

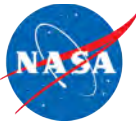
# NASA Ames Research Center Air Traffic Management Research Overview

Sandy Lozito  
Chief, Aviation Systems Division  
July 18, 2017



- Who's ever been delayed at the airport waiting to depart for what appears to be no reason whatsoever?
- Who's ever landed and had to wait for a gate for 20+ minutes?
- Who's ever wanted to fly their sweet new UAV over their massive oil pipeline without slamming into all sorts of other UAVs?

# Why is aviation so important?

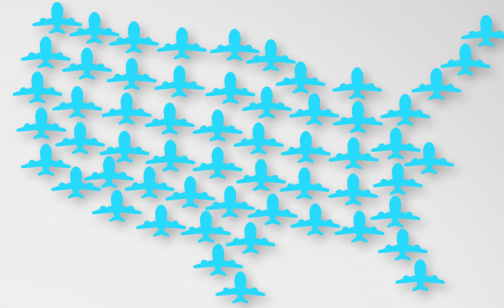


The air transportation system is critical to U.S. economic vitality.



**\$1.5** TRILLION

TOTAL U.S. ECONOMIC ACTIVITY  
(civil aviation-related goods and services, 2012)



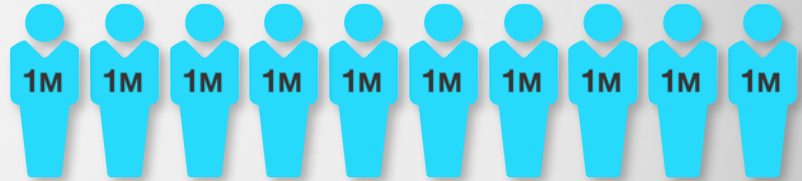
**\$76.1** BILLION

POSITIVE TRADE BALANCE  
(aerospace industry, 2012)



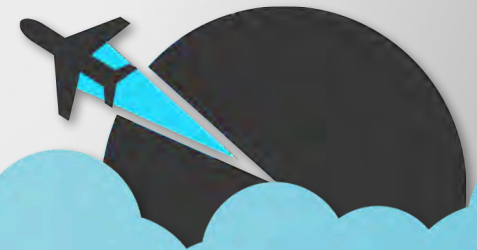
**11.5** MILLION

DIRECT AND INDIRECT JOBS  
(civil and general aviation, 2012)



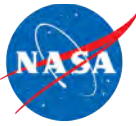
**5.4%** (\$847.1 BILLION)

OF TOTAL U.S. GROSS DOMESTIC PRODUCT (GDP)  
(civil and general aviation, 2012)



# Why should I care?

Take the system view. You may not have flown today but something you needed did.



**17.7** BILLION

TONS OF FREIGHT TRANSPORTED BY AIR

(all U.S. carriers, 2013)



**\$670.8** BILLION

SPENT BY AIR TRAVELERS IN U.S. ECONOMY

(domestic and foreign travelers, 2012)



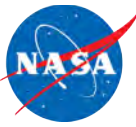
**741** MILLION

PASSENGERS ON U.S. CARRIERS

(domestic and foreign, 2013)



# What are the challenges?



Challenges are driven by emerging global trends.



**16** BILLION

GALLONS OF JET FUEL BURNED IN 2013  
(U.S. airlines)

**\$8.1** BILLION

COST OF DELAYS TO U.S. AIRLINES IN 2013



**\$9.3** BILLION

SPENT BY AIRPORTS ON NOISE ABATEMENT SINCE 1982



**3%**

AND

**5%**

OF GLOBAL CO<sub>2</sub>

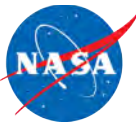
WARMING EFFECTS PROJECTED FROM AVIATION BY 2050



**360** MILLION

PASSENGERS BEING ADDED IN ASIA PACIFIC FROM 2009 TO 2014  
(market is growing and moving East)

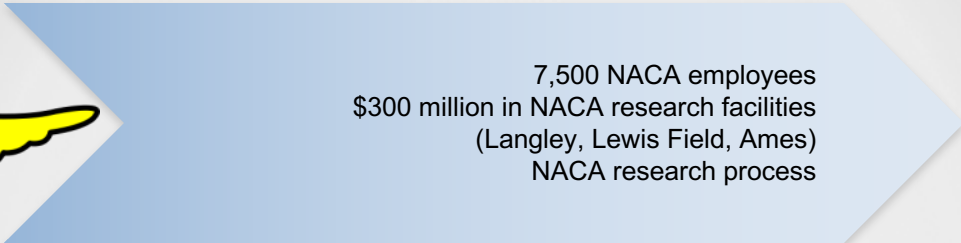
# Why is "Aeronautics" the first "A" in NASA?



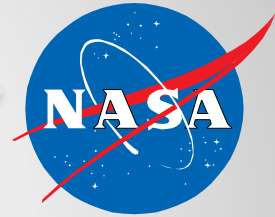
The nation's early aeronautics research led to creation of NASA.



National Advisory Committee for Aeronautics  
March 3, 1915

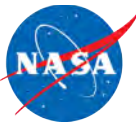


7,500 NACA employees  
\$300 million in NACA research facilities  
(Langley, Lewis Field, Ames)  
NACA research process



National Aeronautics and Space Administration  
October 1, 1958

# What does NASA Aeronautics do?



NASA is with you when you fly.

**Vehicles**

**Safety**

**Integrated Systems Research**

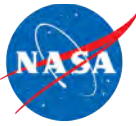
**Air Traffic Management**

**Test Facilities**

The collage features a central circular image of a NASA X-45 hypersonic aircraft. Surrounding it are four main panels: 'Vehicles' (top left) showing a rocket nose cone, a conventional airplane, and a person working with a mesh; 'Safety' (top right) showing a cockpit display with 'RUNWAY CONFLICT' warnings and a person at a control console; 'Air Traffic Management' (bottom left) showing a complex network of flight paths and radar screens; and 'Test Facilities' (bottom right) showing an aircraft in a wind tunnel and a person working on a model.

