

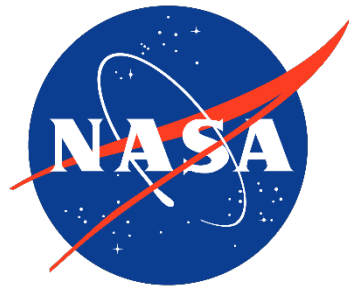
Revolutionary Vertical Lift Technology Project

A blue, futuristic aircraft with the letters 'RVLT' and the NASA logo on its side is shown in flight. The aircraft has a unique design with multiple engines and a large, open cargo bay. It is flying over a city skyline at sunset, with the sun low on the horizon and the sky filled with colorful clouds. The aircraft is positioned in the center of the frame, with its wings spread wide.

Univ. of Conn./Raytheon visit
7/25/2023

Presenter: Linda Taylor, RVLT Electric Propulsion
Authors: Linda Taylor, Pat Hanlon, Xavier Collazo-Fernandez
NASA Glenn Research Center, Cleveland, Ohio

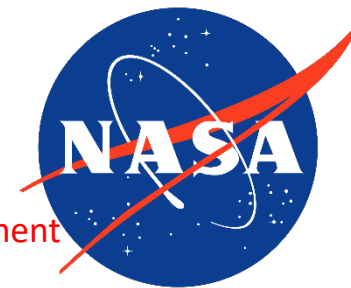
Aeronautics Research Mission Directorate (ARMD)



ARMD has 6 Strategic Thrusts

- Strategic Thrust 1: Safe, Efficient Growth in Global Operations
- Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft
- Strategic Thrust 3: Ultra-Efficient Commercial Vehicles
- Strategic Thrust 4: Transition to Low-Carbon Propulsion
- Strategic Thrust 5: Real-Time System-Wide Safety Assurance
- Strategic Thrust 6: Assured Autonomy for Aviation Transformation

Research Areas



PROPULSION EFFICIENCY

light, efficient, high-speed electric motors
power electronics and thermal management
efficient powertrains

PERFORMANCE

aircraft optimization
rotor shape optimization

ROTOR-ROTOR INTERACTIONS

performance, noise, handling qualities, aircraft arrangement

NOISE AND ANNOYANCE

low tip speed
rotor shape optimization
flight operations for low noise
aircraft arrangement/ interactions
cumulative noise impacts from fleet ops
metrics and requirements
human response to noise
active noise control
cabin noise
electric motor noise

STRUCTURE AND AEROELASTICITY

crashworthiness
durability and damage tolerance

SAFETY AND AIRWORTHINESS

component reliability and life cycle
crashworthiness (airframe, occupant, battery)
bird strike
electric motor reliability assessment
propulsion system failures
FMECA (failure mode, effects, and criticality analysis)
high voltage operational safety
high voltage protection devices

OPERATIONAL EFFECTIVENESS

passenger acceptance/ ride quality
disturbance rejection (control bandwidth, control design)
operations in moderate to severe weather

ROTOR-WING INTERACTIONS

conversion/transition
interactional aerodynamics

AIRCRAFT DESIGN

conceptual design tools
flight dynamics and controls
handling qualities
weight, vibration



Red = primary RVLTL research area
Blue = secondary RVLTL research area

NASA's RVLTL Project Provides Tools and Design Practices for UAM eVTOL Vehicles

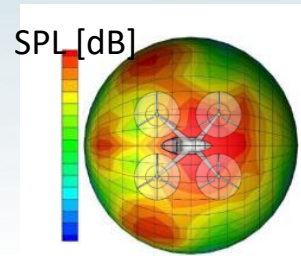
Noise Research



Human Response to UAM Noise



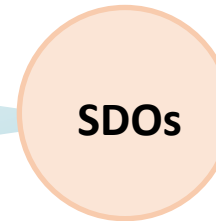
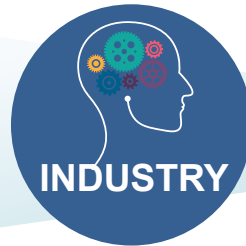
UAM Acoustic Impacts



