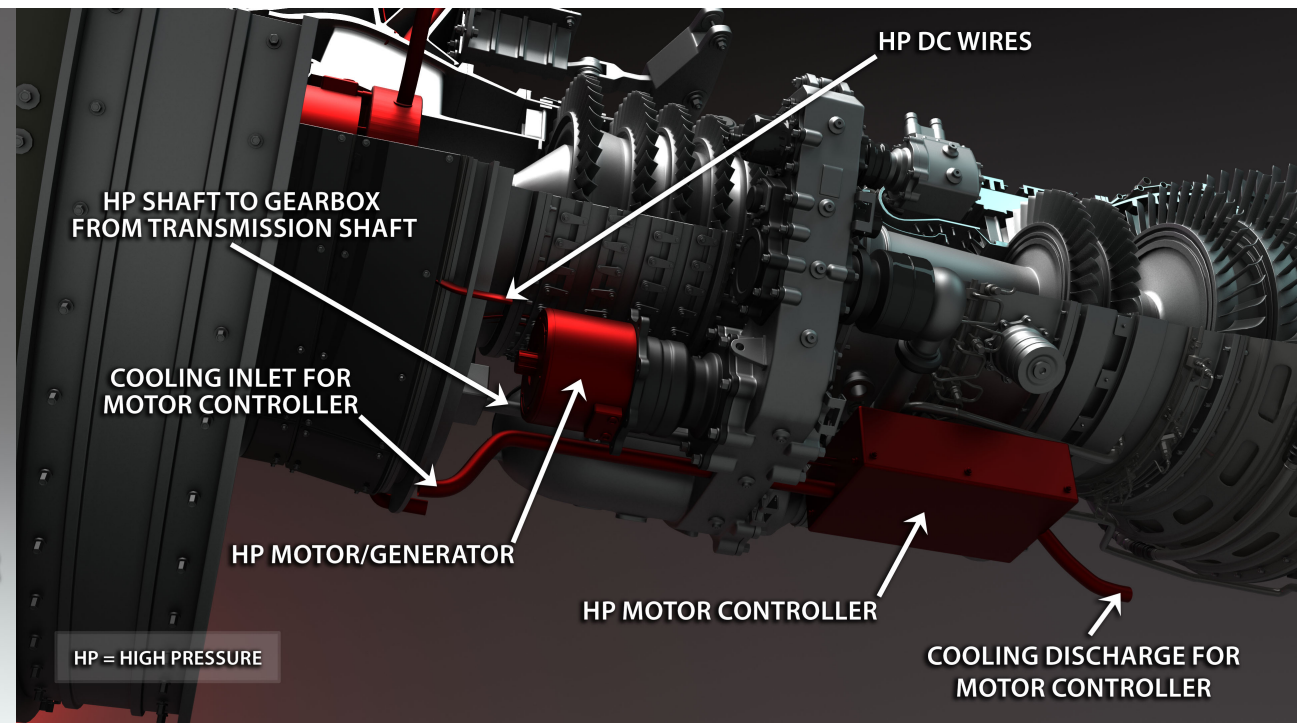
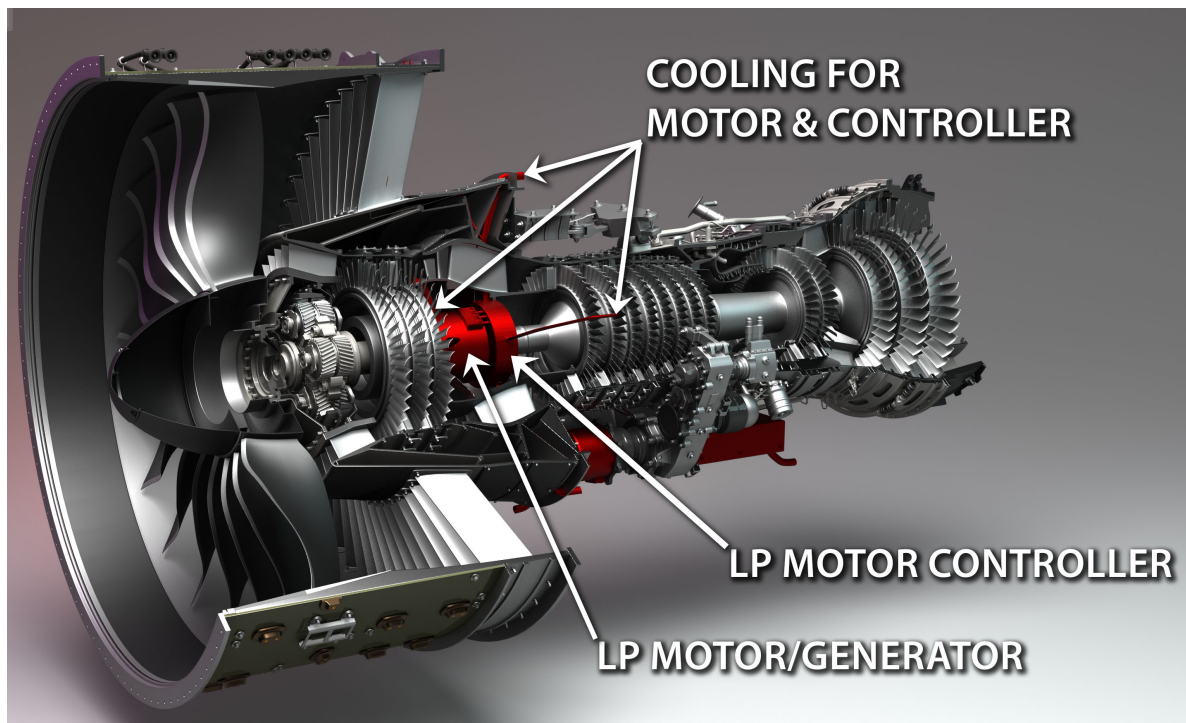
- Partnered with Boeing to modify Saab 340B powered by GE CT7-9B turboprop engines
- Megawatt-class and multi-kilovolt hybrid-electric propulsion system tested in simulated altitude conditions at NASA NEAT facility
- Ground tests are a key step in technology development for a hybrid electric propulsion system for flight tests later this decade.