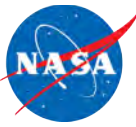
# What vision has NASA set for aviation?

A revolution in sustainable global air mobility.





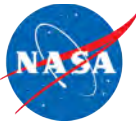
# Who is NASA Aeronautics?



Engineers, pilots, managers, programmers -- we are proud of our legacy of technology contributions to aviation.



# What is NASA Aeronautics working on?



Research activities reflect NASA's vision to ultimately transform aviation.

Air traffic management tools that reduce delays and save fuel

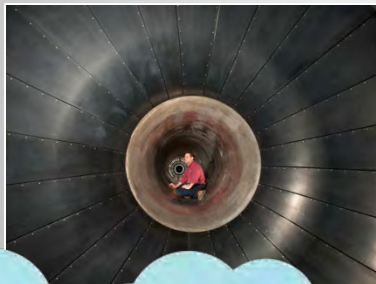
Aircraft shapes that reduce aviation's impact on the environment

Data that reveals the real impacts of alternative jet fuels

Tests of new technologies that increase autonomy in the aviation system

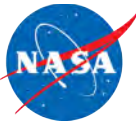
Technologies that lower the volume on sonic booms

Ground tests on ways to detect and prevent engine icing in jet engines



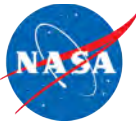


# Test your knowledge!



- NASA is a:
  - A. Privately-owned company
  - B. Federal government agency
  - C. Part of the Department of Defense
  - D. Federally-funded research and development corporation (FFRDC)
  - E. A non-profit organization

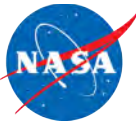
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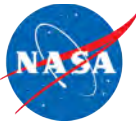


# Test your knowledge!



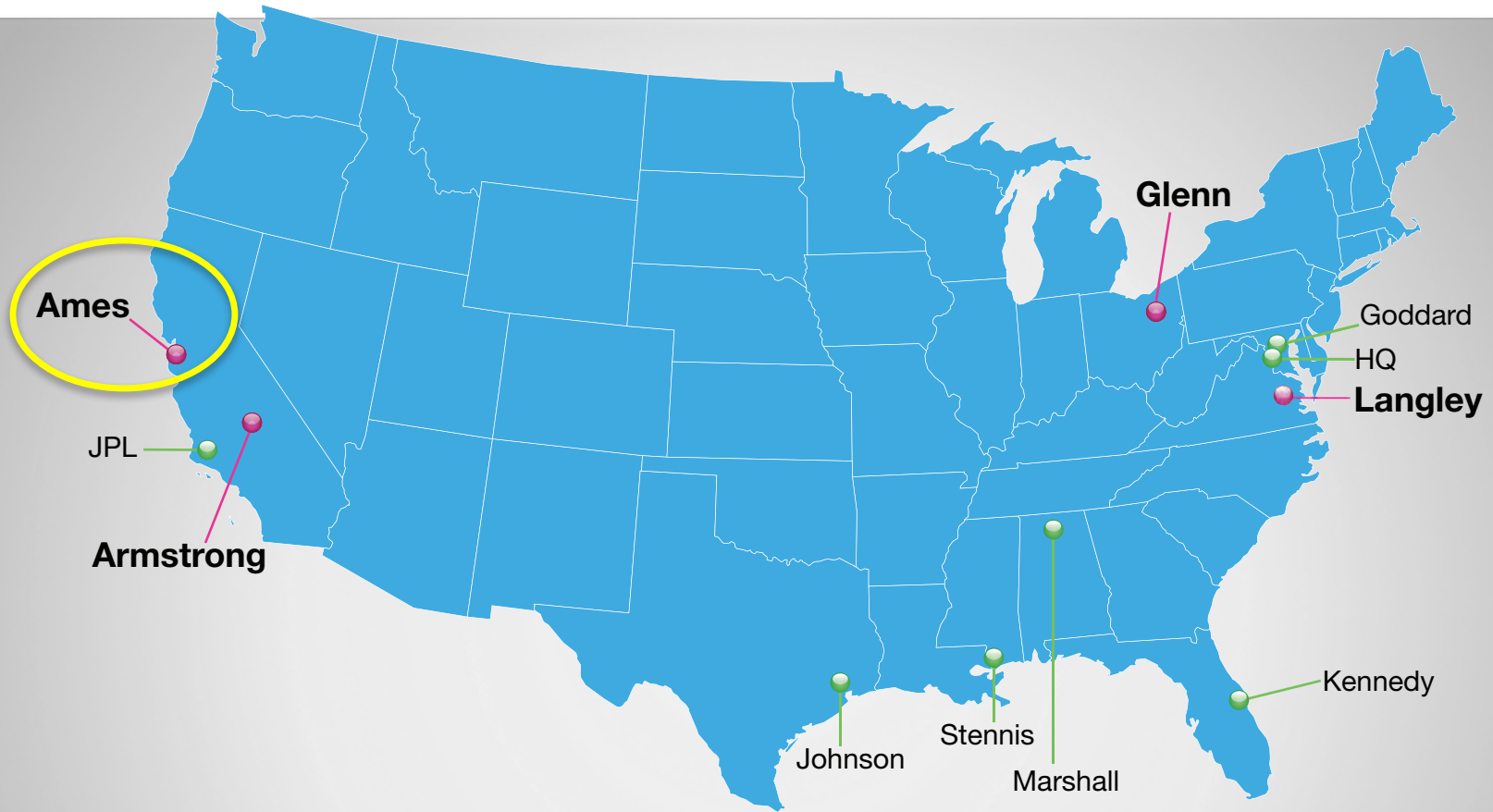
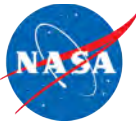
- How many NASA field centers are there, not including HQ?
  - A. Three
  - B. Four
  - C. Five
  - D. Seven
  - E. Ten

# Test your knowledge!



- How many NASA field centers are there, not including HQ?
  - A. Three
  - B. Four
  - C. Five
  - D. Seven
  - E. Ten; how many can you name?