Predictive Tools for UAM Noise



Share technical insights and lessons learned



Safety Research



Crashworthiness & Occupant Protection



Handling Qualities



Electric Powertrain Reliability

Inform eVTOL Systems Standards and Certification

NASA RVLT Project Research Areas

Ames Research Center

- Aeromechanics
- System Analysis
- Computational Methods
- Experimental Capability
- Flight Dynamics & Control
- Acoustics

Center Liaison: Gina Willink

Armstrong Flight Research Center

- UAM Handling and Ride Qualities
- UAM Electric System and Flight Control Integration

Center Liaison: Robert Navarro

Glenn Research Center

- Hybrid/ Electric Systems
- Electro-Mech Powertrains
- Icing
- System Analysis
- Impact Dynamics
- Acoustics

Center Liaison: Devin Boyle

Langley Research Center

- Acoustics
- Computational Methods
- Aeromechanics
- Experimental Capability
- Impact Dynamics
- System Analysis

Center Liaison: Benny Lunsford



Resources and Facilities

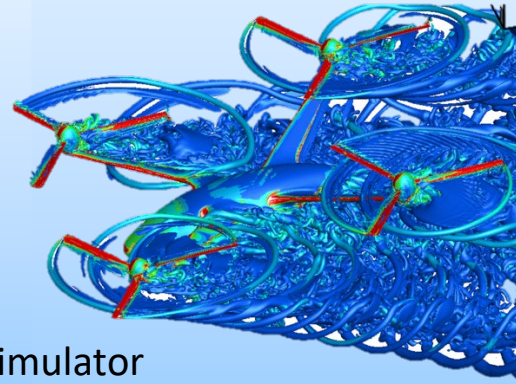


FY22/23 RVLT Summary

**~113/113 Civil Service
Workforce**

Ames Research Center

- National Full-Scale Aerodynamics Complex (NFAC)
- Supercomputing Complex (NAS)
- Vertical Motion Simulator



Armstrong Flight Research Center

- Simulators
- Integration facilities
- Test range



Glenn Research Center

- Power, Motor and Transmission Test Facilities (ERB)
- Icing Research Tunnel

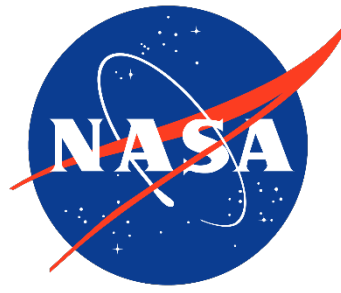


Langley Research Center

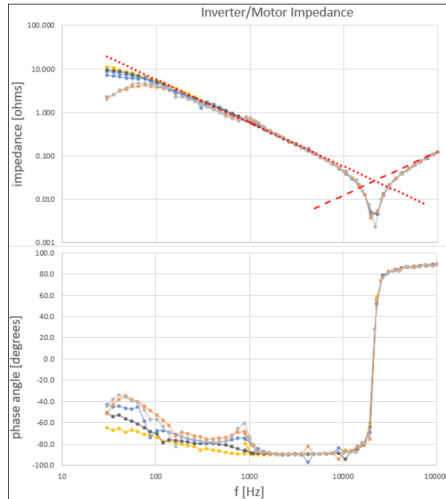
- 14- by 22-Foot Subsonic Tunnel
- Transonic Dynamics Tunnel
- Low-Speed Aero-acoustic Wind Tunnel
- Exterior Effects Synthesis & Sim Lab
- Mobile Acoustics Facility



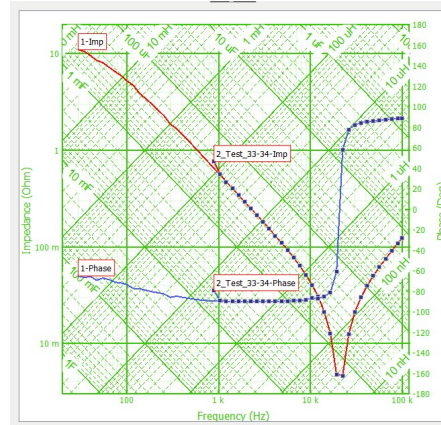
Scaled Power ElEctrified Drivetrain (SPEED)



