NASA’s Direction for Vertical Lift Research
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NASA Aeronautics Six Strategic Thrusts and Community Visions

**Safe, Efficient Growth in Global Operations**
- Achieve safe, scalable, routine, high-tempo airspace access for all users

**Innovation in Commercial Supersonic Aircraft**
- Achieve practical, affordable commercial supersonic air transport

**Ultra-Efficient Subsonic Transports**
- Realize revolutionary improvements in economics and environmental performance for subsonic transports with opportunities to transition to alternative propulsion and energy

**Safe, Quiet, and Affordable Vertical Lift Air Vehicles**
- Realize extensive use of vertical lift vehicles for transportation and services including new missions and markets

**In-Time System-Wide Safety Assurance**
- Predict, detect and mitigate emerging safety risks throughout aviation systems and operations

**Assured Autonomy for Aviation Transformation**
- Safely implement autonomy in aviation applications

Strategic Implementation Plan (released 2020) at: https://www.nasa.gov/aeroresearch/strategy
National Academies Study (2020) at: https://www.nap.edu/catalog/25646/advancing-aerial-mobility-a-national-blueprint
AAM and UAM

NASA Focus is on Advanced Air Mobility (AAM) Missions

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

https://www.nasa.gov/aam-studies-reports/
Advanced Air Mobility (AAM) Mission

Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions
AAM Mission Critical Commitment – What NASA will Deliver

**Vehicle Development and Operations** Develop concepts and technologies to define requirements and standards addressing key challenges such as safety, affordability, passenger acceptability, noise, automation, etc.

**Airspace Design and Operations** Develop UTM-inspired concepts and technologies to define requirements and standards addressing key challenges such as safety, access, scalability, efficiency, predictability, etc.

**Community Integration** Create robust implementation strategies that provide significant public benefits and catalyze public acceptance, local regulation, infrastructure development, etc.

**Critical Commitment:**

Based on validated operational concepts, simulations, analyses, and results from National Campaign demonstrations, the AAM Mission will deliver aircraft, airspace, and infrastructure system and architecture requirements to enable sustainable and scalable medium density advanced air mobility operations.

Achieving a “validated system architecture” will require enabling activities such as 1) the AAM National Campaign Series 2) a robust Ecosystem Partnership model and 3) NASA ARMD Portfolio Execution.
AAM Mission Critical Commitment

**Vehicle Development and Operations** Develop concepts and technologies to define requirements and standards addressing key challenges such as safety, affordability, passenger acceptability, noise, automation, etc.

**Airspace Design and Operations** Develop UTM-inspired concepts and technologies to address key challenges such as safety, access, scalability, efficiency, predictability, etc.

**Community Integration** Create robust implementation strategies that provide significant public benefits and catalyze public acceptance, local regulation, infrastructure development, insurance and legal frameworks, etc.

**Critical Commitment:**
Based on validated operational concepts, simulations, analyses, and results from National Campaign demonstrations, the AAM Mission will deliver aircraft, airspace, and infrastructure system and architecture requirements to enable sustainable and scalable medium density advanced air mobility operations.

**RVLT contribution:** Deliver enabling vehicle technologies

**Contribution from NASA Airspace projects**

https://nari.arc.nasa.gov/aamecosystem

https://www.nasa.gov/aamnationalcampaign
National Campaign Series Fundamentals

• Series Emphasis on Operational Scenarios, and remaining flexible to industry needs
  – NC-DT assesses the readiness of external ranges and partners to collect comprehensive data in support of NC-1 (~spring 2021)
  – NC-1 scenarios will move participants closer to operations by baselining operational expectations and identifying gaps in AAM (~summer 2022)
  – NC-2-4, and associated developmental testing, will progressively mature advanced UAM vehicle configurations and automation research

• Primary test ranges determined by the locations where partners plan to fly

• Ecosystem WG’s will be the primary means for the entire community to provide inputs into the Series
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NASA AAM Facilities and Capabilities Cont.