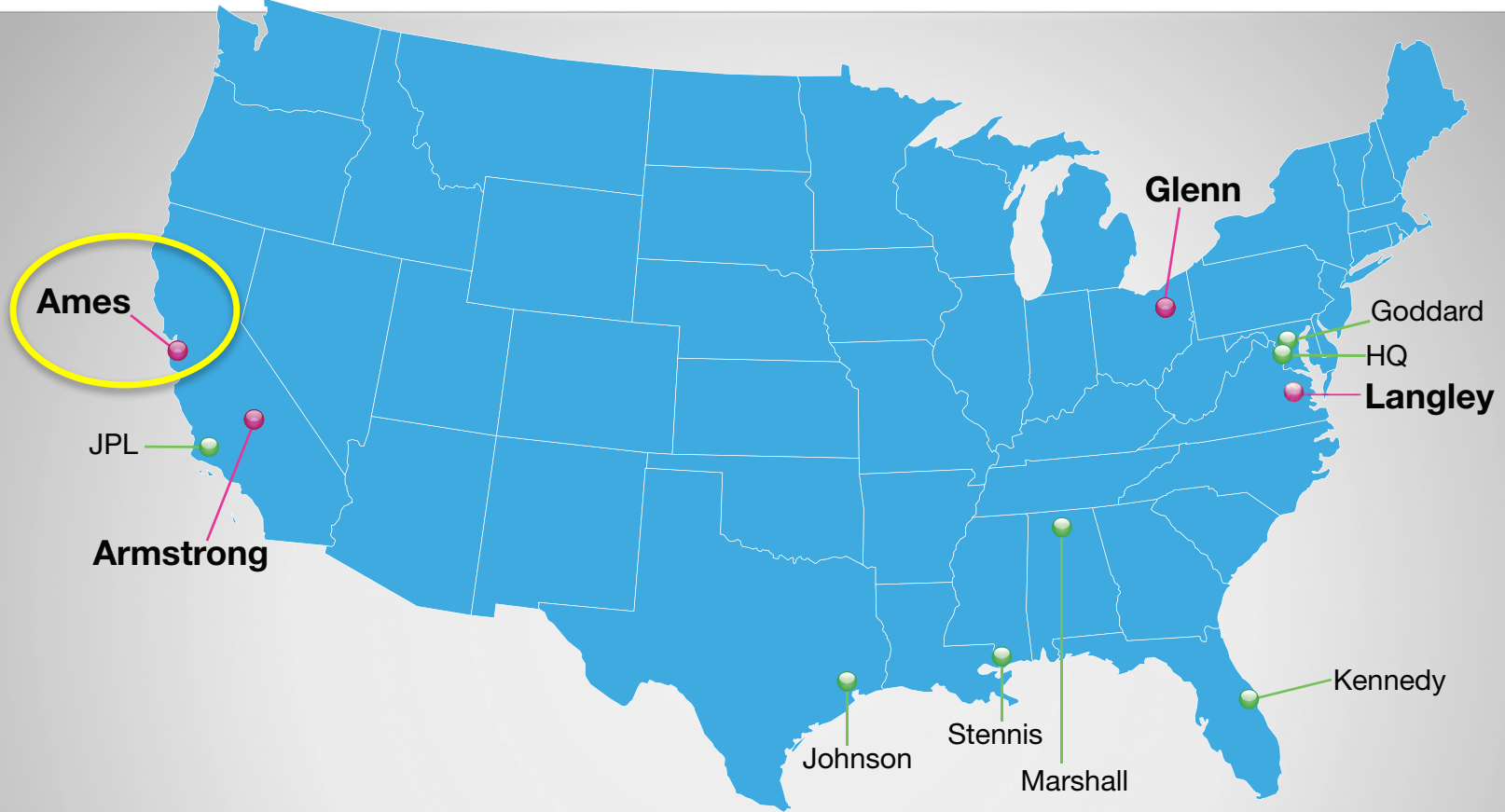
# You are here



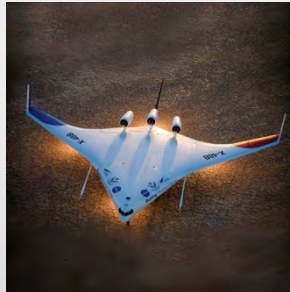
# Where does NASA aeronautics research happen?



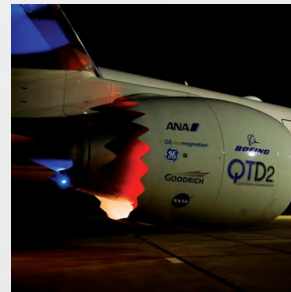
Aeronautics research takes place at four of NASA's centers.