magniX, \$74.3M

- Partnered with Air Tindi and AeroTEC
- Aims to demonstrate electric propulsion technology to power a hybrid De Havilland Canada Dash 7 aircraft, with first flight planned for mid-2020's
- The retrofitted aircraft will be powered by two PT6 engines and two magni650 electric propulsion units (EPUs)

Hybrid Thermally Efficient Core – PEx Key Performance Parameter:

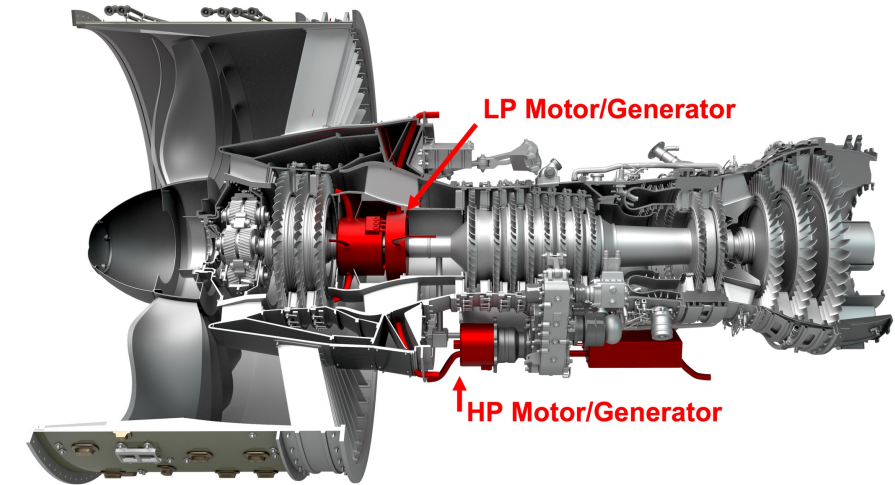
- Achieve 10% to 20% power extraction at altitude from a modern commercial turbofan engine with the thrust, efficiency, operability, and durability to enable the benefits of electrified aircraft propulsion at a vehicle level.



