NASA Aeronautics FY 2017 Budget Request

Investing in our Future

Briefing to REDAC NAS Operations Subcommittee Meeting

John Cavolowsky, Director, Airspace Operations and Safety Program
March 9, 2016
Global Growth in Aviation: Opportunities and Challenges

**Global Air Passengers by Region (% of Total)**

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<tbody>
<tr>
<td>Asia Pacific</td>
<td>27</td>
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<td>Africa</td>
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<td>Middle East</td>
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<tr>
<td>South America</td>
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<tr>
<td>North America</td>
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<tr>
<td>Europe</td>
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<tr>
<td><strong>Total</strong></td>
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- **2014**
  - 3.3B Passenger Trips
  - North America and Europe combined is half of all Passenger Trips
  - 58M Jobs
  - $2.4T GDP
- **2034**
  - 7B Passenger Trips
  - Asia-Pacific Passenger Trips equal to North America and Europe combined
  - 105M Jobs
  - $6T GDP

Over 36,000 New Aircraft required (replacement and growth) over the 20 year period ($4-$5T value)

**Sources:** International Air Transport Association, Air Transport Action Group, Boeing

**Major Opportunities / Growing Challenges**

**Competitiveness**—New state backed entrants, e.g., COMAC (China); Growing global R&D

**Environment**—Very ambitious industry sustainability goals; Large technology advances needed

**Mobility**—More speed to connect the worlds’ major cities; Opportunity for commercial supersonic flight

**U.S. Technological Leadership Required!**
Major US Airlines Collaborating with NASA

**American Airlines**
- **Weather Rerouting**
  Changing the non-profitable flights into profitable flights
- **Terminal Sequencing and Spacing**
  Increasing throughput and fuel efficiency for arrivals

**US Airways**
(now part of American Airlines)
- **Surface Management**
  Reducing delays and fuel consumption

**Southwest**
- **Data Mining**
  Improving efficiency and safety

**United**
- **Efficient Descent Advisor**
  Saving time and reducing fuel burn for arrivals
- **Flight deck Interval Management**
  Increasing throughput with improved arrival spacing for landing

**Virgin America**
- **Traffic Aware Strategic Aircrew Requests**
  Optimizing time and fuel savings for pilot entered route changes
- **Flight Awareness Collaboration Tool**
  Reducing cancellations and delays due to winter storms

**Alaska Airlines**
- **Traffic Aware Strategic Aircrew Requests**
  Optimizing time and fuel savings for pilot entered route changes

Photo credit: markyharky via VisualHunt / CC BY
Major US Airports Collaborating with NASA

**DEN**
Denver International Airport

**Efficient Descent Advisor**
Improving arrival efficiencies

**DFW**
Dallas Fort Worth International Airport

**Precision Departure Release Capability**
Increasing departure time conformance

**CLT**
Charlotte Douglas International Airport

**Integrated Arrival/Departure/Surface (IADS)**
Reducing overall departure delay

**PHX**
Phoenix Sky Harbor International Airport

**Terminal Sequencing and Spacing (TSAS)**
Increasing throughput and fuel efficiency for arrivals

**LAX**
Los Angeles International Airport

**Terminal Sequencing and Spacing (TSAS)**
Increasing throughput and fuel efficiency for arrivals

**Flight deck Interval Management (FIM)**
Increasing runway throughput for arrivals
U.S. leadership for a new era of flight
NASA Aeronautics Ready for Flight
Accomplishments and Planning

N+3 Subsonic & Supersonic Concept/Technology Studies
N+2 Environmentally Responsible Aviation (ERA) Project Initiated

2008-2013

2014/15

2016/17

2018-2026

Ground Testing of N+3 configurations and technologies

8 Integrated Tech Demos Completed, Tech transitioned to industry. HWB ready for Flight Dem/Val.

LBFD PDR Completed

U EST PDR Completed

Ready for X-Plane Integration & Demonstration

NASA Aero Vision and Strategy Established

Roadmaps Completed

Technology Transitions to FAA: MSP, EDA, PDRC, TSAS

ATD-1 Completed and transferred to FAA

ATD-2, 3 Completed & Transferred to FAA

Ready for NextGen TBO Integration & Demonstration

NASA FAA NextGen Research Transition Teams (RTTs) Initiated

www.nasa.gov
Ten Year Investment Plan—FY 2017 Budget Accelerates Key Components of NASA Aeronautics Plan

Fund the Next Major Steps to Efficient, Clean and Fast Air Transportation Mobility

**New Aviation Horizons**

Start a continuing series of experimental aircraft to demonstrate and validate high impact concepts and technologies. Five major demonstrations over the next 10+ years in the areas of Ultra-Efficiency, Hybrid-Electric Propulsion, and Low Noise Supersonic Flight.

- Major New Initiative within IASP

**Enabling Tools & Technologies**

Major series of ground experiments to ready key technologies for flight.