AMES



ARMSTRONG



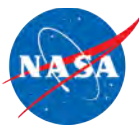
GLENN



LANGLEY



# March 3, 2015 was the 100<sup>th</sup> anniversary of what?

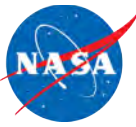


1940 – Ames Aeronautical Laboratory



# Moffett Field

1943

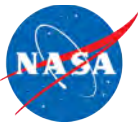


\* National Advisory Committee on Aeronautics (predecessor to NASA)



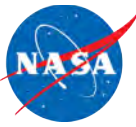
# USS Macon

February 1934



# Navy Squadrons VF-6, VB-2, VS-2, & VT-2

July 1934



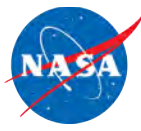


# First Ames Test Plane – O-47A

October 1940

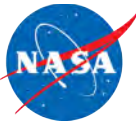


# Aerial View of Ames Research Center



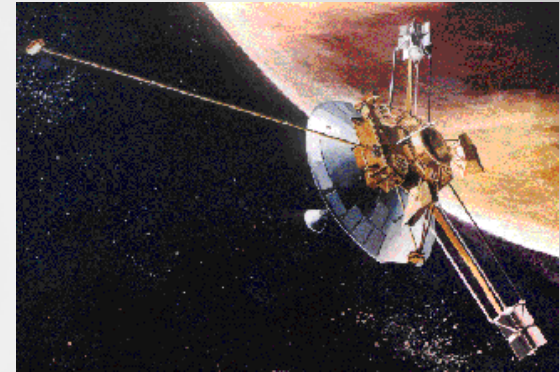


# Ames Contributions



Has conducted pioneering aeronautics research since WWII

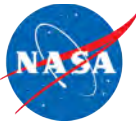
Designed and developed the Pioneer spacecraft, including Pioneer 10, the first spacecraft to encounter Jupiter and the first spacecraft to leave the solar system (1983)



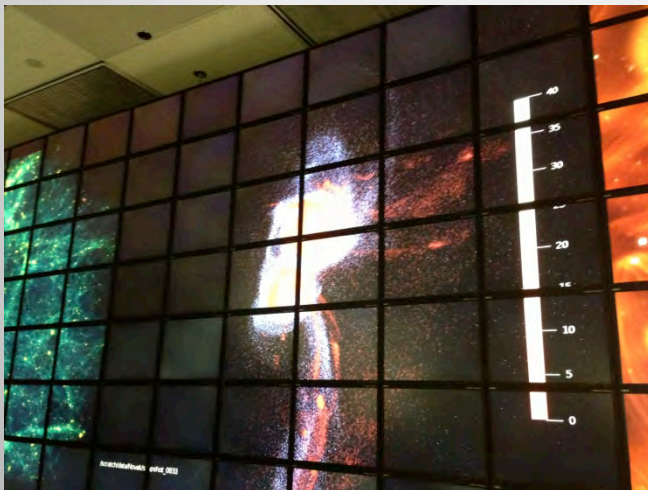
Designed the heat shield for the Stardust comet sample return mission



# Ames Contributions, cont.

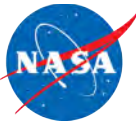


Home to the Pleiades supercomputer, one of the fastest in the world

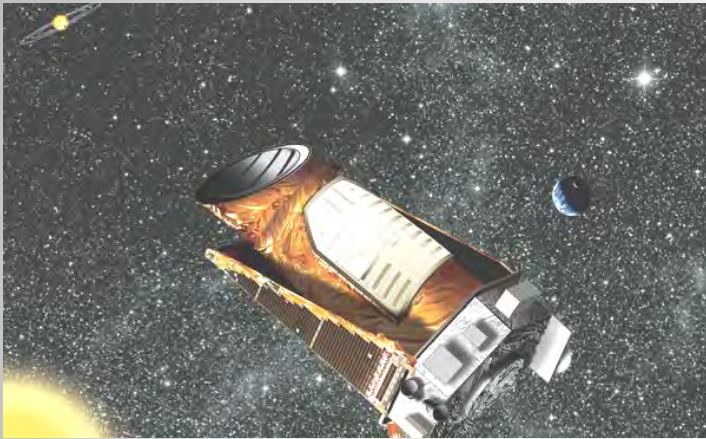




# Ames Contributions, cont.



Leads the Kepler mission to detect earth-like planets in other solar systems



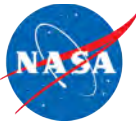
Made major contributions to heat shield development, parachute testing, and scientific instruments aboard the Mars Science Laboratory (Curiosity)



Led the LCROSS mission that has discovered water on the moon



# Four NASA Mission Directorates



- Aeronautics Research Mission Directorate (ARMD)  
*(Dr. Jaiwon Shin)*
- Human Exploration and Operations Mission Directorate (HEOMD)  
*(William Gerstenmaier)*
- Science Mission Directorate (SMD)  
*(Dr. John Grunsfeld)*
- Space Technology Mission Directorate (STMD)  
*(Dr. Michael Gazarik)*

We have aligned our research efforts with these six research thrusts.

## 3 Mega-Drivers



## 6 Strategic Research & Technology 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



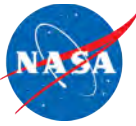
### Real-Time System-Wide Safety Assurance

- Develop an integrated prototype of a real-time safety monitoring and assurance system



### Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications



## Mission Programs

### Airspace Operations and Safety Program

Airspace Technology Demonstrations Project (ATD)

Shadow Mode Assessment Using Realistic Technologies for the National Airspace System Project (SMART-NAS)

Safe Autonomous Systems Operations Project (SASO)

### Advanced Air Vehicles Program

Advanced Air Transport Technology Project (AATT)

Revolutionary Vertical Lift Technology Project (RVLT)

Commercial Supersonic Technology Project (CST)

Advanced Composites Project (AC)

Aeronautics Evaluation and Test Capabilities Project (AETC)

### Integrated Aviation Systems Program

Environmentally Responsible Aviation Project (ERA)

Unmanned Aircraft Systems Integration in the National Airspace System Project (UAS in the NAS)

Flight Demonstrations and Capabilities Project (FDC)