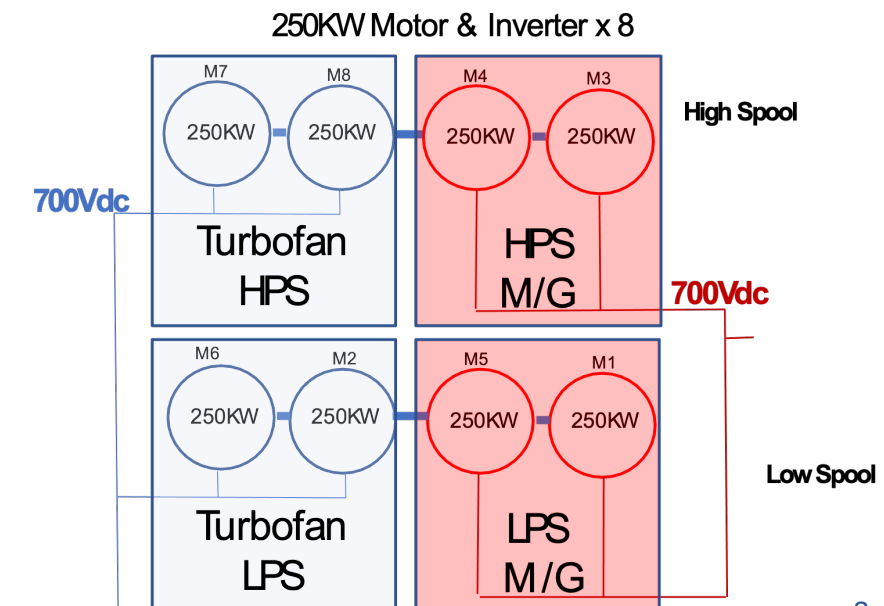
NEAT TEEM Controls Test



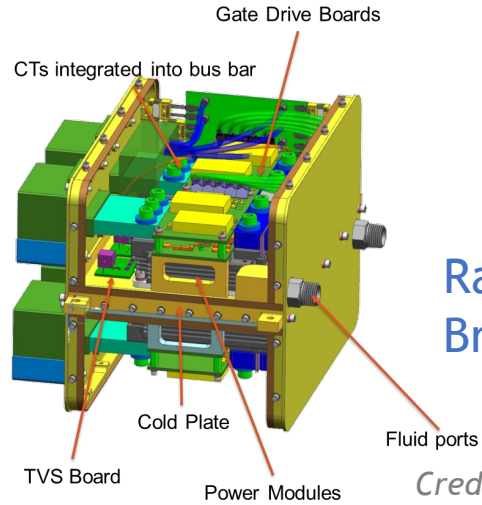
- **Background:** Focused on evaluating advanced control logic for EAP conceptual designs that combine gas turbine and electrified component technology to reduce fuel burn and emissions.
- **Test Objectives:** Turbine Electric Energy Management (TEEM): Real-time demonstration of a control concept of optimizing the energy usage of a hybrid-electric propulsion system during transient operation.
- **Results:** Demonstrated dynamics of full-scale hybrid turbofan model and mechanically coupled EM system using Adaptive Sliding Mode Inertia Controller and Scaling algorithm.



Hybrid Turbofan Concept



NEAT TEEM Hardware Configuration



Raytheon Circuit
Breaker

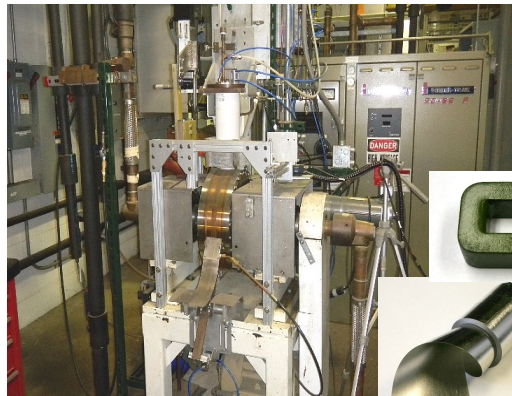
Credit: Raytheon Technologies

Circuit Breaker (MW scale, ~1kV, 1000A)

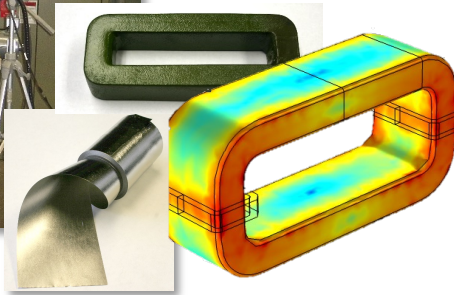
- Pratt and Whitney (P&W, RTX, and Collins Aerospace)
- General Electric Aviation (GEA and GE Research)
- Naval Post-Graduate School-POC: Rodger Dyson (rodger.w.dyson@nasa.gov)

