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NASA Electric Aircraft Testbed (NEAT) Summary of Capabilities

Version 3.0, July 2024

Amy Jankovsky, Nuha Nawash, and José Méndez
Glenn Research Center, Cleveland, Ohio

March 2025

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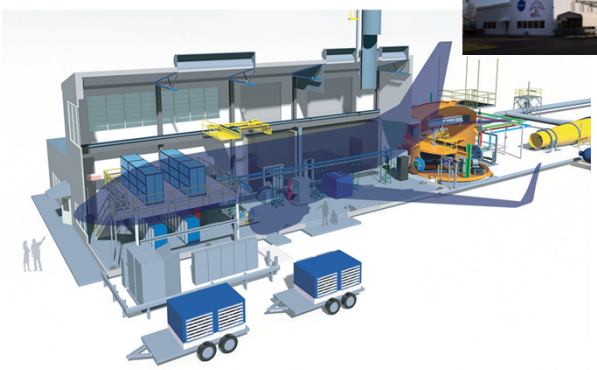
Electrified Aircraft Propulsion

NASA Electric Aircraft Testbed (NEAT)

- Designed to enable end-to-end development and testing of the electric portion of MW-scale electrified aircraft powertrain systems
- Designed with a reconfigurable architecture that industry, academia, and Government can utilize to further mature electrified aircraft technologies.



Capability

- Potential to power up to 12 MW (more if regenerating)*
- Cooling tower with 950 kW cooling capacity (additional chillers, etc. can be used as well)
- Altitude (up to 60,000 feet pressure)

**3 kVA available as 480 V AC three phase power to date on our sub-station E*

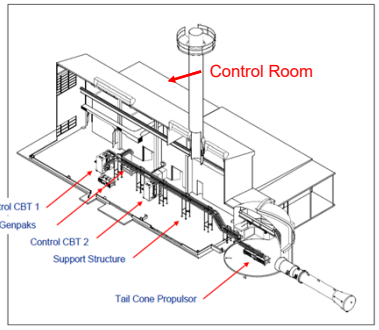
Electrified Aircraft Propulsion

NASA Electric Aircraft Testbed (NEAT)

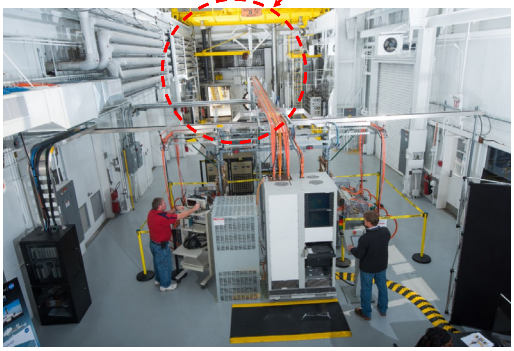
Main Test Area

- Test area large enough for 737-class electric powertrain (sea level)
- Pictures show NEAT in 2017 STARC-ABL configuration
  - 500 kW subscale, simplified electrical architecture
  - Sea Level (chamber used for horizontal space only)

STARC-ABL Testbed Configuration



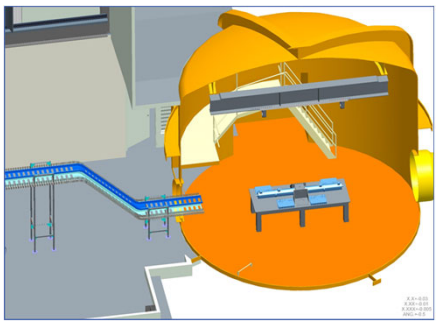
Altitude Chamber



NASA Electric Aircraft Testbed (NEAT)

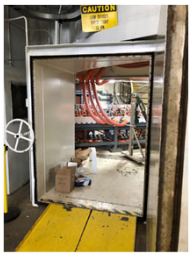
Altitude Chamber

- Altitude Chamber adjacent to main test area
  - 25 ft diameter X 21 ft high, cylindrical steel shell chamber
  - Reinforced concrete floor
  - Access:
    - Access door (7 ft tall x 6 ft wide)
    - 48” bulkhead open to main test area
    - 65” bulkhead open to outside
    - Other plates and flanges
  - Operated at 60,000 ft (15 minute pump down)

