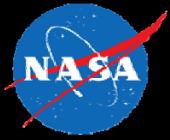




# NASA Vertical Flight Research

Susan A. Gorton  
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**



# Three Aviation Mega Drivers

NASA Aeronautics research strategy proactively addressing critical long-term needs



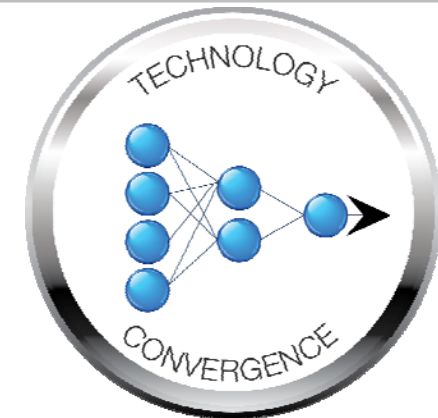
Traditional measures of **global** demand for **mobility** - economic development and urbanization - are growing rapidly and creating transportation and competitive opportunities and challenges

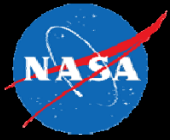


Large and growing energy and **environmental** issues create enormous affordability and sustainability **challenges**



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





# 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



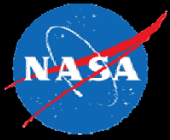
## Real-Time System-Wide Safety Assurance

- 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



# ARMD Programs/Projects With Application to Vertical Lift

## Airspace Operations and Safety Program

- Airspace Technology Demonstrations
- Shadow Mode Assessment in NAS
- Safe Autonomous Systems Ops
- **UAS Traffic Management**

## Advanced Air Vehicles Program

- **Aeronautics Evaluation and Test Capabilities**
- Advanced Air Transport Technology
- **Advanced Composites**
- Commercial Supersonic Technology
- **Revolutionary Vertical Lift Technology**

## Integrated Aviation Systems Program

- Environmentally Responsible Aviation
- UAS in the National Airspace System
- Flight Demonstrations and Capabilities

## Transformative Aeronautics Concepts Program

- **Convergent Aeronautics Solutions**
- **Transformative Tools and Technologies**
- **Leading Edge Aero Research for NASA (LEARN)**





# Advanced Air Vehicles Program

Mission 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.

Advanced Air Vehicles Program

Continues much of the research that was in the Fundamental Aeronautics Program, with a new focus on research that is directly related to the newly defined strategic thrusts. It now houses the Advanced Composites Project that was previously in the Integrated Systems Research Program. It also includes the ground test portion of the former Aeronautics Test Program.