- Research and ground demonstration for an advanced small engine core for very high bypass engines and as a hybrid-electric propulsion enabler
- Development of next generation physics-based models needed to design advanced configurations

- Increases to AAVP and TACP

**Revolutionizing Operational Efficiency**

Accelerate demonstration of full gate-to-gate Trajectory Based Operations.

- Increase to AOSP

**Fostering Advanced Concepts & Future Workforce**

Increased investment in new innovation through the NASA workforce and Universities.

- Increase to TACP

**UAS**

Strong continued research leadership in enabling UAS integration into the National Airspace. Extending the UAS in the NAS project for an additional 4 years.

- Increases to IASP and AAVP

**Hypersonics**

Increased investment to ensure a strong National fundamental research capability.

- "Revolutionizing Operational Efficiency"
- "Fostering Advanced Concepts & Future Workforce"
- "UAS"
- "Hypersonics"

Build off of major current developments and accomplishments

Continue to incentivize new innovation
### FY 2017 Budget

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Aeronautics budget includes paid-for 10-year mandatory funding from the Administration’s 21st Century Clean Transportation Plan. See appendix for additional detail.

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<th>Mandatory Budget Authority $ Millions</th>
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Ultra-Efficient Subsonic Demonstrators

D-8
Potential Purpose Built X-Plane
Propulsion-Airframe Integration enables reduced aircraft drag

HWB
Multiple Integrated Technologies
Non-circular composite fuselage
Aerodynamically efficient fuselage shape

Truss-Braced Wing
Potential Purpose Built X-Plane
Top mounted engines enable Ultra-High Bypass Engines

Very High Aspect Ratio wings substantially increases wing efficiency

Composite fuselage of conventional shape
More electric sub-systems

Very-High Bypass Engines, reaching physical installation limits

Highly-efficient wing of conventional aspect ratio

787 Image credit: Boeing
Low Boom Flight Demonstrator

- Demonstrate that noise from sonic boom can be reduced to a level acceptable to the population residing under future supersonic flight paths.
- Create a community response database that supports an International effort to develop a noise based rule for supersonic overflight.
- Establish U.S. Leadership for this New Global Market
Hybrid Electric Propulsion
Prove Out Transformational Potential

Explore and demonstrate vehicle integration synergies enabled by hybrid electric propulsion.

Increasingly electric aircraft propulsion with minimal change to aircraft outer mold lines.

Modeling
Explore Architectures
Test Beds
Component Improvements

Gain experience through integration and demonstration on progressively larger platforms.

Knowledge through Integration & Demonstration

www.nasa.gov
New Aviation Horizons Flight Demo Plan

- Hybrid Electric Propulsion Demonstrators
  - Transport Scale
  - Ground Test Risk Reduction
  - Preliminary Design
  - Design & Build
  - Flight Test
  - Total Demonstration Cost ROM: $700M
- “Purpose-Built” UEST Demonstrators
  - Small Scale “Build, Fly, Learn”
  - Preliminary Design
  - Design & Build
  - Flight Test
  - Ground Test Risk Reduction
  - Design & Build
  - Flight Test
  - Life Cycle Cost ROM: $400-500M
  - Potential Candidates
  - Life Cycle Cost ROM: $400-500M
- Fully integrated UEST Demonstrator
  - Preliminary Design
  - Design & Build
  - Flight Test
  - Life Cycle Early Cost Est: $850M
  - Life Cycle Cost Est: $430M

- FY17
- FY18
- FY19
- FY20
- FY21
- FY22
- FY23
- FY24
- FY25
- FY26

- Validated ability for U.S. Industry to Build Transformative Aircraft that use 50% less energy and produce over 40dB (cumulative) less noise
- Validated HEP Concepts, Technologies And Integration for U.S. Industry to Lead the Clean Propulsion Revolution
- Enables Low Boom Regulatory Standard and validated ability for industry to produce and operate commercial low noise supersonic aircraft

Images Credit: Lockheed Martin

www.nasa.gov 12
**Trajectory Based Operations: Concept to Demo**

Next Step in NASA Research and NextGen Development

**Gate-to-Gate Optimization**
Gate-to-Gate 4DT TBO: Complete gate-to-gate flight optimization incorporating system constraints and user request.