## Seedling Program

### Transformative Aeronautics Concepts Program

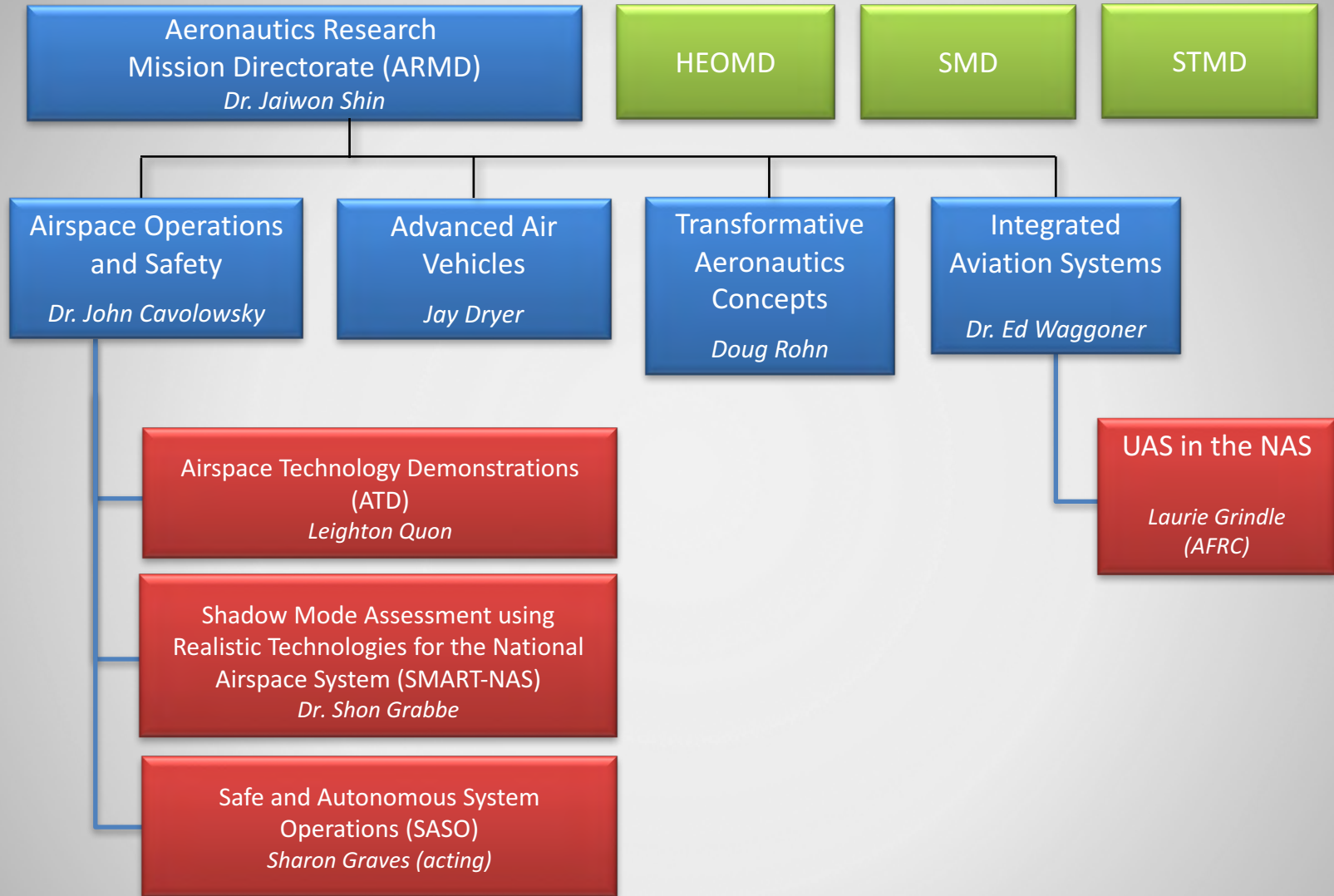
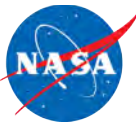
Convergent Aeronautics Solutions Project (CAS)

Transformational Tools and Technologies Project (TTT)

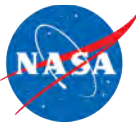
Leading Edge Aeronautics Research for NASA Project (LEARN)



# Missions, Programs, Projects



# NASA Ames Research Center



Last updated 10/3/16

Office of the Director  
 Center Director: Dr. Eugene L. Tu  
 Deputy Center Director: Dr. Thomas A. Edwards  
 Associate Center Director- Technical: Dr. Steven Zornetzer  
 Associate Center Director – Mission Support: Deborah Feng

Office of the Chief Engineer  
 Chief Engineer: Dr. Tina Panontin

NASA Astrobiology Institute  
 Director: Dr. Carl B. Pilcher

Office of the Chief Scientist  
 Chief Scientist: Jacob Cohen

Solar System Exploration Research  
 Virtual Institute(SSERVI)  
 Director: Dr. Yvonne Pendleton