## Projects

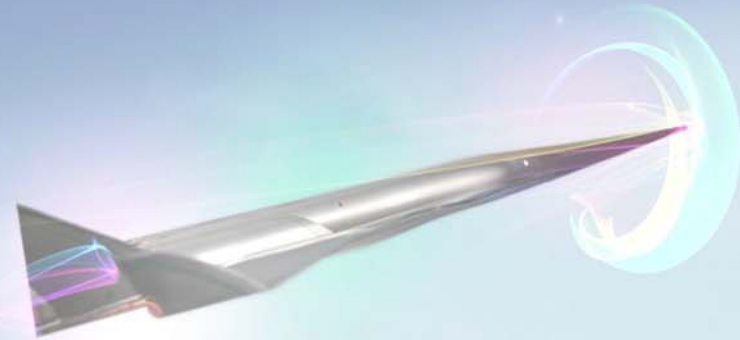
Advanced Air Transport Technology

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.**

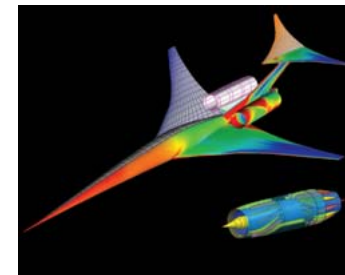
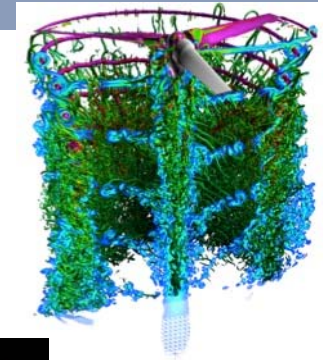
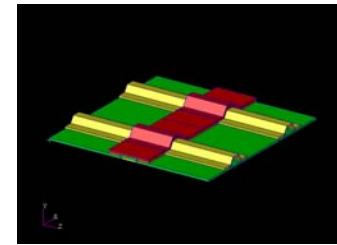
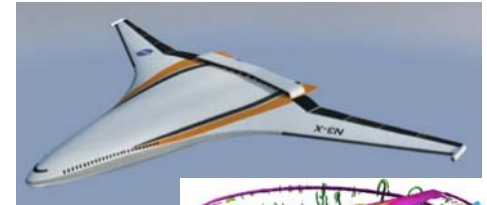
**Advanced Air Transport Project (AATT)** Conducts fundamental research to improve aircraft performance and minimize environmental impacts from subsonic air vehicles

**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

Mission Program

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

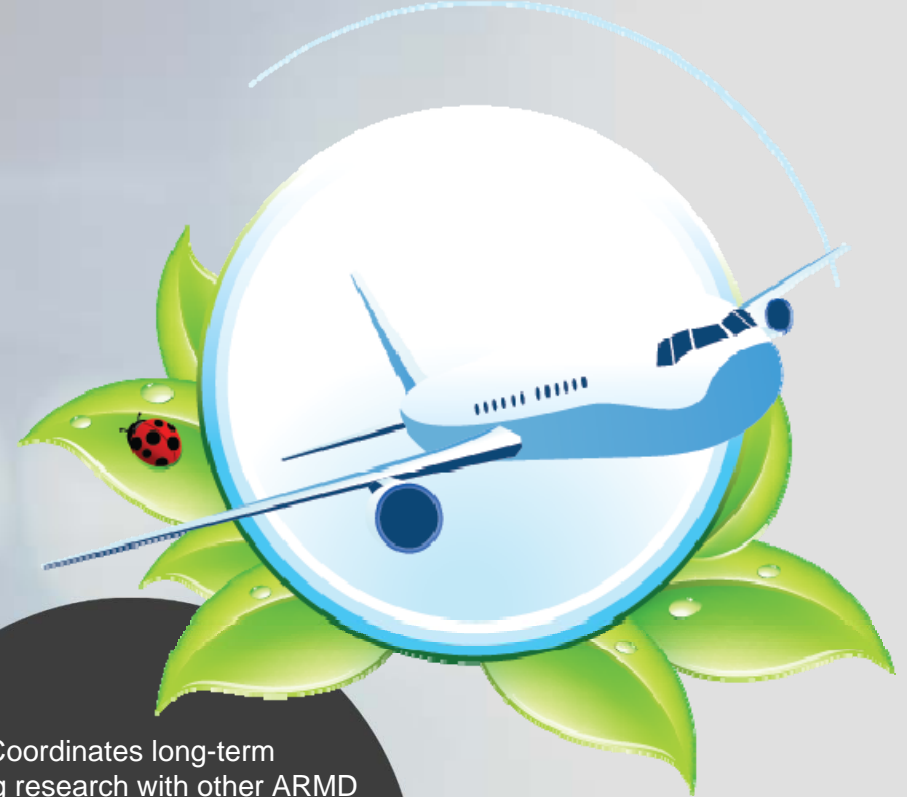
Coordinates long-term ongoing research with other ARMD programs as done by the Integrated Systems Research Program. Continues the Environmentally Responsible Aviation and UAS in the NAS projects and includes the flight test portion of the former Aeronautics Test Program.