Materials Studies

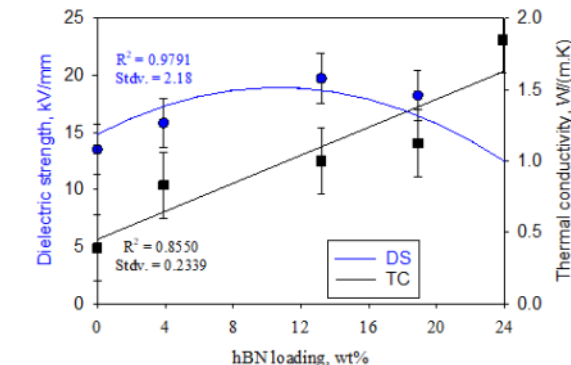
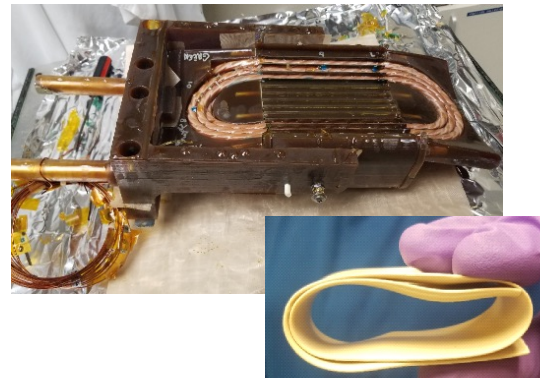
- Custom devices from NASA soft magnetic materials
- Lifetime modeling for insulations systems
- Multifunctional insulation systems for electric machines



Custom annealed,
impregnated, powder-
coated Core



Electric Machine Insulation



Addresses key requirements for Megawatt, Kilovolt systems at altitude

POCs: Dr. Alex Leary-Magnetic Passive Components (alex.m.leary@nasa.gov), Dr. Andrew Woodworth-Electric Machine Insulation and Fault Management work (andrew.a.woodworth@nasa.gov)

SUBsonic Single Aft eNginE (SUSAN) Electrofan



Problem: Aircraft emissions must be reduced by at least a factor of two, with a goal of zero emissions.

Constraint: Must use existing airport infrastructure, be flight certifiable, and be more cost effective

Solution To Be Developed: Hybrid Electric Large Aircraft

Concept

Regional Low-Cost Carrier Airliner Concept (EIS 2040)

- Hybrid Electric Distributed System
- 20MW Total Power
- Single Aft Mounted Turbogenerator (BLI)

Features

Payload	180 passengers
Range (design/economic)	2500/750 miles
Speed	0.80 Mach
First Flight	TBD

Key Technologies

Distributed propulsion with airframe integration
Turbofan that both produces thrust and drives generators
Electric Motor System, Drives, Cables
Advanced batteries: metal air and others

Solid-State Dynamic Thermal Management System

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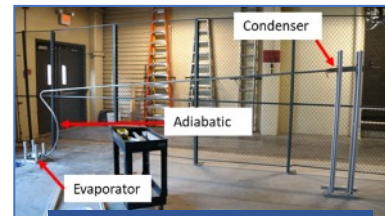
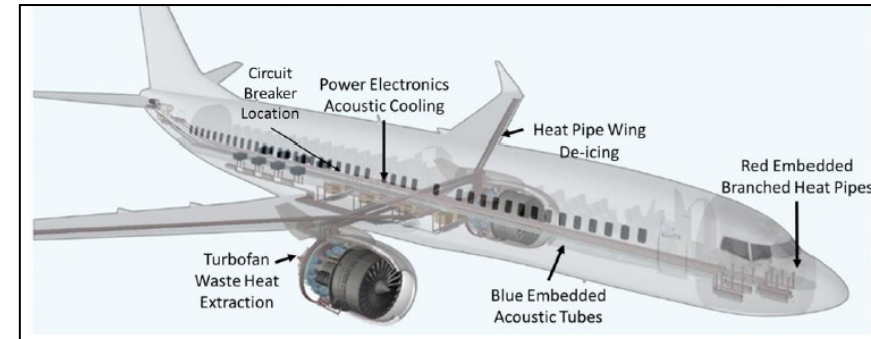


- **Solid-State Exergy Amplification**

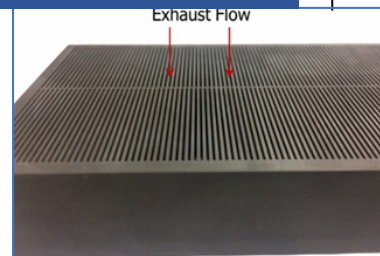
- No moving parts
- No pumped fluids
- No increased drag
- Maximize specific power
- Improve powertrain efficiency

