NASA Vertical Flight Research
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Project Manager
Revolutionary Vertical Lift Technology

AHS International Forum 71
May 7, 2015
Topics

- Aeronautics Research Mission Directorate Strategy and Drivers
- ARMD Re-structured Program and Projects
- Vertical Flight Applications and Opportunities
Traditional measures of global demand for mobility - economic development and urbanization - are growing rapidly and creating transportation and competitive opportunities and challenges.

Revolutions in the integration of automation, information, communication, energy, materials and other technologies enable opportunity for transformative aviation systems.

Large and growing energy and environmental issues create enormous affordability and sustainability challenges.

Three Aviation Mega Drivers
NASA Aeronautics research strategy proactively addressing critical long-term needs.

www.nasa.gov
**NASA Aeronautics Six Strategic Thrusts**

**Safe, Efficient Growth in Global Operations**
- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

**Innovation in Commercial Supersonic Aircraft**
- Achieve a low-boom standard

**Ultra-Efficient Commercial Vehicles**
- Pioneer technologies for big leaps in efficiency and environmental performance

**Transition to Low-Carbon Propulsion**
- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

**Real-Time System-Wide Safety Assurance**
- Develop an integrated prototype of a real-time safety monitoring and assurance system

**Assured Autonomy for Aviation Transformation**
- Develop high impact aviation autonomy applications
ARMD Programs Address Strategic Thrusts

**Airspace Operations and Safety Program**
- Safe, Efficient Growth in Global Operations
- Real-Time System-Wide Safety Assurance
- Assured Autonomy for Aviation Transformation

**Advanced Air Vehicles Program**
- Ultra-Efficient Commercial Vehicles
- Innovation in Commercial Supersonic Aircraft
- Transition to Low-Carbon Propulsion
- Assured Autonomy for Aviation Transformation

**Integrated Aviation Systems Program**
- Flight Research-Oriented Integrated, System-Level R&T supporting all six thrusts
- X-Planes/Test Environment

**Transformative Aeronautics Concepts Program**
- High-risk, leap-frog ideas supporting all six thrusts
- Critical cross-cutting tool and technology development
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<td>- Airspace Technology Demonstrations</td>
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<td>- Shadow Mode Assessment in NAS</td>
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<td>- UAS Traffic Management</td>
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<td><strong>Advanced Air Vehicles Program</strong></td>
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<td>- Aeronautics Evaluation and Test Capabilities</td>
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<td>- Advanced Air Transport Technology</td>
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<td>- Advanced Composites</td>
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<td>- Commercial Supersonic Technology</td>
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<td>- Revolutionary Vertical Lift Technology</td>
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<td><strong>Integrated Aviation Systems Program</strong></td>
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<td>- UAS in the National Airspace System</td>
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<td>- Flight Demonstrations and Capabilities</td>
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<td><strong>Transformative Aeronautics Concepts Program</strong></td>
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<td>- Convergent Aeronautics Solutions</td>
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<td>- Transformative Tools and Technologies</td>
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<td>- Leading Edge Aero Research for NASA (LEARN)</td>
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</table>
Advanced Air Vehicles Program

Conducts fundamental research to improve aircraft performance and minimize environmental impacts from subsonic air vehicles.

Develops and validates tools, technologies and concepts to overcome key barriers, including noise, efficiency, and safety for vertical lift vehicles.

Explores theoretical research for potential advanced capabilities and configurations for low boom supersonic aircraft.

Conducts research to reduce the timeline for certification of composite structures for aviation.

Ensures the strategic availability, accessibility, and capability of a critical suite of aeronautics ground test facilities to meet Agency and national aeronautics testing needs.

Projects
- Advanced Air Transport Technology
- Revolutionary Vertical Lift Technology
- Commercial Supersonics Technology
- Advanced Composites
- Aeronautics Evaluation and Test Capabilities
Advanced Air Vehicles Program

Cutting-edge research that will generate innovative concepts, technologies, capabilities & knowledge to enable revolutionary advances for a wide range of air vehicles.