Simulation Results



Physical Sys. Results

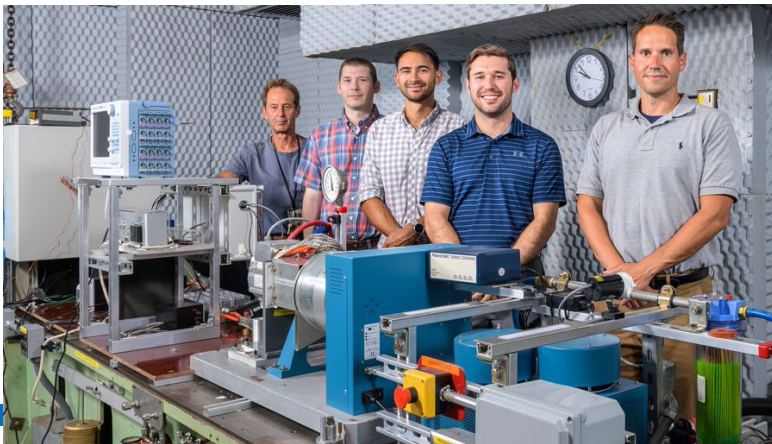


Capabilities

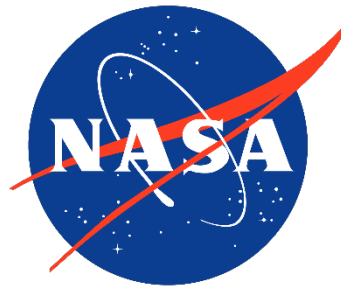
- 400 VDC and 12,000 RPM
- Up to 7 kW (dyno limit)
- Mechanical, electrical, vibration data

Testing

- Motor/inverter characterization & integration
- Baseline testing of motors for AREAL testbed
- Software model validation
- Test motor, controls, power electronics

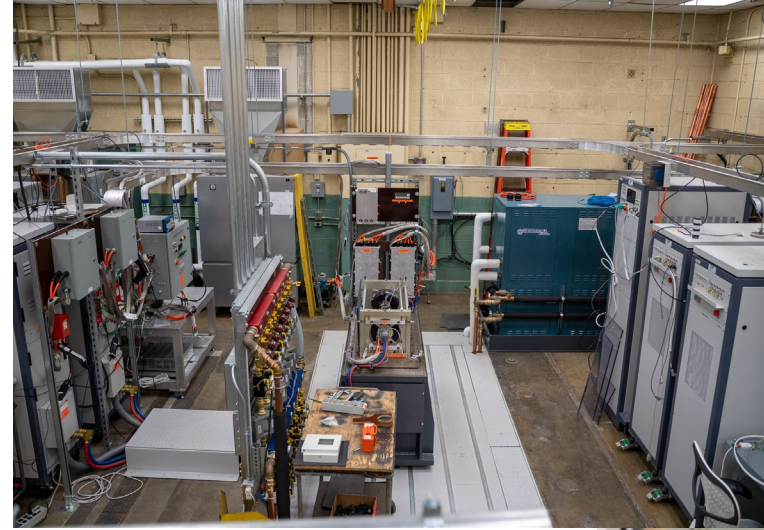


Aeronautics Reconfigurable Electrified Aircraft Lab (AREAL)



Capabilities

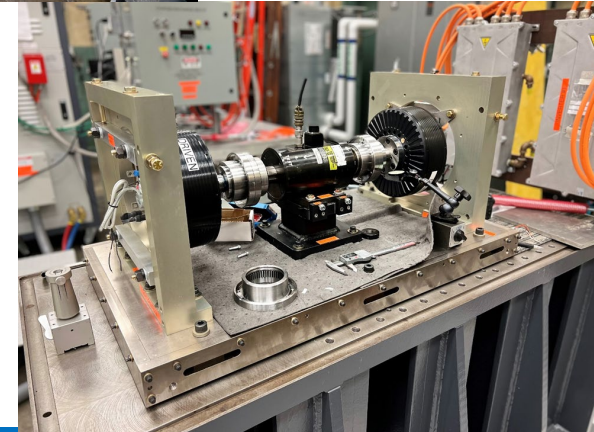
- 1 kVDC peak
- 200 kW nominal source capacity
- Emulated, reconfigurable system
 - Single-string, multi-string
- Power quality investigations
- Fault capability



