National Aeronautics and Space Administration

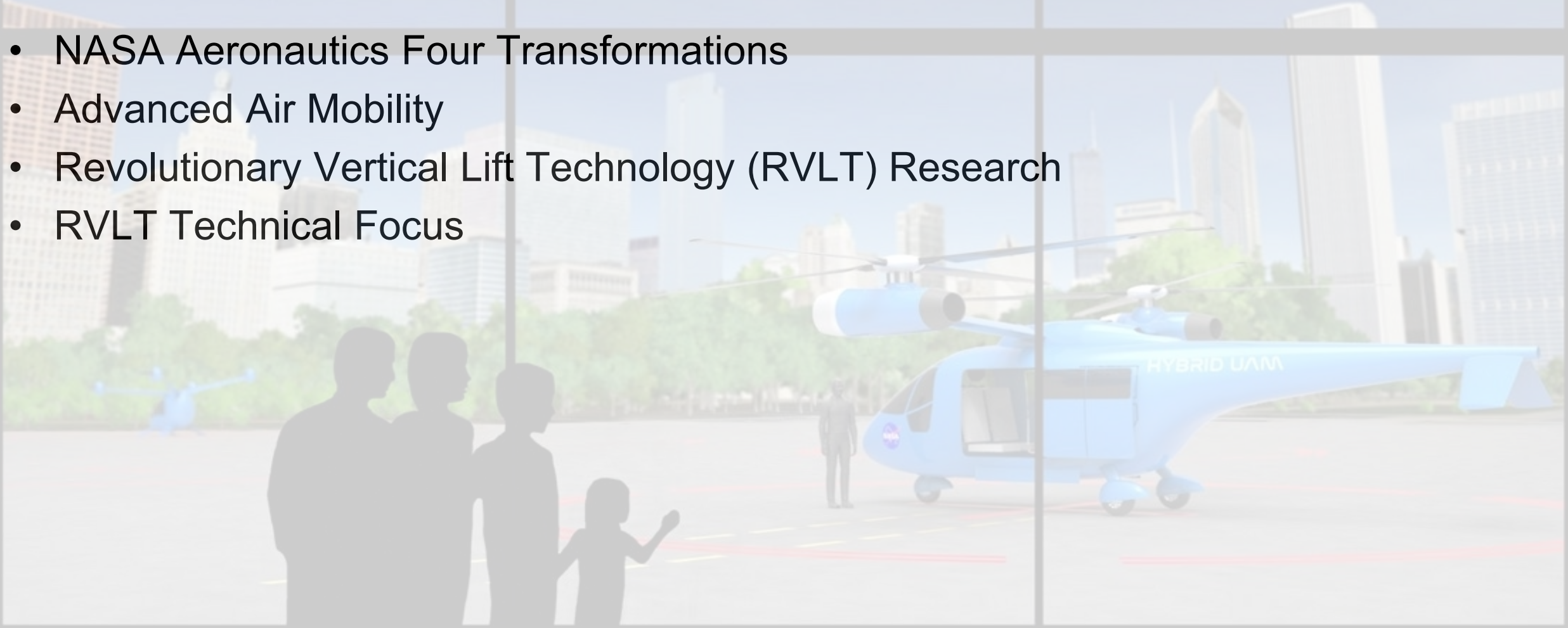


NASA Aeronautics Vision for Transforming Aviation

Susan A. Gorton
Project Manager, Revolutionary Vertical Lift Technology
Vertical Flight Society's 79th Annual Forum & Technology Display

Overview

- NASA Aeronautics Four Transformations
- Advanced Air Mobility
- Revolutionary Vertical Lift Technology (RVLT) Research
- RVLT Technical Focus