**Advanced Air Transport Project (AATT)** Conducts fundamental research to improve aircraft performance and minimize environmental impacts from subsonic air vehicles.

**Revolutionary Vertical Lift Technology Project (RVLT)** Develops and validates tools, technologies & concepts to overcome key barriers, including noise, efficiency, & safety for vertical lift vehicles.

**Advanced Composites Project (AC)** Conducts research to reduce the timeline for development and certification of composite structures for aviation.

**Commercial Supersonics Technology Project (CST)** Develops tools and explores concepts for potential advanced capabilities & configurations for low boom supersonic aircraft.

**Aeronautical Evaluation & Test Capabilities Project (AETC)** Ensures the strategic availability, accessibility, & capability of a critical suite of aeronautics ground test facilities to meet Agency & national aeronautics testing needs.
Integrated Aviation Systems Program

Conducts research on promising concepts and technologies at an integrated system level

Explores, assesses, and demonstrates the benefits of promising technologies in a relevant environment

Conducts research into environmentally responsible aviation and unmanned system integration into the national airspace

Supports flight research needs across the ARMD strategic thrusts, programs and projects

Completes flight demonstrations

Coordinates long-term ongoing research with other ARMD programs as done by the Integrated Systems Research Program. Continues the Environmentally Responsible Aviation and UAS in the NAS projects and includes the flight test portion of the former Aeronautics Test Program.

Projects
- Environmentally Responsible Aviation
- UAS Integration in the NAS
- Flight Demonstrations and Capabilities
Placeholder for AOSP
Transformative Aeronautics Concept Program Placeholder
Major Acoustic Flight Research Tests
Last 5 Years

- 2011 – Maneuver Test, Bell 430, Eglin AFB
- 2013 – Acoustics Week, CV-22, AH-64D, UH-60M, Eglin AFB, FL
- 2014 – 2015 – Three Phase Altitude Variation Test, AS350B, EH-60L, NV/CA
Acoustic Flight Testing – Mobile Acoustic Facility

Command & Control Trailer

Wireless Acoustic Microphone Systems (WAMS)

Microphone on Ground Board

Weather: LIDAR and Balloon

WAMS Trailer

WAMS
Eglin 2011 NASA/Bell/Army Maneuver Test

- Objectives
  - Understand maneuver acoustics
  - Validate ground footprint acoustic codes
  - Incorporate maneuvers into acoustic ground footprint prediction codes
- Acoustic measurement of
  - Source noise
  - Steady and transient maneuvers
  - Approach profiles
- Test executed June-July 2011
- Initial results presented in paper at 2012 American Helicopter Society Forum
OBJECTIVE
Acquire validation data to assess community noise impact and improve design capability for low noise rotor systems.

ACCOMPLISHMENTS
Flight test was conducted July-Aug 2013. The test results constitute a benchmark acoustic database of detailed acoustic source noise characteristics for a range of typical operating conditions, including highly-loaded rotors conducting terminal approach maneuvers.

SIGNIFICANCE
• Data acquired for highly loaded rotors performing descents, landings, hover and maneuvers
• Expands the capability and accuracy of the prediction tools such as the Rotorcraft Noise Model (RNM) and the Acoustics Propagation and Emulation Toolset (APET).
• First time that the acoustic signature of these aircraft were measured with the NASA microphone array technique for use in analysis.

Partners: Army AMRDEC, Apache PM, Blackhawk PM, Chicken Little Joint Project Office, Naval Air Surface Warfare Center
**OBJECTIVE** Acquire flight test data from two aircraft (with significant difference in gross weight) at three altitudes. Use data to validate altitude variations and maneuvers in FRAME (Fundamental Rotorcraft Acoustic Modeling from Experiments)

**ACCOMPLISHMENTS** Testing logistics arranged for 2 aircraft, 3 Calif. sites, involving multiple organizations. A total of 1510 data points were acquired at the three sites in 65.5 data acquisition flight hours