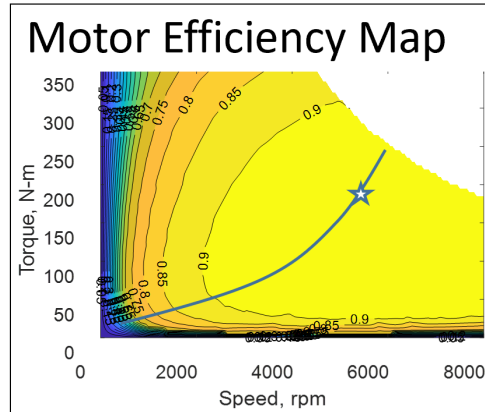
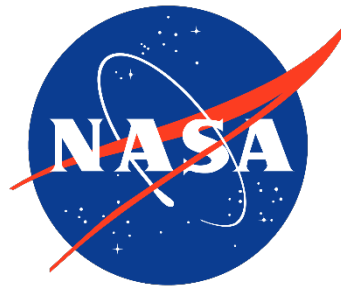
Testing

- Nominal, transient, fault operation
- Characterization and response

Data generated will be used to validate models and
Inform standards

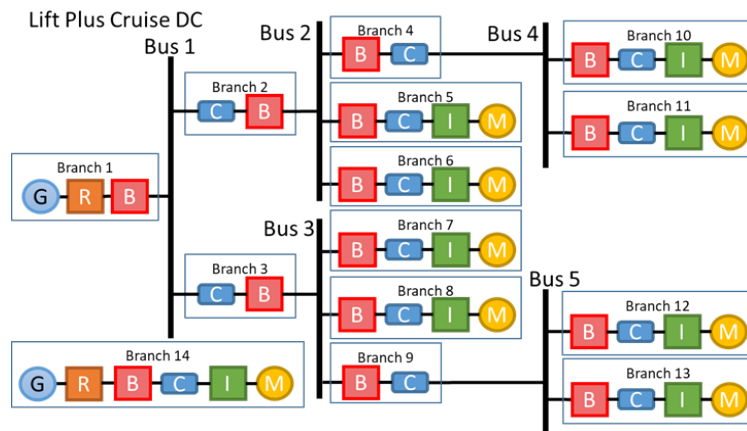


Electrical Power System – Sizing and Analysis Tool (EPS-SAT)



MATLAB[®]-based object-oriented framework that:

- Estimates aerospace power system performance
- Allows for component/architecture trades
- Allows for sensitivity analyses
- Exposes strengths and weaknesses of designs
- Can be used to better direct investment dollars

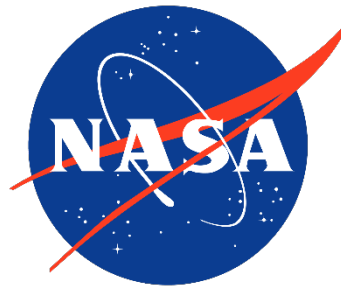


Supports AC, DC, and Multi-string architectures

Electrical power system reliability studies

Approved for US release

Numerical Propulsion System Simulation (NPSS)