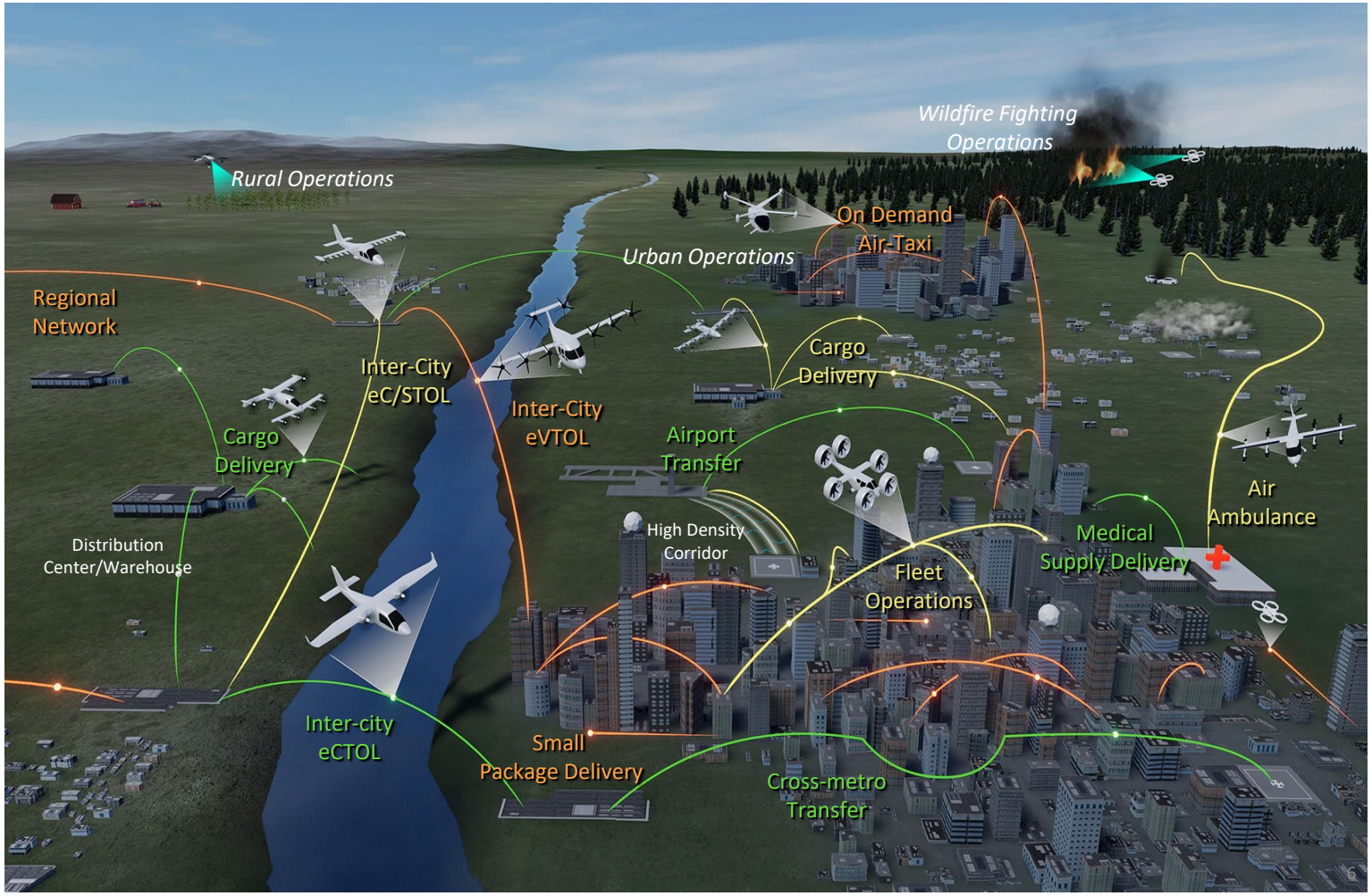
Four Transformations for Sustainability, Greater Mobility, and Economic Growth



ADVANCED AIR MOBILITY (AAM)

AAM and UAM

- AAM missions characterized by
  < 300-500 nm range
- Vehicles require increased automation and are likely electric or hybrid-electric
- Rural and urban operations are included
- Missions can be public transportation, cargo delivery, air taxi, or emergency response
- Urban Air Mobility (UAM) is a subset of AAM and is a segment that is projected to have high economic benefit and be the most difficult to develop
  - UAM requires an airspace system to handle high-density operations
  - UAM requires an advanced urban-capable vehicle
  - UAM vehicle variants can target other missions



Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

RVLT is one of the eight NASA projects that support the AAM Mission

Advanced Capabilities for Emergency Response Operations

Wildfire Detection/Mitigation Concept of Operations



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

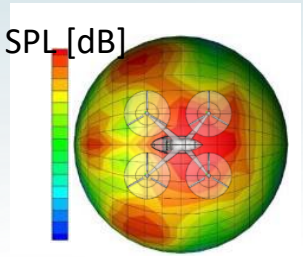
Noise Research



Human Response to UAM Noise



UAM Acoustic Impacts



Predictive Tools for UAM Noise



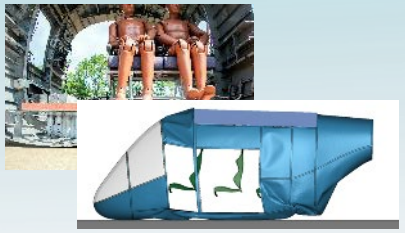
Safety Research



Electric Powertrain Reliability



Handling Qualities



Crashworthiness & Occupant Protection

Share technical insights and lessons learned



Delivering Tools and Technologies to the eVTOL Community

Focus Area:
Tools to Explore the Noise and Performance of Multi-Rotor UAM Vehicles

Objective

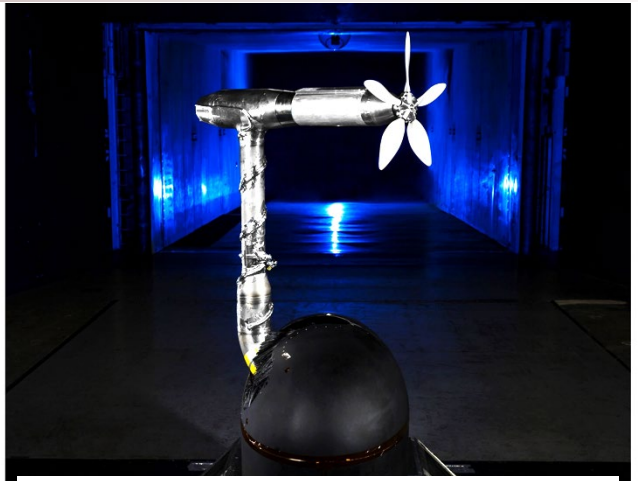
Develop, demonstrate, validate, and document a set of conceptual design tools capable of assessing the tradeoffs between UAM vehicle noise and efficiency.

Approach

- ***Develop*** new interfaces between comprehensive analysis-CFD-acoustics tools
- ***Demonstrate*** tool chain via workshops
- ***Validate*** tool chain with data from wind tunnel tests using new test rigs representative of UAM-like configurations
- ***Document*** tools, toolchains, and validation datasets; include best practices

Status

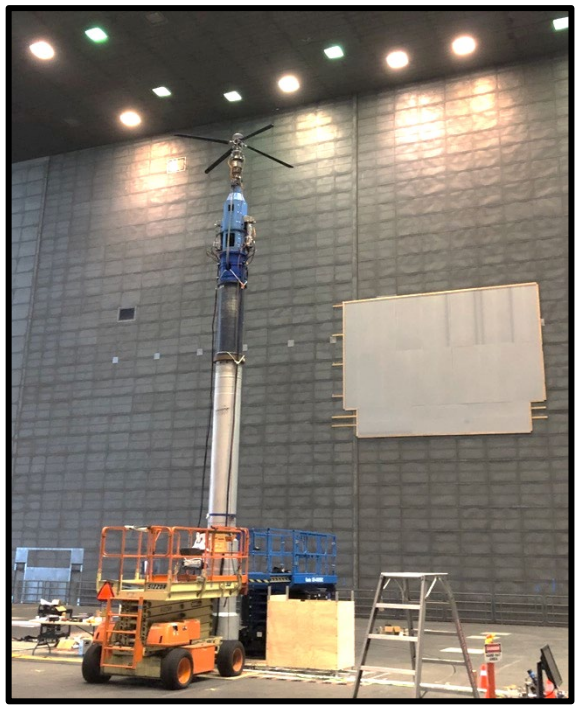
- Significant recent progress to develop test stands and acquire specific experimental validation data for eVTOL configurations
- Hover validation testing (joint with Army) close to completion



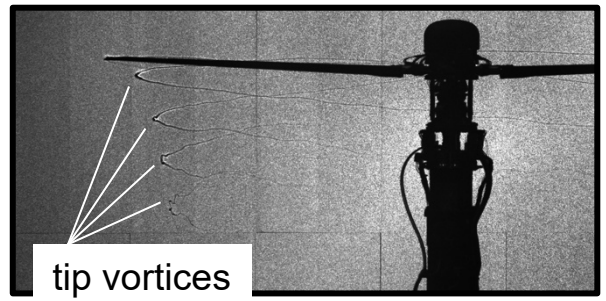
Vertical Lift Propeller in the 14- by 22-Ft Subsonic Wind Tunnel