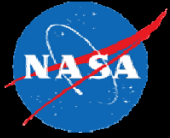
## Projects

Environmentally Responsible Aviation

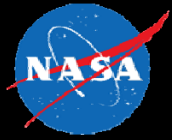
UAS Integration in the NAS

Flight Demonstrations and Capabilities

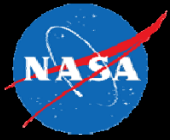




# Placeholder for AOSP



# 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



WAMS



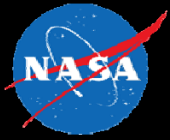
Weather:  
LIDAR and  
Balloon



WAMS Trailer



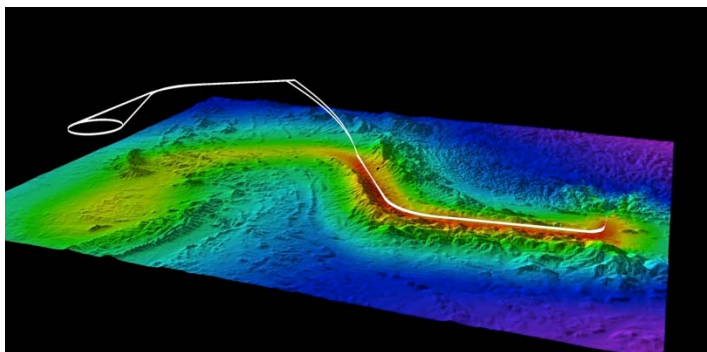
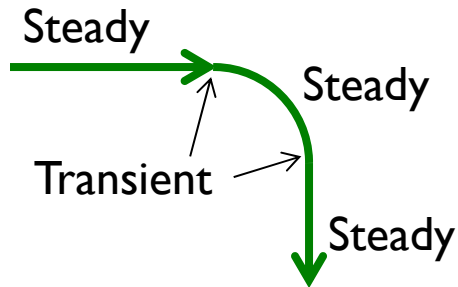




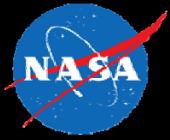
# Eglin 2011 NASA/Bell/Army Maneuver Test



Bell 430 Aircraft



- 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
- NASA report TM-2014-218226, published May 2014: Maneuver Acoustic Flight Test of the Bell 430 Helicopter Data Report.



# 2013 Acoustic Flight Test Research @ Eglin AFB

## 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.



CV-22 Osprey



AH-64D Apache



HH-60M Blackhawk

15



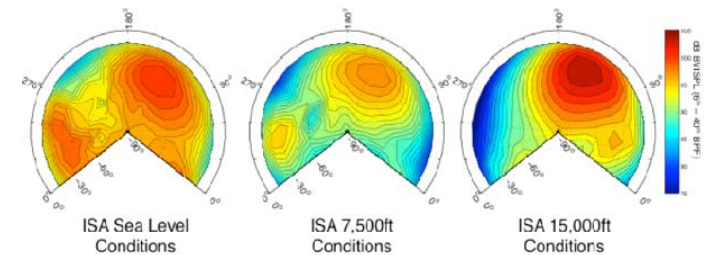
# Altitude Variation Flight Test

**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

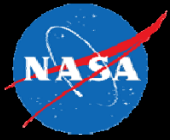
Sweetwater USMC Auxiliary Airfield	6800 ft	✓	Sept 22-Oct 11, 2014
Amedee Army Auxiliary Airfield	4000 ft	✓	Oct 20- Nov 22, 2014
USNAC Salton Sea	sea level	✓	Feb 3-Feb 16, 2015

**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.



FRAME Predicted Acoustics at Three Altitudes





# Photos from USNAC Salton Sea

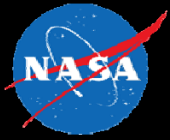
Light vehicle, AS350



Medium lift vehicle, EH-60L







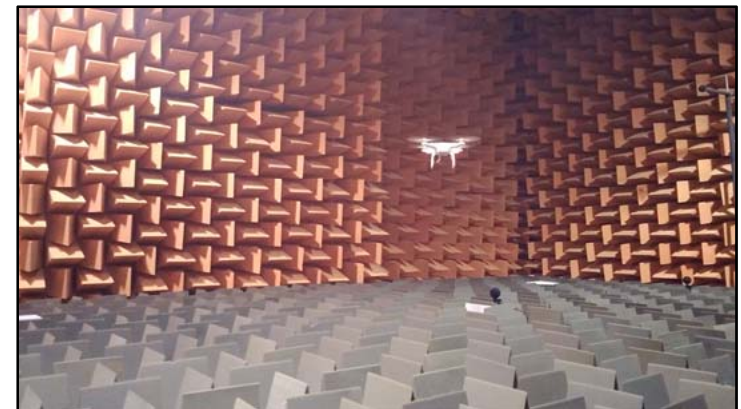
# Flight Testing on sUAS

**Effort initiated in past 6 months to measure sUAS noise**  
**Initial outdoor effort at private airport in Virginia Beach**