Office of the Chief Technologist  
 Chief Technologist: Dr. Harry Partridge

Office of Diversity & Equal Opportunity  
 Division Chief: Barbara Miller

Office of the Chief Counsel  
 Chief Counsel: Thomas W. Berndt

NASA Research Park Office  
 Director: Janice Fried

**Aeronautics Directorate (A)**  
 Director: Huy Tran

**Science Directorate (S)**  
 Director: Dr. Michael D. Bicay

**Exploration Technology Directorate (T)**  
 Director: Dr. Rupak Biswas

**Programs and Projects Directorate (P)**  
 Director: Dr. Jay Bookbinder

**Partnerships Directorate (B)**  
 Director: Gary Martin

**Engineering Directorate (R)**  
 Director: Dr. David Korsmeyer

**New Ventures and Communications Directorate (V)**  
 Director: Dolores Beasley

**Safety & Mission Assurance Directorate (Q)**  
 Director: Mike Liu

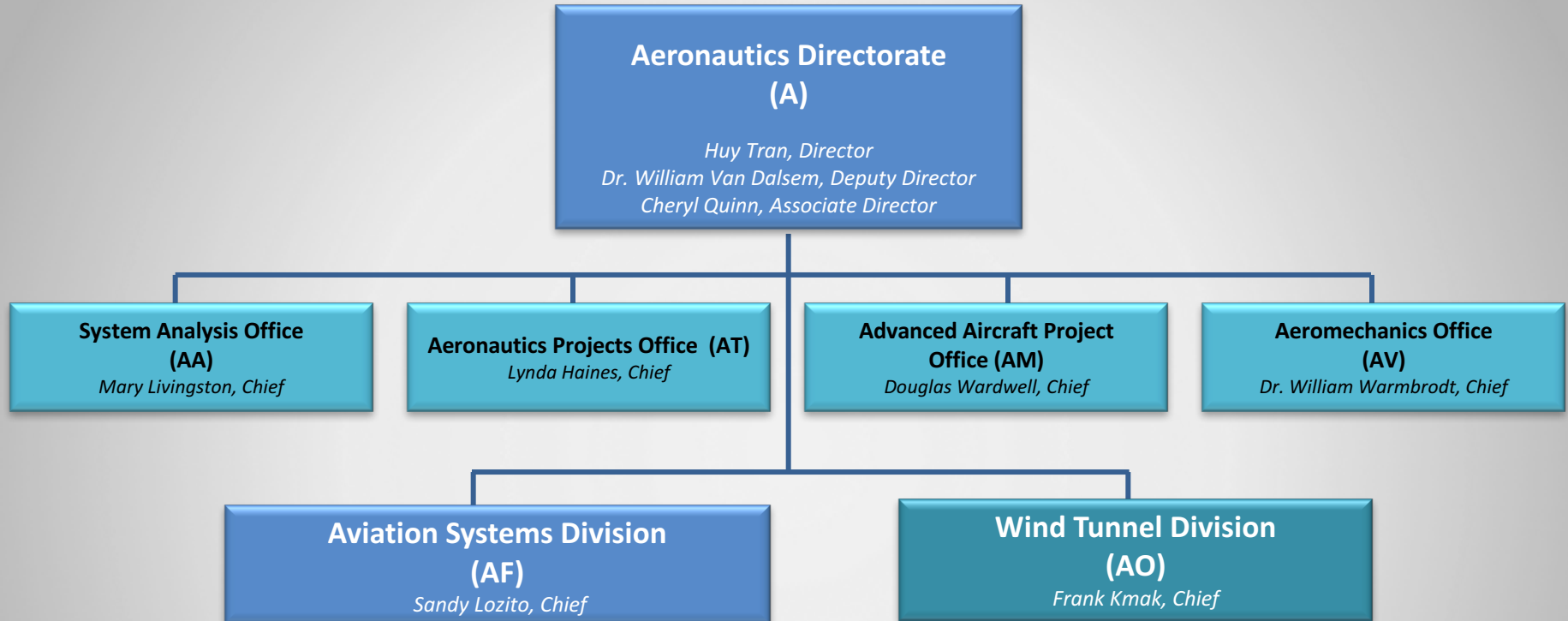
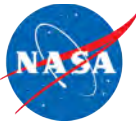
Agency CFO

**Center Operations Directorate (J)**  
 Director: Jim Alwyn (acting)

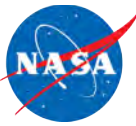
**Human Capital Directorate (H)**  
 Director: Carol Carroll

**Information Technology Directorate (I)**  
 CIO: Jerry Davis

**Office of the Chief Financial Officer (C)**  
 Director/CFO: Paul R. Agnew



# Aeronautics Directorate Aviation Systems Division (AF)



**Sandy Lozito, Chief**  
**Katharine Lee, Deputy Chief**  
**Julie Nguyen, Assistant Chief for Operations**

74 civil servants  
135 contractors

**Senior Technologist for Air Transportation  
Systems**  
Dr. Parimal Kopardekar

**Aerospace Simulation Research  
& Development  
(AFS)**  
**Steven Beard,**  
Chief  
**Karen Cate,**  
Assistant Branch Chief

20 civil servants  
76 contractors

**Systems Modeling &  
Optimization  
(AFO)**  
**Karl Bilimoria**  
Chief (Acting)

15 civil servants  
30 contractors

**Flight Dynamics, Trajectory  
and Controls  
(AFT)**  
**Todd Farley,**  
Chief

19 civil servants  
9 contractors

**Aerospace High Density  
Operations  
(AFH)**  
**Bimal Aponso,**  
Chief

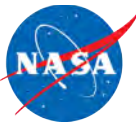
16 civil servants  
16 contractors

<http://aviationsystemsddivision.arc.nasa.gov>





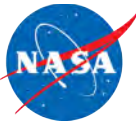
# Aviation Systems Division (Code AF)



March 17, 2014



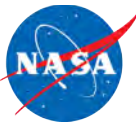




- ATM Research
  - *Airspace domains* – en route, terminal area, surface, nation-wide, regional
  - *Engineering skills* – airspace operations and procedures, optimization, scheduling, trajectory prediction and analysis, data mining, learning algorithms, human factors and automation, software development, computer and systems engineering
- Flight Simulation
  - Operating world-class, high fidelity flight simulators
  - Developing flight simulation scenarios, math models, etc.

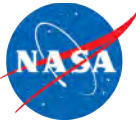


# Challenges We Confront



- The air transportation system of the future will need to accommodate a higher demand of commercial air traffic as well as manage a complex mixture of flying vehicles, and meet requirements for maintained safety as well as reduce environmental impact.
- Future commercial air transportation is likely to be comprised of not only the legacy aircraft seen today, but will have to operate alongside more advanced, capable aircraft, and all sizes of unmanned aerial systems (UAS) all vying for the same airspace access.
- The operators of the system increasingly rely on technology advances to make the overall system run more efficiently without compromising safety.