Multirotor Test Bed installed in the 7- by 10-ft Wind Tunnel



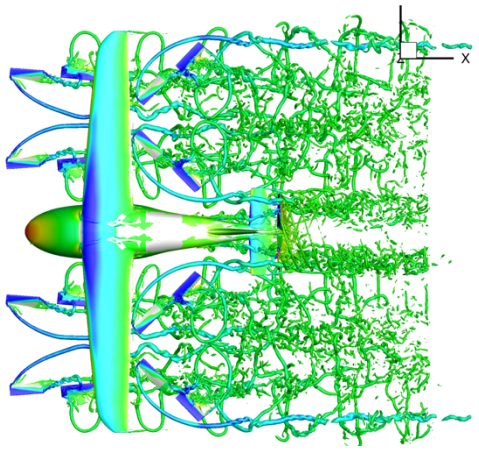
Above: Hover test installation in the NFAC 80- by 120-ft Wind Tunnel
Below: Shadowgraphy image

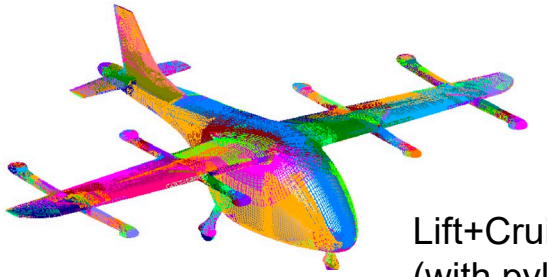


High-Fidelity Simulations & Conceptual Design Tool Chain Progress

- Significant performance improvements in latest release of **structured RANS** solver, OVERFLOW
- Improved the robustness and quality of automatically-generated overset structured meshes
- High-fidelity CFD simulations of Lift+Cruise with RPM control using OVERFLOW
- Completed high-fidelity CFD simulations of the RVLT Quadrotor and L+C with FUN3D, demonstrating capability to model configurations with RPM control with **unstructured RANS**. Also demonstrated adjoint optimization capability using FUN3D for Quadrotor.
- Initiated conceptual design and sizing trade studies for new Tiltrotor and Tiltduct UAM concept vehicles
- Held Conceptual Design Toolchain Workshop #3 targeting US UAM industry participants. Workshop #4 to be held this summer.

L+C with OVERFLOW



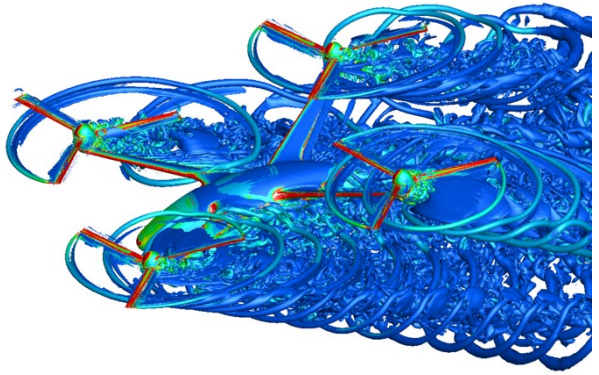


Lift+Cruise (with pylons & gears)

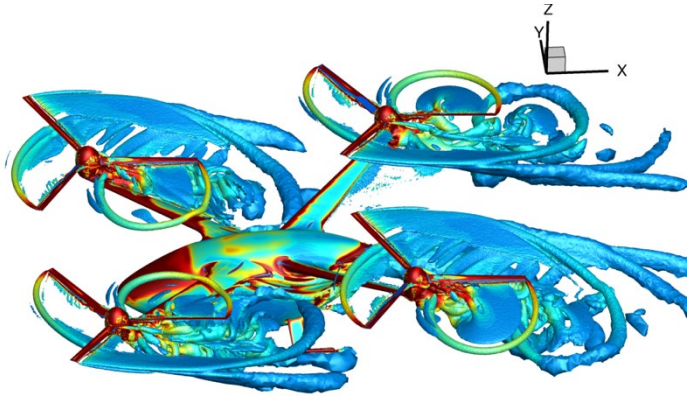


Tiltwing Cruise Mode

Quadrotor with OVERFLOW



Quadrotor modeled with FUN3D



Significant recent progress in computational modeling of eVTOL configurations

Focus Area:
Urban Air Mobility (UAM) Operational Fleet Noise Assessment

Objective

Develop, validate, demonstrate, and document best practices for fleet noise modeling; demonstrate fleet noise assessments of representative UAM operations using the Aviation Environmental Design Tool (AEDT)