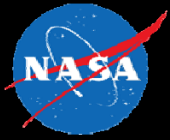
- **Two Vertical Lift sUAS**
- **Two Fixed Wing sUAS**

**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**







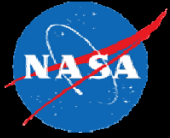
# Upcoming External Opportunities

## 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>

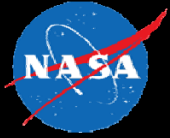
## NASA ARMD Research Opportunities in Aeronautics (ROA 2015)

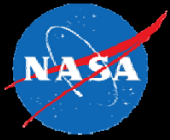
- <http://www.aeronautics.nasa.gov/nra.htm>



## Summary

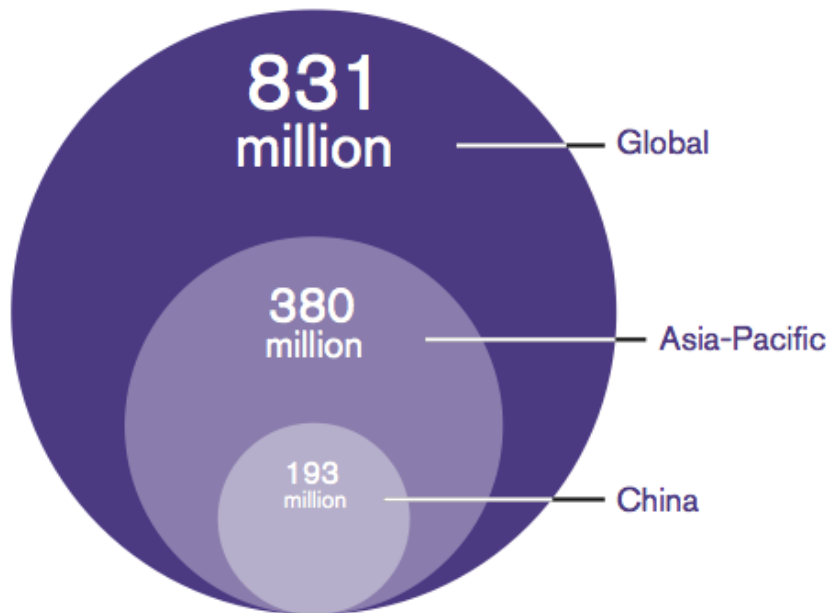
- **NASA Aeronautics Research Mission Directorate has restructured to implement a forward-looking Strategic Plan**
- **Flight research remains an important part of the ARMD portfolio**
- **Vertical lift flight research is integrated into projects as needed**
- **On-going efforts in**
  - **Flight Acoustics Research**
  - **sUAS Acoustics**
- **Opportunities for collaboration and innovation**





# Aviation Market Growing and Moving East

Growth in passengers and traffic dominated by Asia Pacific region and aircraft orders and deliveries reflect this shift