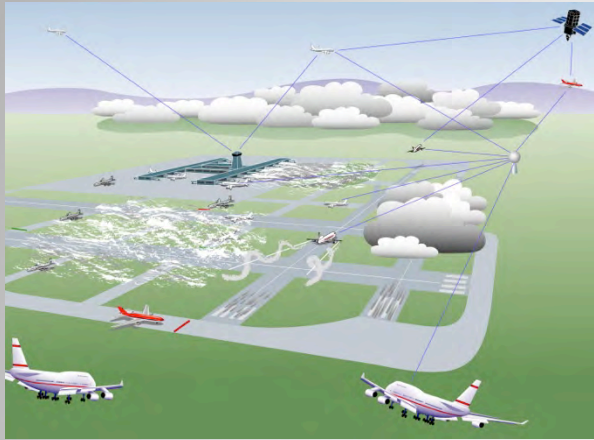
# What is the focus of the Aviation Systems Division?



Unmanned Aerial Systems/  
UAS Traffic Management



FutureFlight Central

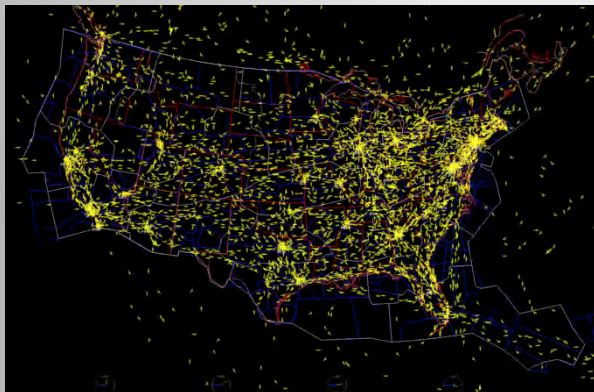


Air Traffic  
Management

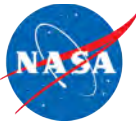


Vertical Motion Simulator

High Fidelity Flight  
and Airspace  
Simulation



Boeing 747 Simulator



The network of United States airspace: air navigation facilities, equipment, services, airports or landing areas, aeronautical charts, information/services, rules, regulations, procedures, technical information, manpower, and material.

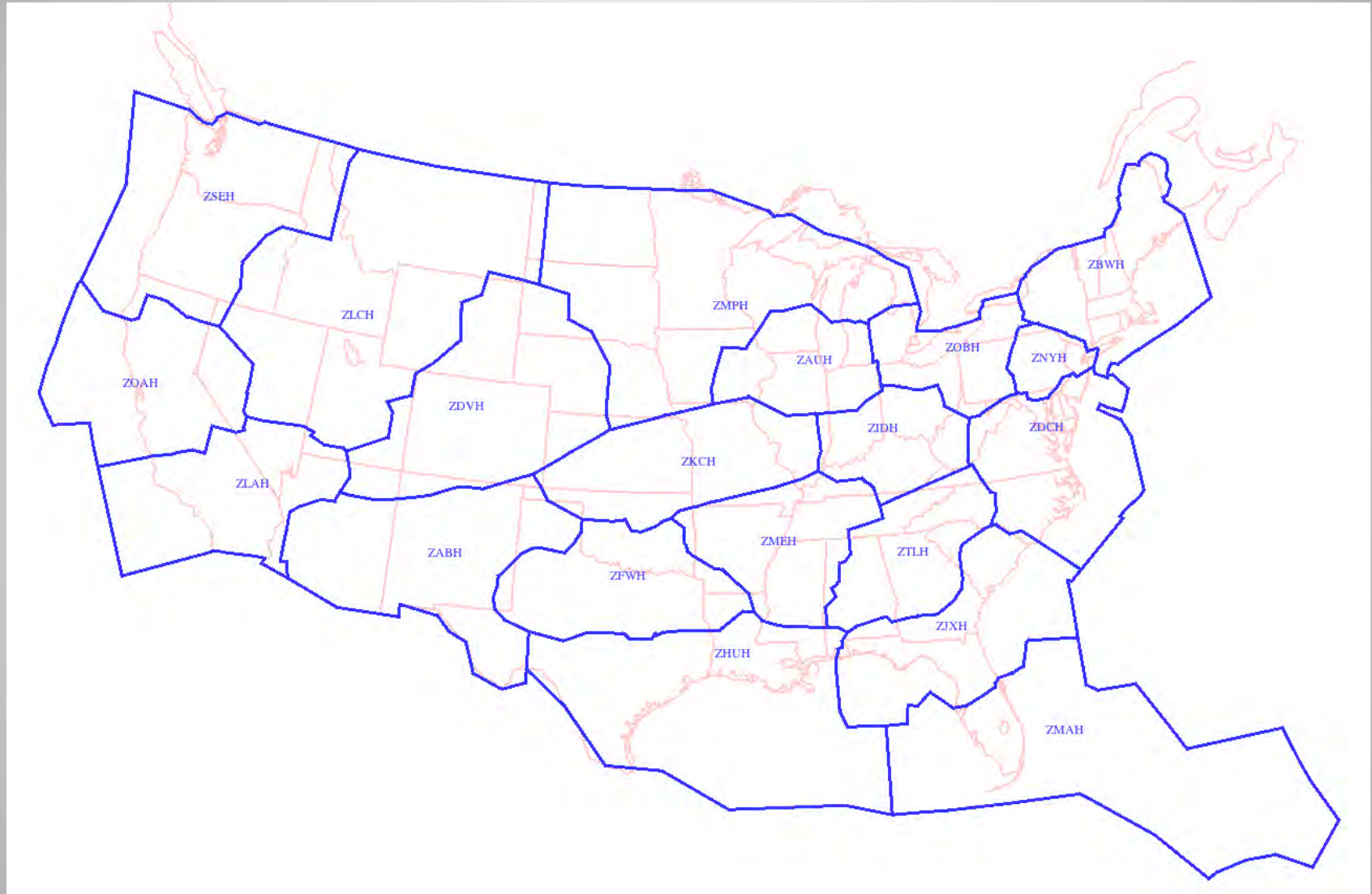
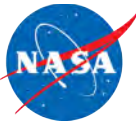
- 280,000+ aircraft
- 19,854 airports
- 16,000 air traffic controllers
- Etc...