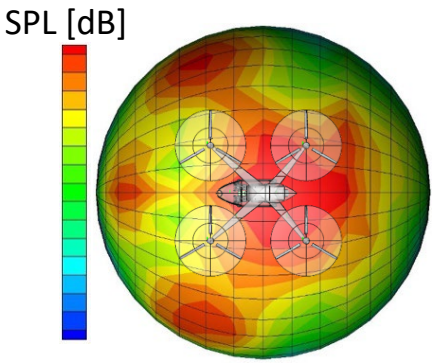
Approach

- ***Develop, validate, assess, and document*** new tools to compute NPD (noise-power-distance) data for UAM vehicles, procedures for representing UAM missions in AEDT, and models for audibility & annoyance of UAM vehicles

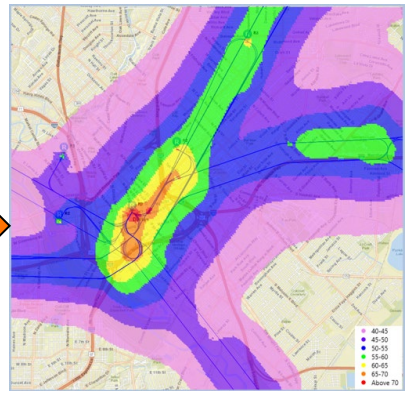
Status

- Significant FY22/23 progress to develop tools to streamline NPD data generation, establish new approaches to perform fleet noise predictions, and collect data to inform annoyance models for UAM vehicles
- Completed feasibility study for remote psychoacoustic testing with positive outcome

Source hemisphere for UAM reference vehicle flight condition – used to calculate input to AEDT



Sample fleet noise assessment with AEDT (Day-night average sound level noise exposure)

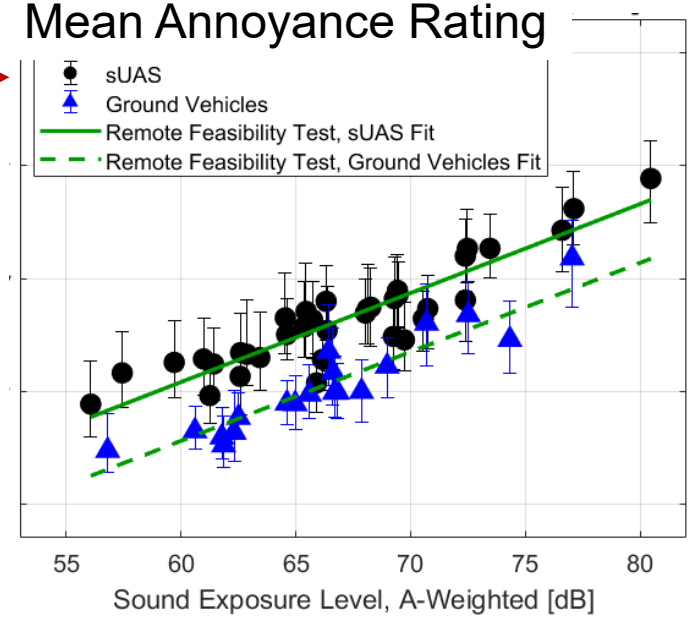


NASA Amazon Web Services Cloud



Annoyance Response Prompt for Each Sound

Mean Annoyance Rating



Focus Area:
Reliable and Efficient Propulsion Components for Urban Air Mobility (UAM)