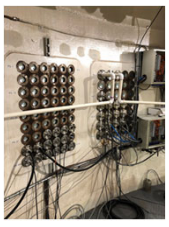


Layout Drawing showing interior of chamber

48” Bulkhead



Access Door



Instrumentation connections into altitude chamber

NASA Electric Aircraft Testbed (NEAT)

Facility Support

- Primary Cooling System – Propylene Glycol/Water
  - 950 kW
  - Dedicated cooling in external pump building
  - System designed to provide up to 400 gpm of cooling water at approximately 90 ºF
- Additional Cooling – Polyalphaolefin (PAO) coolant system
  - 50 kW
  - System designed to provide up to 50 gpm at 176 ºF
- Instrument Air and Gearbox Pressurization Systems recently upgraded to:
  - 240 CFM @ 100 PSIG
  - Dew point: –40 ºF
  - Provides air to gearbox and other equipment
- Facility PLCs, Interfaces, Data Acquisition, etc.
  - Data acquisition system currently configured for NASA use, not as a means to protect “customer data” typically provided in a research facility

Cooling System

Electrified Aircraft Propulsion

NASA Electric Aircraft Testbed (NEAT)

Facility Support (Continued)

- Dyno/Drive Control Software
  - NASA developed software for flexible drive and dyno control
    - Customizable
    - Configurable to run combinations of dynos and motors/drives
    - Runs on embedded hardware with GUI control on a PC
  - Torque and speed loop control of multiple motors to support a range of configurations and power requirements
  - Range checking and configurable limits for key parameters
  - Ability to provide external partner GUI for speed setpoints
  - Customizable serial interface for two-way status and setpoint control
  - dSPACE hardware and software capable
  - User interface capabilities in place for NASA motor drives and dSPACE can be modified and/or enhanced to work with partner systems

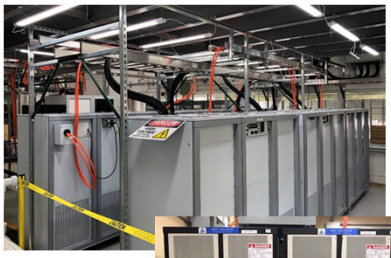
Electrified Aircraft Propulsion

NASA Electric Aircraft Testbed (NEAT)

Electrical Power

- External Power source
  - 12 MVA available at 4160 VAC
  - 3 MVA of 3-phase, 480 VAC transformed to date for testbed use
  - Further transformer upgrades made when additional power is required, up to the full 12 MVA
- Available voltages (converted for testbed use)
  - Total of 3 MW DC power
    - 12 Magna units*, can be wired in series or parallel
    - Each unit is 250 kW, 0-700 VDC, 0-357 A
  - Total of 550 kW of bidirectional DC power
    - 2 Arbin units
    - Each is 275 kW, 0-700V DC, 0-392 A

**We also have 4 additional Magna units. With the current building capacity, these won't immediately increase total DC power available but will provide more flexibility in voltage and current combinations.*



Magna Power Supplies behind barricade

Arbin Bidirectional Power Supplies

NASA Electric Aircraft Testbed (NEAT)

Electrical Power

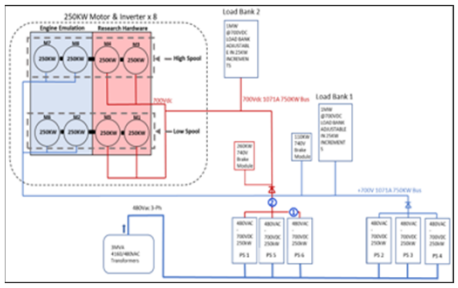
- Load Banks
  - 2 MW of DC load banks
  - 2 units, each is 1 MW, 700 V, stored outdoors
- Facility ground loop
- Batteries
  - Arbin units can be used as battery simulators
  - Planning to incorporate batteries, but none have been tested to date
  - Working with GRC battery organization and SMEs to safely accommodate in future
- Bus Protection
  - DC bus ground fault monitors for 1000, 1760, and 3000 V
  - DC bus brake module for up to1090 Vdc, 450 A braking

Resistive Load Banks

NASA Electric Aircraft Testbed (NEAT)