<table>
<thead>
<tr>
<th>Location</th>
<th>Altitude</th>
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<td>USNAC Salton Sea</td>
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**SIGNIFICANCE** FRAME will use test data to model estimated noise radiation that accounts for altitude and gross weight variations. Acoustic prediction accuracy for flight planning will be greatly improved.
Photos from USNAC Salton Sea

Light vehicle, AS350

Medium lift vehicle, EH-60L
Flight Testing on sUAS

Effort initiated in past 6 months to measure sUAS noise
Initial outdoor effort at private airport in Virginia Beach
  • Two Vertical Lift sUAS
  • Two Fixed Wing sUAS
Experience gained in acoustic flight testing of sUAS
  • Wind velocity and direction are significant factors
  • Center of gravity and pitch impact noise
  • Doppler effect is an issue at higher speeds and closer range
Leading Edge Aeronautics Research for NASA (LEARN) Fund for Non-NASA Researchers

- LEARN UAS Autonomy Test Bed NRA Solicitation Released
- White Papers Due - June 1, 2015
- [http://nari.arc.nasa.gov](http://nari.arc.nasa.gov)

NASA ARMD Research Opportunities in Aeronautics (ROA 2015)

- [http://www.aeronautics.nasa.gov/nra.htm](http://www.aeronautics.nasa.gov/nra.htm)
• NASA Aeronautics Research Mission Directorate has restructured to implement a forward-looking Strategic Plan

• Flight research remains an important part of the ARMD portfolio

• Vertical lift flight research is integrated into projects as needed

• On-going efforts in
  • Flight Acoustics Research
  • sUAS Acoustics

• Opportunities for collaboration and innovation
Growth in passengers and traffic dominated by Asia Pacific region and aircraft orders and deliveries reflect this shift.

China to add 80 new airports by 2020

India’s commercial service airports grow from 80 to 500 by 2021

Source: US Dept of Commerce

Estimated additional passenger volume in 2016 as compared with 2011

Asia-Pacific traffic to triple by 2030
Growing Commercial Aircraft Market and Competition

Civil aircraft manufacturers in 2013
Boeing (LCA)
Airbus (LCA)
Embraer (LCA, RJ)
Bombardier (RJ)

Civil aircraft manufacturers in 2033
Boeing (LCA)
Airbus (LCA)
Embraer (LCA, RJ)
Bombardier (LCA, RJ)
Mitsubishi (RJ)
Sukhoi (RJ)
China/COMAC (LCA, RJ)
India (TBD)

Source: Boeing, NASA

www.nasa.gov
NASA Aeronautics has solid partnerships, high relevancy, and is delivering high impact.

Strategy builds upon success and recognizes:
- Rising competition in international R&D
- Challenges in mobility, energy, and environment
- Opportunities to infuse rapidly advancing non-aerospace sector technologies

ARMD’s Program investments provide for transformative research for long-term leadership, collaborative partnerships to achieve real near to mid-term results, and leverages high impact research advancements from non-aerospace fields.

“The Time Bomb of Complacency – AvWeek Editorial, September 2, 2013

“An alarm needs to be sounded. A vital and vigorous aeronautics research program is essential... NASA's unveiling of a new strategy for aeronautics research is a bold and welcome move.”

www.nasa.gov
## FY 2016 Budget

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<th>Budget Authority ($M)</th>
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Special Session: Future VTOL Demonstrations, Suite IA
Moderated by Mike Hirschberg, AHS International
• Dan Bailey, US Army Aviation Development Directorate: “Future Vertical Lift (FVL) and the Joint Multi-Role (JMR) Technology Demonstrations”
• Dr. Ashish Bagai, DARPA: “DARPA VTOL Programs”
• Dr. James Wang, AgustaWestland: “Next Generation Civil TiltRotor for Clean Sky 2”
• Tomasz Krysinski, Airbus Helicopters: “Low Impact Fast & Efficient RotorCraft (LifeRCraft) for Clean Sky 2”
• Dr. Jai Moo Kim, Korea Aerospace Research Institute: "KARI Tiltrotor UAV Demonstrators and Performance Enhancement Tests"