- **Areas of Development**

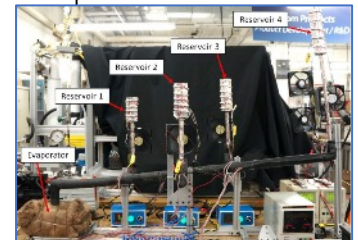
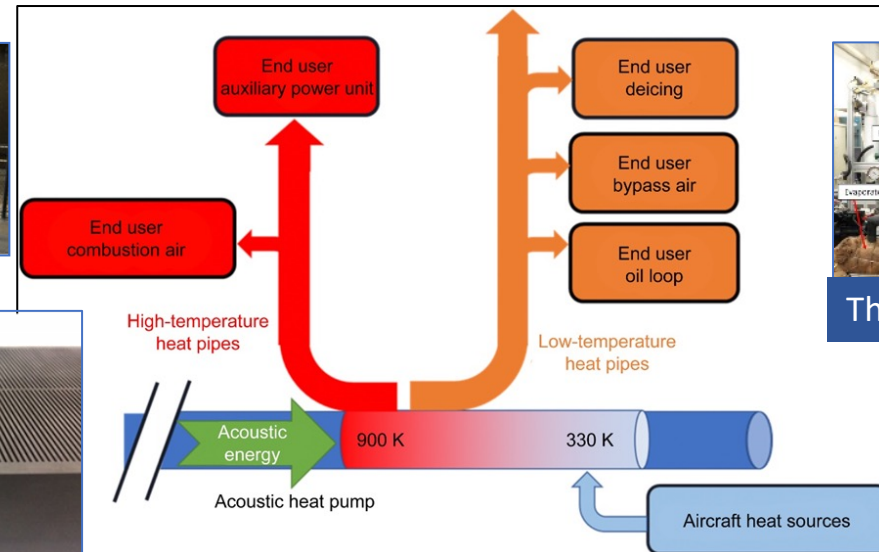
- Turbofan WHR HX
- Acoustic Heat Pump
- OHP Heat Collection
- Thermal Transport
- Thermal Recycling
- Dynamic Thermal Redirection
- Gradient-based System Optimization