Objective

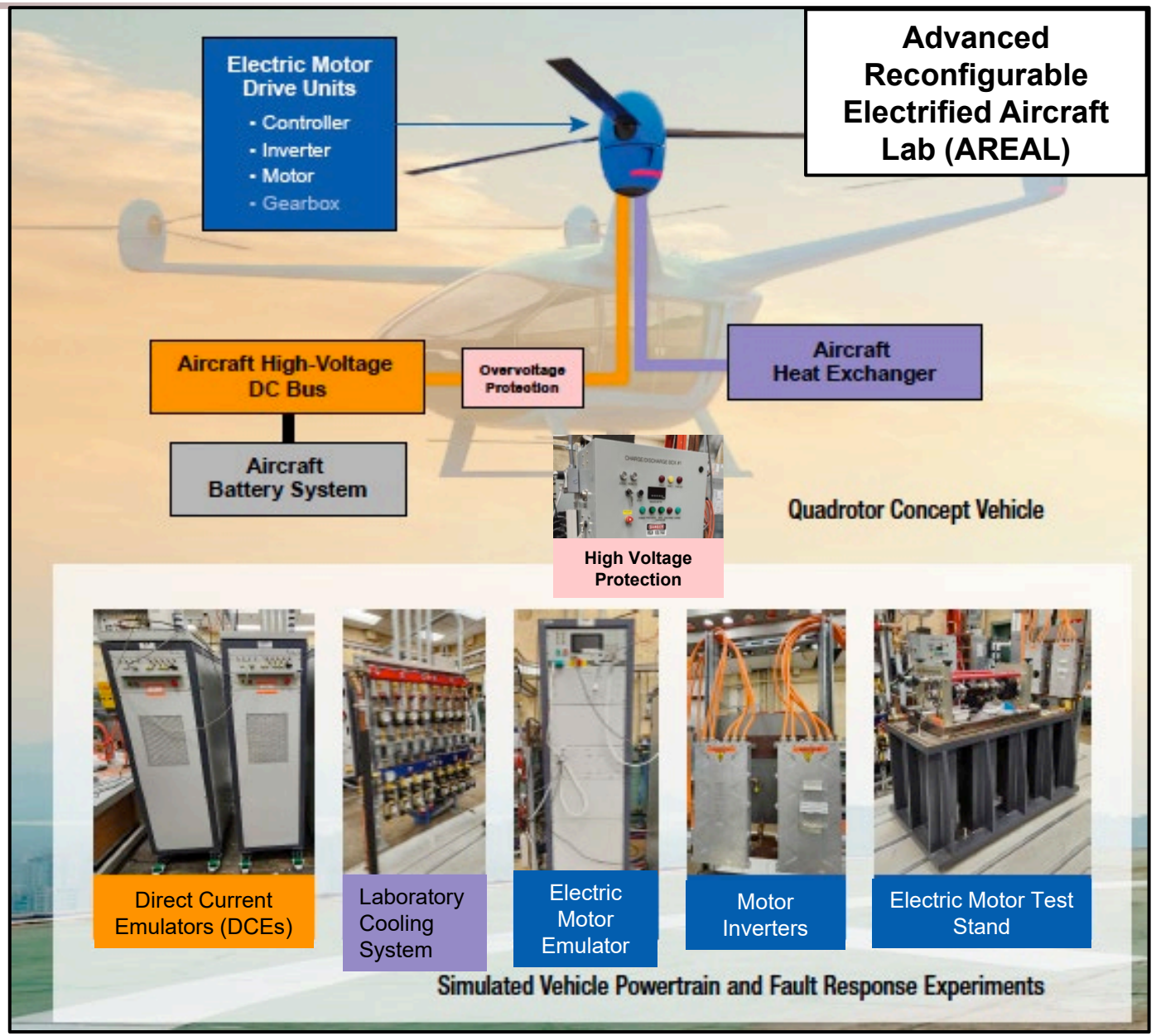
- Develop design and test guidelines, acquire data, and explore new concepts that improve propulsion system component reliability by several orders of magnitude over state-of the-art technology

Approach

- **Iterative design, model, test, and analyze**
  - Develop experimental / analysis capabilities
  - Conduct tests (reliability of components, tool validation)
  - Develop design guidelines & test procedures

Status

- Advanced design of integrated, modular electronics/motor. Funded Univ. of Wisconsin to design/build/test 20 kW fault-tolerant modulator motor demonstrator
- Completed modification of 150 kW test cell to establish single-string powertrain rig (AREAL); single string testing on-going.
- Motor winding reliability assessment complete
- Motor optimization studies complete