Electrical Powertrain R&D

- Reconfigure commercial-off-the-shelf machines and inverters to study the electric portion of electrified aircraft powertrains
- Studies to date:
  - 500 kW subscale Single-aisle Turboelectric Aircraft with Aft Boundary Layer Propulsion (STARC-ABL) powertrain[1,2]
  - Hybrid parallel Turbine Engine Energy Management System (TEEMS)[3]
  - Advanced measurement techniques[4]



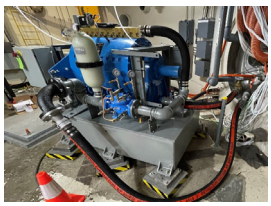
Reconfigurable testbed configuration for controls and advanced measurement research

1. Simon, D.L., Bianco, S.J., Saus, J.R. Amthor, A.E., Sachs-Wetstone, J.J., Horning, M.A., (2023), "*Real-time Hardware-in-the-Loop Evaluation of a Partially Turboelectric Propulsion Control Design*," AIAA Aviation/Electric Aircraft Technology Symposium (EATS), San Diego, CA, June 2023.
2. Bianco, S.J., Simon, D.L., "*Control and Scaling Approach for the Emulation of Subscale Dynamic Torque Loads*," AIAA Aviation/Electric Aircraft Technology Symposium (EATS), San Diego, CA, June 2023.
3. Hill, E.D., Amthor, A.E., Soloway, D.I., Simon, D.L., Connolly, J.W., (2023), "*Model Predictive Control Strategies for Turbine Electrified Energy Management*," ASME-GT2023-101735, ASME Turbo Expo Conference, Boston, MA, June 26-30, 2023.
4. Dever, T.P., Sadey, D.J., Hunker, K.R., Collazo, X.F., Hanlon, P.A., Kascak, P.E., Theman, C.J., Malone, B.P., (2023), "*Impedance Measurements of Motor Drives and Supplies in NASA NEAT Facility*," AIAA Aviation/Electric Aircraft Technology Symposium (EATS), San Diego, CA, June 2023.

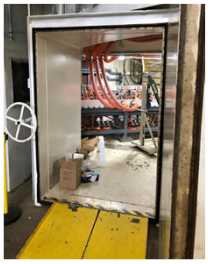
NASA Electric Aircraft Testbed (NEAT)

Electrical Machine Testing

- Ability to test MW+ machines in powertrain configurations, and to potentially test promising machines at altitude
- Commercial off-the-shelf machines and drives can be configured as dynamometer
  - Two dual-250 kW Parker Motors can be connected to one shaft for 1 MW of shaft power
  - Mechanical Layout shows that two strings can fit in altitude chamber
  - Protective shroud used to keep at 1 ATM while under vacuum
- Dedicated 3.3 MW Water Brake dynamometer being added
- Have two 3:1 gearboxes
  - Intended to accommodate different operating speeds for powertrain components
  - Gearboxes capable of 1 MW each
  - NASA's COTS machines can operate up to 7000 rpm. When attached to a gearbox, test articles can operate at higher speeds
- Higher torque 5.0 MW gearbox to operate with Water Brake Dyno being added



3.3 MW water brake dyno in altitude chamber



1 MW dyno in altitude chamber

Lufkin 3:1 Gearbox

NASA Electric Aircraft Testbed (NEAT)

Safety

- All NEAT tests subject to NASA's safety process
  - NEAT is under purview of the Area 9 Safety Committee
  - Safety Review and Safety Permit application process
  - Qualified operators only permitted during run phase
- High Voltage Precautions in use
  - All high V cabling out of reach and barricaded
  - Power supplies have built-in overvoltage and overcurrent features
  - Inverters have built-in trip points
  - Ground fault monitoring
  - Operations rules and facility alarms, interlocks and shutdowns in use

Electrified Aircraft Propulsion

NASA Electric Aircraft Testbed (NEAT)

Potential Partnering

- NEAT was conceived of as a reconfigurable testbed for use by NASA and its partners
- Testing has been conducted with research partners with the goal of advancing US competitiveness in Electrified Aircraft Propulsion
- NEAT has not operated as a "pay for use" test asset to date
- Cost
  - No daily cost available to date
  - Each configuration has been unique, and can require design modifications to the current electrical system
  - However, expenditures are known, and a price estimate can be created for a specific configuration and test duration

Electrified Aircraft Propulsion