Icing Research  Landing and Impact Research Facility  Low Speed Aeroacoustic Wind Tunnel  Mobile Acoustics Facility  Mobile Operations Facility  Research Flight Deck

Testbed Virtual Infrastructure  UAS Flight Test Control Room  Vertical Motion Simulator  X-57 Maxwell  12' Tunnel–Low-cost Exploratory Facility  14- by 22-Foot Subsonic Tunnel

Many others including wind tunnels, aircraft, ranges, cockpit sims, supercomputers, etc.
NASA RVLT Project Research Areas

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

Armstrong Flight Research Center
- National Campaign execution
- UAM electric system and flt control integration
- eVTOL reliability

Glenn Research Center
- Hybrid/ Electric Systems
- Electro-Mech Powertrains
- Small Turboshift Engines
- Icing
- System Analysis
- Impact Dynamics
- Acoustics

Langley Research Center
- Acoustics
- Computational Methods
- Aeromechanics
- Experimental Capability
- Impact Dynamics
- System Analysis
NASA Concept Vehicles – Generic Geometries that Capture Many UAM Features

NASA reference vehicles ◆ Widely shared ◆ Fully documented ◆ Realistic performance ◆ Realistic set of compromises ◆ No plans to build or fly these concepts ◆

• Vehicles contain relevant UAM features and technologies
  – Battery, hybrid, diesel propulsion
  – Distributed electric propulsion
  – High efficiency rotors
  – Quieter rotors
  – Wake interactions

• Provide configurations for
  – Communication of NASA’s Urban Air Mobility research
  – Design and analysis tool development
  – Technology trade studies and sizing excursions
  – Modeling operational scenarios
  – Common configurations for studies in acoustics, flight dynamics, propulsion reliability, etc.
Research Areas for UAM eVTOL Vehicles

PROPULSION EFFICIENCY
- High power, lightweight battery
- Light, efficient, high-speed electric motors
- Power electronics and thermal management
- Light, efficient small turboshaft engine
- Efficient powertrains

SAFETY and AIRWORTHINESS
- FMECA (failure mode, effects, and criticality analysis)
- Component reliability and life cycle
- Crashworthiness
- Electric motor reliability assessment
- Propulsion system failures
- High voltage operational safety
- High voltage protection devices

OPERATIONAL EFFECTIVENESS
- Disturbance rejection (control bandwidth, control design)
- Ops in moderate to severe weather
- Passenger acceptance/ride quality
- Cost (purchase, maintenance, DOC)

PERFORMANCE
- Aircraft optimization
- Rotor shape optimization
- Hub and support drag minimization
- Airframe drag minimization

ROTOR-ROTOR INTERACTIONS
- Performance, vibration, handling qualities
- Aircraft arrangement
- Vibration and load alleviation

NOISE AND ANNOYANCE
- Low tip speed
- Rotor shape optimization
- Flight operations for low noise
- Aircraft arrangement/interactions
- Cumulative noise impacts from fleet ops
- Active noise control
- Cabin noise
- Electric motor noise
- Metrics and requirements

STRUCTURE AND AEROELASTICITY
- Structurally efficient wing and rotor support
- Rotor/airframe stability
- Crashworthiness
- Durability and damage tolerance
- High-cycle fatigue

Red = primary RVLT research area
Blue = secondary RVLT research area
RVLT Near Term Focus for Research
FY20-FY22

Vehicle Propulsion Reliability

**Reliable and Efficient Propulsion Components for UAM**
- Re-configure laboratories for electric propulsion testing
- Conduct initial single string tests
- Develop tools to assess motor reliability
- Develop high reliability conceptual motor design

UAM Fleet Noise

**UAM Operational Fleet Noise Assessment**
- Generate Noise Power Distance (NPD) database for several UAM reference configurations and trajectories
- Conduct Fleet Noise assessments
- Initiate psychoacoustic testing to assess human response to UAM vehicles

Noise and Performance

**Tools to Explore the Noise and Performance of Multi-Rotor UAM Vehicles**
- Plan and conduct validation experiments
- Improve efficiency and accuracy of conceptual design tools
- Conduct high-fidelity configuration CFD for validation and reference
- Improve community transition and training for analysis tools

Safety and Acceptability

**Targeted Research in These Areas**
- Occupant protection and survivability
- Acceptable handling and ride qualities for UAM vehicles
- Ice accretion and shedding for UAM
Summary

NASA is focused on

- Advanced Air Mobility as one of the priorities for Aeronautics research
- Vertical lift vehicle technology supporting Urban Air Mobility
- Airspace technologies for AAM
- National Campaign Demonstrations
- Ecosystem Working Groups

RVLT is focused on

- VTOL R&T to improve noise and safety

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.