Focus Area: Acceptable Handling and Ride Qualities for Urban Air Mobility (UAM) Vehicles

Objective

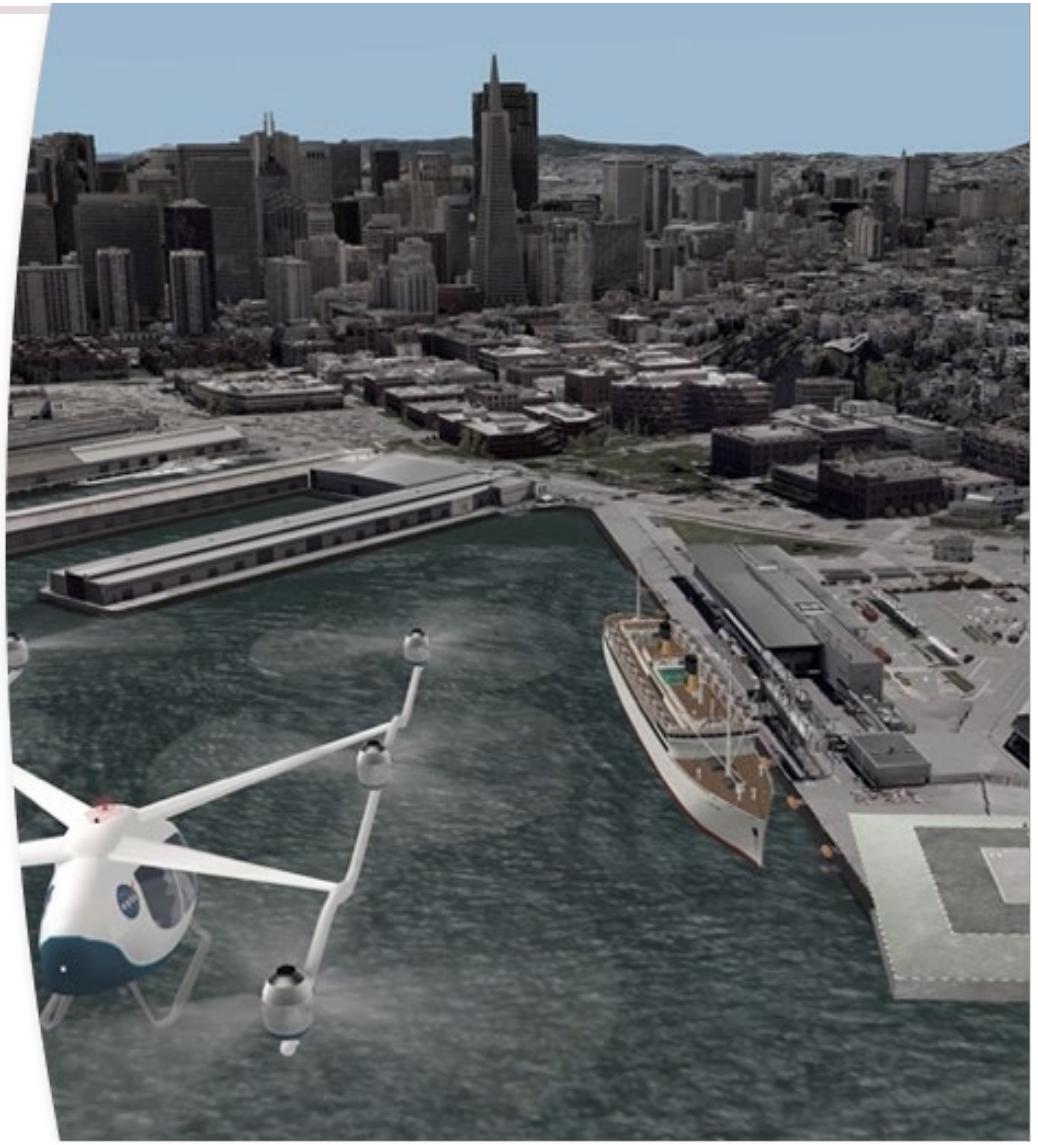
- Provide handling and ride qualities (HQ and RQ) guidelines and flight dynamics and control modeling tools for UAM vehicle design

Approach

- Use two tracks: 1) testing; and 2) tools development
- Identify coupling between HQ and RQ metrics

