NASA Advanced Air Mobility Vehicle Research

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Four Transformations for Sustainability, Greater Mobility, and Economic Growth

- Ultra-efficient Airliners
- Future Airspace and Safety
- High-speed Commercial Flight
- Advanced Air Mobility
Advanced Air Mobility (AAM)

Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions
Vehicle Safety and Noise Research Supporting AAM

- Reliable Electric Propulsion
- High-Fidelity Simulation
- Performance and Acoustic Testing
- Conceptual Design Tools
- Noise and Annoyance Modeling
- Crash Safety Testing and Modeling
- Piloted Handling Qualities Simulation
- Passenger Ride Quality

Investing in the future of advanced vertical flight
Focus Area: Reliable and Efficient Propulsion Components for UAM

**Objective:** Deliver design-and-test guidelines and data to improve electric propulsion component reliability for UAM vehicles

**Approach:**
- Develop tools to assess electric motor reliability and explore new design concepts
- Develop validated electrical component and system models
- Define test methods and electric power quality requirements for eVTOL propulsion architectures

**Status:**
- Developed powertrain **reliability models** and design guidelines for reliable electric machines
- Built and evaluating advanced **fault tolerant modular electric motor demonstrator** with the University of Wisconsin
- Conducted first electrical input impedance test for an electric machine
- Providing high power data to validate models and inform standards using the Advanced Reconfigurable Electrified Aircraft Lab (200 kW, 800 VDC bus)
- **Leading consensus standards development** of High Voltage Power Quality SAE AS-7499 and Permanent Magnet Motor Performance SAE AS-8441 standards
- Developed and validated electrical component/system modeling tools for community use

*Informing consensus standards development*
Focus Area: Tools to Explore the Noise and Performance of UAM Vehicles

Objective: Deliver a validated and documented set of tools for assessing tradeoffs between the noise and performance for UAM aircraft

Approach
- Plan and conduct a series of validation tests
- Improve the efficiency and accuracy of conceptual design and analysis tools
- Improve technology transfer and training for analysis tools

Status
- Hover Validation Test with Army completed in May 2023; benchmark hover data available: https://rotorcraft.arc.nasa.gov/HVAB/
- Acoustic Characterization Test completed in Aug 2023; characterizing baseline 14x22 wind tunnel acoustics for future testing
- TiltRotor Aeroelastic Stability Testbed (TRAST) Test with Army completed in Dec 2023; sharing whirl flutter data to advance understanding for next generation tiltrotor aircraft
- Propeller Test with Agility Prime AFRL and Joby Aviation completed Dec 2023; data being used to validate NASA tools, which will be shared with the community
- Upcoming: outwash, tiltwing performance, propeller noise, multi-rotor acoustic, and tiltwing acoustic tests

Acquiring and sharing validation data
Focus Area: Tools to Explore the Noise and Performance of UAM Vehicles

Status (continued)

- **Improving accuracy and efficiency** of flow solvers (OVERFLOW and FUN3D)
  - Improved computational efficiency and scaling performance with a focus on emerging HPC architectures (GPU)
  - Improved coupling with other rotorcraft analysis tools including comprehensive analysis and acoustic codes
- Developing tools to **automate overset structure grid generation** to reduce the time from conceptual design to CFD simulations
- Continuing support and development of the NASA rotorcraft design and analysis tool (NDARC), which includes example models of multiple NASA UAM concept aircraft
- Incorporating new capabilities within the NASA acoustics tool ANOPP2, including a simulation tool to simplify the calculation of noise power distance data for fleet noise assessments
- Continuing to hold **Conceptual Design Toolchain Workshops** targeting UAM industry designers (full workshop in August 2023, mini-workshop focused on acoustics in March 2024)

Streamlining tools to enable faster and more accurate predictions
Focus Area: UAM Operational Fleet Noise Assessment

**Objective:** Deliver a method to assess the acoustic impact of UAM fleet operations on the community using accepted tools such as the FAA Aviation Environmental Design Tool (AEDT)

**Approach**
- Generate Noise Power Distance (NPD) database for UAM reference vehicle configurations and trajectories
- Develop method to assess the acoustic impact of UAM fleet operations
- Conduct psychoacoustic testing to assess human response to UAM vehicle acoustics

**Status**
- Developed and documented *methods to assess the acoustic impact* of UAM operations using the Aviation Environmental Design Tool (AEDT)
- Shared simulated vehicle noise and performance data for UAM concept aircraft, which enables near-term studies
- Conducted psychoacoustic tests assessing masking and the relationship between operational tempo of UAM vehicles and annoyance
- Developed initial *annoyance model accounting for ambient masking noise*

*Developing methods to enable near-term assessments and inform land use planning, including vertiport siting*
Focus Area: UAM Crashworthiness and Occupant Protection

Objective: Deliver full-scale and component-level data to inform eVTOL standards development; and test guidelines, modeling best practices, and vehicle technologies for crash mitigation

Approach
• Conduct full-scale and component level tests
• Develop test guidelines, modeling best practices, and vehicle technologies for crash mitigation
• Deliver crash and impact data to consensus standards organizations

Status
• Updated the material model used in cabin impact simulations to inform future full-scale drop tests
• Continued developing and testing energy absorbing structures to reduce occupant injury risk
• Leading consensus standards development of bird strike impact test method SAE AS-7254
• Conducted drop tests of deenergized battery modules from 50 feet and post-test forensic inspections to assess likelihood of thermal runaway

Informing consensus standards development to improve occupant safety

Structural Damage Correlation

Anthropomorphic Test Dummy used for testing of seats and occupant protection
Focus Area: Acceptable Handling and Ride Qualities for UAM

**Objective:** Deliver handling and ride qualities (HQ and RQ) guidelines and flight dynamics and control modeling tools for UAM vehicle design

**Approach**
- Conduct human subject testing to assess handling and ride qualities
- Establish handling and ride qualities guidelines for UAM vehicles
- Develop flight dynamics and control modeling tools for conceptual design

**Status**
- Completed checkout tests of new Ride Quality Laboratory combining virtual reality and 6DOF motion base for upcoming UAM passenger studies
- Completed testing and validation of control software for the Human Vibration Lab 5DOF vibration chair
- Evaluating and preparing Flight Dynamics and Control Modeling Tool for Conceptual Design (FlightCODE) for public release
- Developed capability to integrate uncertainty quantification with FlightCODE enabling robust design and control system evaluation
- Developing electric propulsion models for NDARC and FlightCODE
- Developed a proof-of-concept flight dynamics and control safety assessment toolbox

*Developing validated handling and ride quality recommendations*
Additional Advanced Air Mobility Missions are Emerging

Developing tools, technologies, and concepts to improve the next generation of eVTOL vehicles capable of supporting multiple missions:

- Increased payload and speed
- More range / flight time
- Lower cost (life cycle, maintenance)
- Operations in adverse weather

- Assessments
- Evacuations
- Logistics
- Search and Rescue

- Detection
- Monitoring
- Logistics
- Suppression

- Intracity patient transport
- Clinic staff transport
- Organ / supply transport

- Agriculture
- Conservation / Environmental surveys
- Wildlife management

- Air Taxi
- Aerial Fire Management
- Medical Transport
- Environment
- Public Good Missions
Summary

- NASA Aeronautics is focused on:
  - Safe, efficient, adaptable, and environmentally sustainable air transportation
  - Ultra-efficient transports, high-speed commercial flight, future airspace, and Advanced Air Mobility

- RVLT is focused on:
  - Vehicle safety and noise research supporting Advanced Air Mobility
  - Advancing the AAM industry through collaboration and standards development