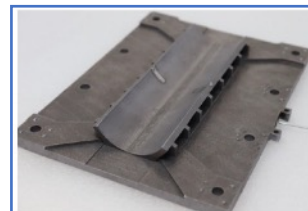
Thermal Transport



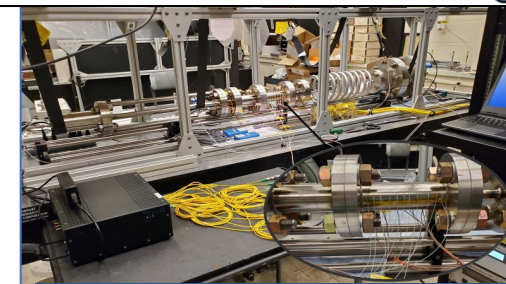
Waste Heat Recovery



Thermal Redirection

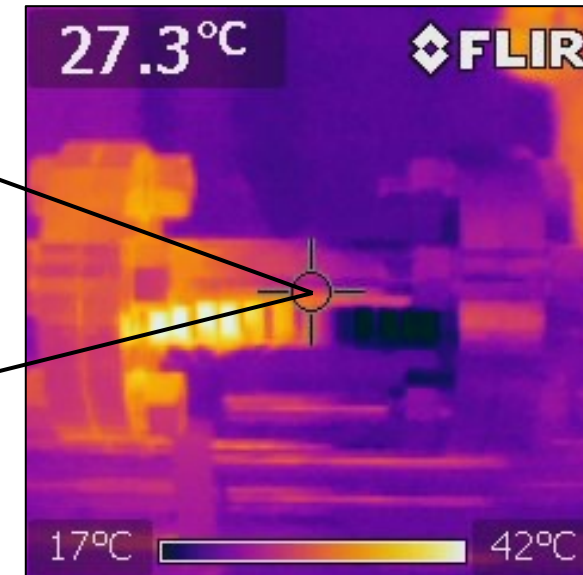
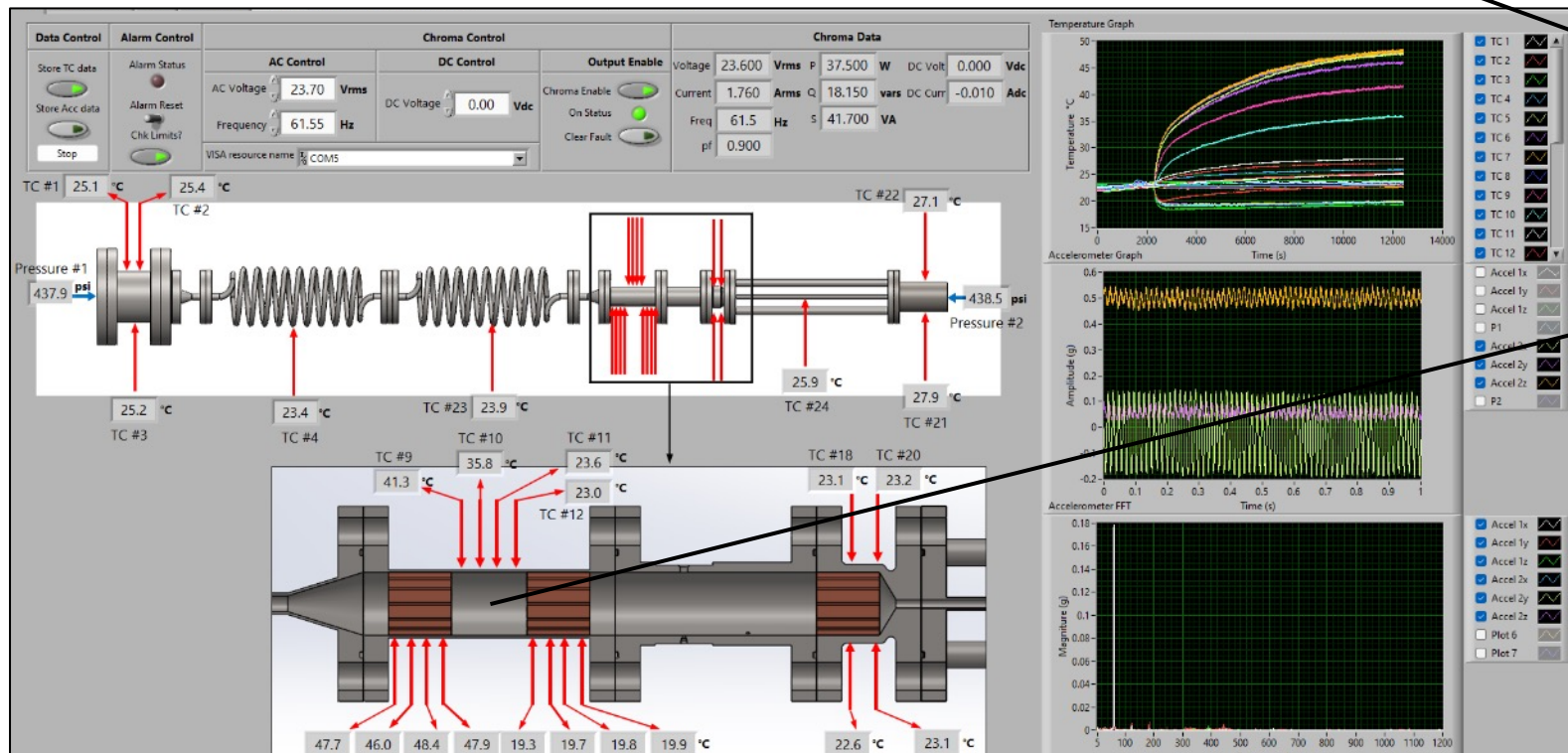


OHP Heat
Collection



Acoustic Heat Pump

10-meter Acoustic Heat Pump Prototype Test Results



Thermal energy heat pump at single location along 10-meter tube with no detected acoustic waveguide tube heating

NASA IS INVESTING IN ELECTRIFIED
AIRCRAFT PROPULSION (EAP) TO
ENABLE A NEW TECHNOLOGY S-CURVE
OF INNOVATION IN AVIATION

NASA is broadly investing in Electrified Aircraft Propulsion (EAP)

NASA investments are guided by a combination of potential market impacts and technical key performance parameters.

The impact of EAP varies by market and NASA is considering three markets: on-demand mobility, regional and national/international air transportation.

Technical advances in key areas have been made that indicate EAP is a viable technology.

Flight research is underway to demonstrate integrated solutions and inform standards and certification processes.

Additional work is needed to transition the technology to a commercial product and further improve the technology to realize the benefits across the world.