Status

- Virtual reality Ride Quality Simulator (RQS) procured and in process of installation
- Human Vibration Lab (HVL) upgrades underway
- 3-DOF vibration chair being manufactured for use in the Vertical Motion Simulator (VMS)
- FLIGHTLAB® model development and analysis of RVLT UAM concept vehicles underway (Gen-2)
- Completed VMS handling qualities evaluation in October and November using high complexity powertrain models



Hexacopter in VMS Simulation

Focus Area:
UAM Crashworthiness and Occupant Protection

Objective

- Deliver: 1) full-scale and component-level data to inform eVTOL industry consensus standards development; and 2) test guidelines, modeling best practices, and vehicle technologies for crash mitigation.

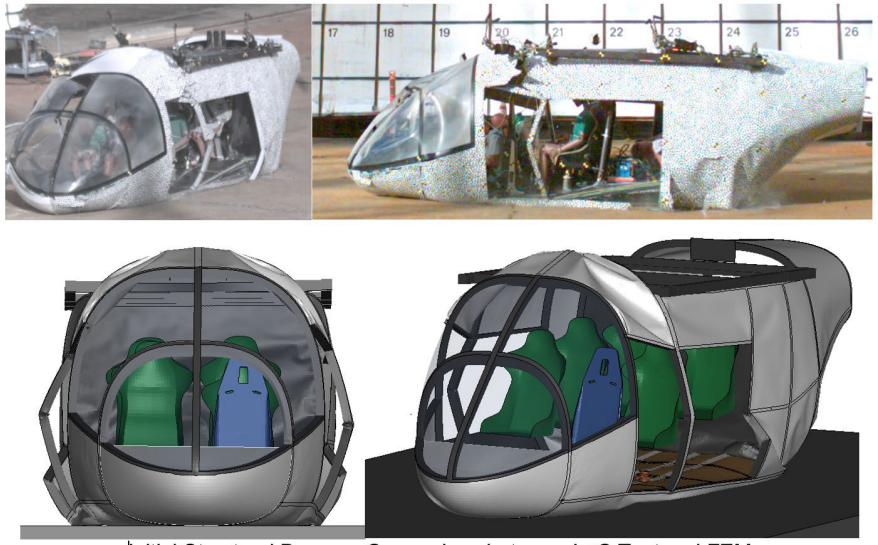
Approach

- Develop data for occupant protection in unknown vehicle crash environments
- Make advances in modeling techniques to support Certification by Analysis
- Address bird strike impact standards
- Investigate battery pack safety upon and after impact

Status

- Completed Lift+Cruise full-scale drop test in Nov 2022
- Updated modeling approaches for composite cabins, seats, and occupants
- Initiated work on electric battery packs under impact
- Generated bird strike simulant data

Initial pre-test modeling



Initial Structural Damage Comparison between L+C Test and FEM

Post-test modeling updates



Figure 1. Correlation of L+C Structural Collapse Predictions

Summary

- NASA Aeronautics has a focus on global, sustainable, transformative aviation technologies
- Priority on ultra-efficient transports, high-speed commercial flight, future airspace and advanced air mobility
- Eight NASA projects support vehicle and airspace research for the Advanced Air Mobility area
- Research on-going in many areas with partners and collaborators

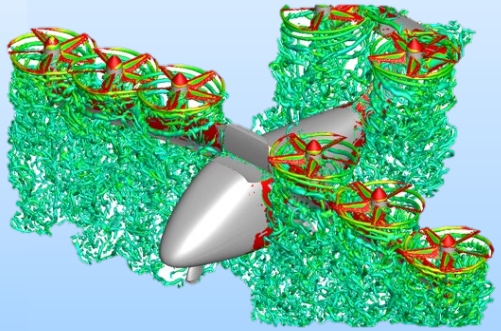
Resources and Facilities

FY23/24 RVLT Summary

~113/113 Civil Service Workforce
~ $35M/40M per year (includes salary)

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
- 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



**FY24 President's Budget*

NASA RVLT Project Research Areas

Ames Research Center
Moffett Field, CA

- Aeromechanics
- System Analysis
- Computational Methods
- Experimental Capability
- Flt Dyn & Ctrl
- Acoustics

Armstrong Flight Research Center
Edwards, CA

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

Glenn Research Center
Cleveland, OH

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

Langley Research Center
Hampton, VA

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