**Concept Validation**
- Architectural Definition
- Tech Gap Assessment

**Technology Maturation**
- Fast-time Simulation
- Human In The Loop Simulation
- Integrated Field Demo

**Demo**

**Initial Integrated Demand Management**

**ATD-1**
ATD-1: Efficient descent, approach, and landing for all flights inbound to an airport

**ATD-2**
ATD-2: Coordinated preflight, taxi, takeoff, and departure paths for all outbound flights at an airport

**Complex Terminal Area Trajectory Management**

**Ground Side Demo**

**Flight Side Demo**

**ATD deliverable**

Develop and Demonstrate NextGen Capabilities: Reducing fuel use and flight delays

IDM TBO: Integrates departure, en route, and descent flight operations for greater optimization

Enables airlines to operate increasingly efficient 4D "gate-to-gate" trajectories

Enables airlines to optimize efficient operations into and out of busy airports and terminal area airspace

ATD-1: Efficient descent, approach, and landing for all flights inbound to an airport

ATD-2: Coordinated preflight, taxi, takeoff, and departure paths for all outbound flights at an airport

www.nasa.gov
New Era For NASA Aeronautics

Investing In Our Future - Investments in NASA’s cutting edge aeronautics research today are investments in a cleaner, safer, quieter and faster tomorrow for American aviation:

• A future where Americans are working in stable, well-paying jobs.
• A future where we fly on aircraft that consume half as much fuel and generate only one quarter of current emissions.
• A future where flight is fueled by greener energy sources.
• A future where our air transportation system is able to absorb nearly four billion more passengers over the next 20 years without compromising the safety of our skies.
• A future where our airports are better neighbors because aircraft noise is contained well within the airport boundary.
• A future where people can travel to most cities in the world in six hours or less in an airplane that can fly faster than the speed of sound on bio-fuels.
Back-Up
## Lab-to-Field

### Efficient Descent Advisor (EDA)
- Provides speed and path advisories to save time and fuel in arrivals descents from En Route airspace to runway
- United Airlines, DEN, FAA and Denver Air Route Traffic Control Center
- Transferred to FAA – Jan 2012
- Product Benefits:
  - $143M / year savings
  - Improved meter-fix delivery accuracy
  - Potential FAA deployment 2018
  - 60% reduction in metering related clearances

### Precision Departure Release Capability (PDRC)
- Precision release of tactical departures for efficient en route stream merge; Analogous to cars merging onto a busy freeway
- American Airlines, DFW and FAA
- Transferred to FAA – Jan 2013
- Product Benefits:
  - 50% increase in departure time conformance
  - $20M / year savings
  - To airlines from increased en route slot merge compliance

### ATD-1: Terminal Sequencing & Spacing Tool (TSAS)
- Advanced scheduling and sequencing of arrivals and runway
- Terminal controller advisories to maintain precision schedules
- American Airlines (formerly US Airways), FAA
- Transferred to FAA – July 2014
- Product Benefits:
  - $300-$400M / year savings
  - Increased throughput
  - >90% PBN conformance during high density, mixed equipage arrival operations improving fuel and operational efficiency
## Lab-to-Field

### ATD-1: Flightdeck Interval Management (FIM)
- **Product Benefits**
  - Improved delivery accuracy during high density arrival operations
  - Improving throughput and reducing passenger delay
- **Status**
  - FIM Flight Test Feb 2017
  - Transfer to FAA in 2017
- **NASA’s work on these technologies**
  - Speed advisories for airborne precision spacing
  - United Airlines, Boeing, Honeywell, FAA and ACSS

### ATD-2: Integrated Arrival/Departure/Surface (IADS)
- **Product Benefits**
  - 40% reduction in overall departure delay (estimate)
  - $8.2B potential savings over 20-year lifecycle (estimate)
- **Status**
  - Baseline field testing begins Sep 2017
  - Metroplex testing begins Sep 2019
- **NASA’s work on these technologies**
  - Improves predictability and operational efficiency in metroplex environment, including arrival, departure and surface prediction, scheduling and management
  - American Airlines, CLT, FAA and NATCA

### ATD-3: Dynamic Weather Reroutes (DWR)
- **Product Benefits**
  - Analysis indicates potential savings of about 100,000 flying minutes for 15,000 flights, or about 6.7 minutes/flight on average
- **Status**
  - Operational testing in AA IOC since July 2012
  - Will be extended to develop ATD-3 and transfer to FAA
- **NASA’s work on these technologies**
  - Recovers delay caused by static weather reroute plans in En Route environment
  - American Airlines Integrated Operations Center (IOC), DFW and FAA

### ATD-3: Traffic Aware Strategic Aircrew Requests (TASAR)
- **Product Benefits**
  - Optimizes to save time or fuel; Projections for carriers optimized for (12 representative city pairs)
  - Time, 4.2 minutes
  - Fuel, 575 pounds
  - Increases ATC approvability through ADS-B IN data
- **Status**
  - NASA flight test in 2015
  - Integration with airlines in 2016
  - Operational testing in airline fleets 2017-2018
- **NASA’s work on these technologies**
  - Pilot onboard automation tool to optimize aircraft’s trajectory
  - Leverages networked connectivity to real-time operational data
  - Flight test partners Alaska Airlines and Virgin America

Note: Analysis of all Fort Worth Center traffic in 2013, excluding arrivals to the major Dallas airports, Dallas-Fort Worth International (DFW) and Dallas Love Field (DAL).