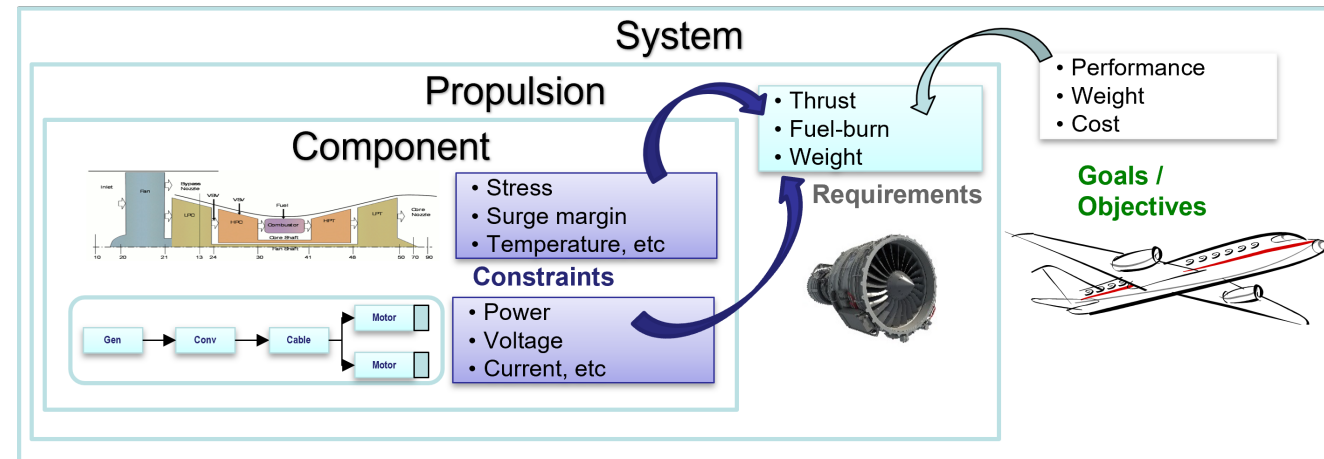


Added electrical port (to be included in next official release)

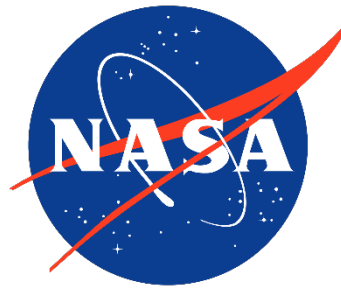
- Address fuel burn, emission, noise, cost, performance
- Consider component min/max operating conditions
- Difficulty in producing designs without simultaneous modeling

Multidisciplinary propulsion system sizing and analysis

- Turbomachinery
- Electrical
- Thermal



Standards Development – SAE Standards



AS7499 - Aircraft High Voltage Power Quality Standard

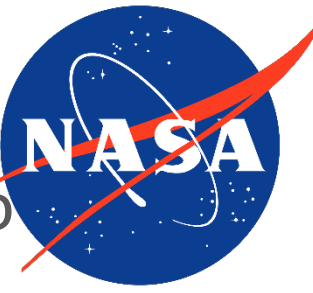
- Establishes power system boundaries
- System stability
- Fault recovery
- 'Plug and play' approach to

AS8441 – Minimum Performance Standard for Permanent Magnet Propulsion Motors and Associated Drives

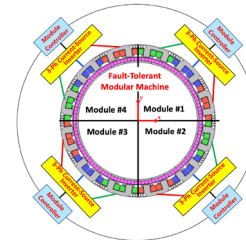
- Using PM machine as baseline
- PM-driven electric engines



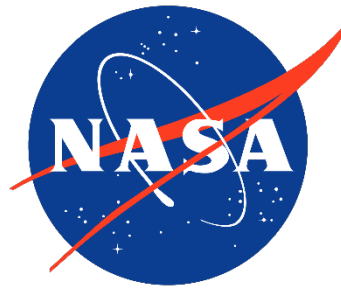
Motor/Drive Research



- NASA ULI Project: Integrated Motor/Electronics Design led by the Ohio State University
 - Modular motor and drive design
 - Integrated motor, drive, and thermal
 - 1 MW target
- RVLT-funded spin-off of ULI design through the University of Wisconsin
 - Fault-tolerant motor and drive concept
 - Integrated motor and drive
 - 20 kW demonstrator to be delivered 2024
- NASA SBIR Phase II: High Power Density Induction Motors and Drives Aircraft Application by Ohio State University and Hyper Tech
 - Integrated motor and drive design
 - Navigate away from permanent magnets
 - 2 MW target



Status



- Low power tests successfully completed in SPEED
- Novel impedance measurement approach developed in SPEED – utilized in AREAL and NEAT
- Low power data generated for model validation
- Single-string higher power tests to begin in AREAL within 1-2 weeks
- Working on direction for next TC

Summary

- NASA is focused on:
Advanced Air Mobility as one of the priorities for Aeronautics research
- RVLT is focused on:
 - VTOL research and technology to improve noise and safety of Urban Air Mobility vehicles
 - Working to coordinate/leverage other Aero projects (AATT/EPFD/ect.)



The RVLT vision is to create a future where VTOL configurations operate quietly, safely, efficiently, affordably, and routinely as an integral part of everyday life.