Estimated additional passenger volume in 2016 as compared with 2011

China to add 80 new airports by 2020

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

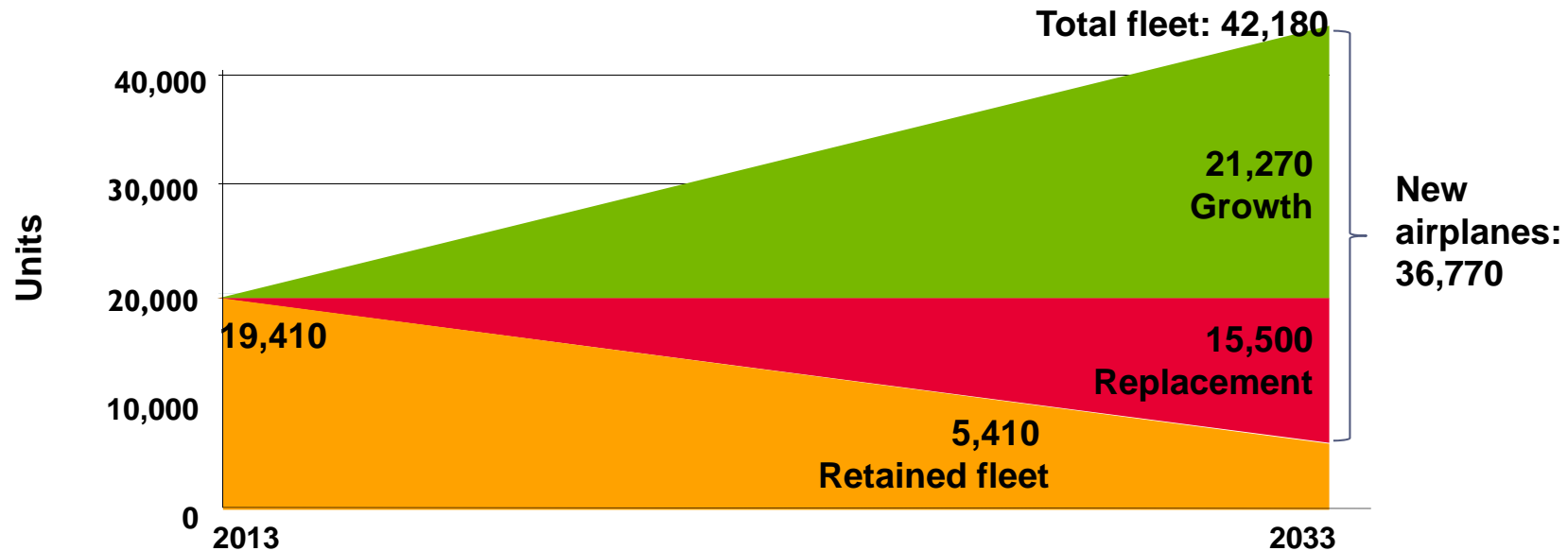
Source: US Dept of Commerce



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





# NASA's FY 2016 Budget Builds on ARMD Strategy that Began Execution in FY 2015

Embarking on the next 100 years of excellence.

- ▶ 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

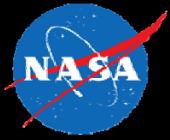
"Civil aviation [is] blessed with growing demand, record orders and increasing deliveries, but facing global competitors, affordability and sustainability challenges, and an industry-shaking technological revolution."

Graham Warwick,  
AvWeek, September 2013

## 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](http://www.nasa.gov)



# FY 2016 Budget

Budget Authority (\$M)	Actual	Enacted	Request	Outyears are Notional			
	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
<b>Aeronautics</b>	<b>\$566.0</b>	<b>\$651.0</b>	<b>\$571.4</b>	<b>\$580.0</b>	<b>\$588.7</b>	<b>\$597.5</b>	<b>\$606.4</b>
Airspace Operations and Safety			142.4	153.2	159.6	160.0	163.0
Advanced Air Vehicles			240.9	243.2	241.2	231.0	232.8
Integrated Aviation Systems			96.0	85.6	89.0	101.6	104.8
Transformative Aeronautics Concepts			92.1	98.0	98.9	104.9	105.8
Aviation Safety	80.0						
Airspace Systems	91.8						
Fundamental Aeronautics	168.0						
Aeronautics Test	77.0						
Integrated Systems Research	126.5						
Aeronautics Strategy and Management	22.7						



- ▶ 8:15am -12:15pm; 23 min presentation; 5 min Q&A; 2 min introduction
- ▶ ~15 charts

Special Session: Future VTOL Demonstrations, Suite 1A

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”
- Susan Gorton, NASA: “NASA Vertical Flight Research”
- Dr. James Wang, AgustaWestland: “Next Generation Civil TiltRotor for Clean Sky 2”
- Tomasz Kryszinski, 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”