# Air Traffic Control System Command Center

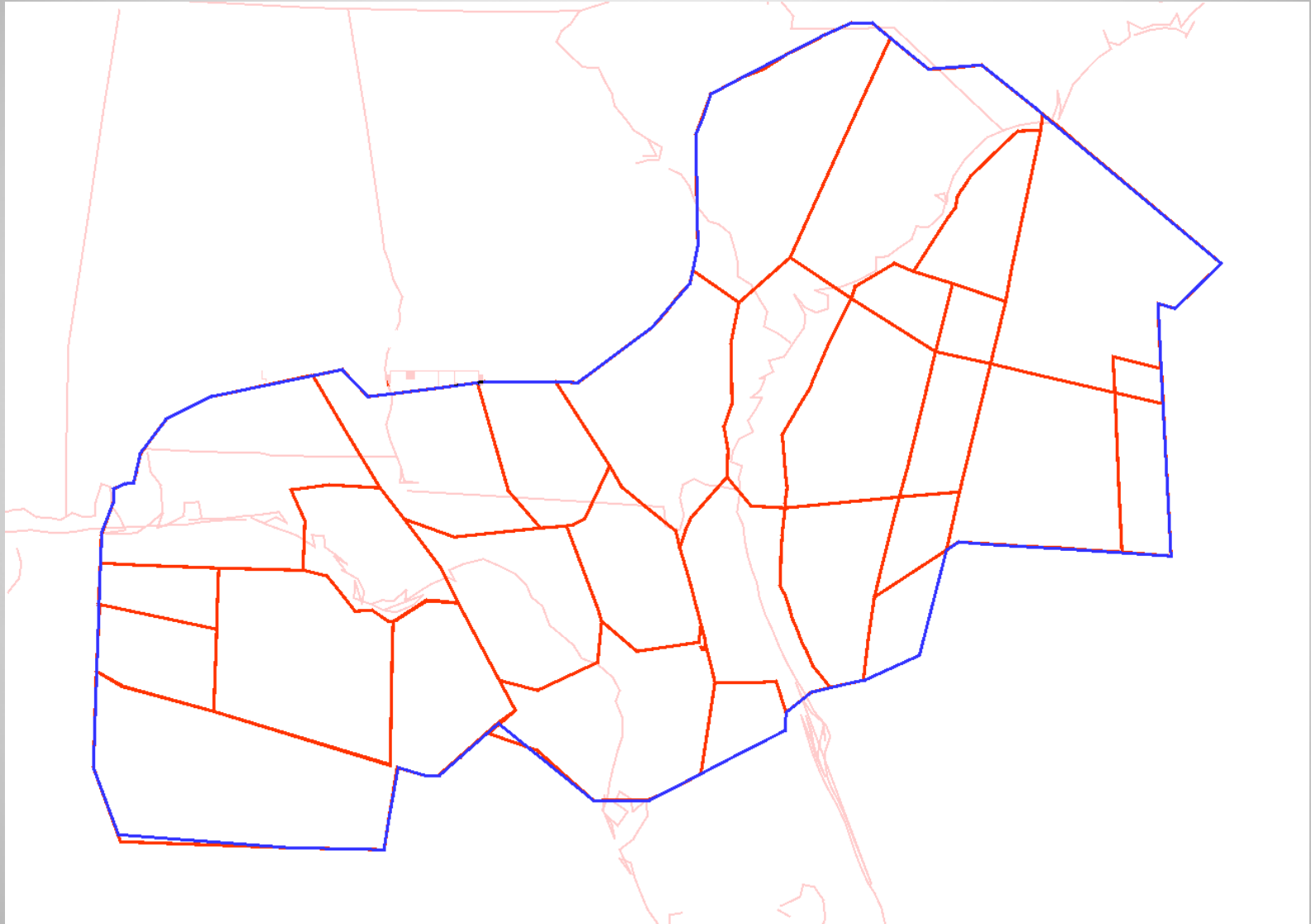
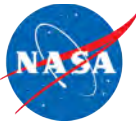




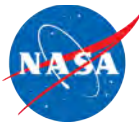
# Air Route Traffic Control Centers



# Jacksonville Sectors



# AF Simulation Facilities



Boeing 747-400



Advanced Concepts Flight Simulator



Vertical Motion Simulator



FutureFlight Central

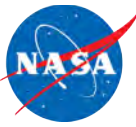


Air Traffic Management Simulation





# North Texas Research Station



## Dallas/Fort Worth International

679,820 flights in 2014  
3<sup>rd</sup> among US airports  
(per ASPM/ATADS)

## NTX Research Station...

- NASA research assets embedded in a high-demand, varied operational air transport environment
- Access to ARTCC, TRACON, Towers, 3 air carrier AOCs (American, Envoy and Southwest), and 2 major airports all within 12 miles.
- Supports NASA NextGen research activities from concept development through operational field evaluation.



## PARTNERSHIPS



## American Airlines

More than 1.1M flights in 2014  
1<sup>st</sup> among US air carriers  
(per BTS includes USAir)

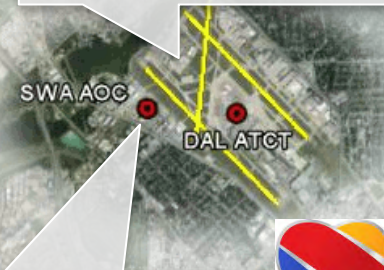


## NTX Laboratory...

- 5000 ft<sup>2</sup> purpose-built, dedicated, air traffic management research facility
- Re-configurable computer labs, dedicated radio tower, established data links to local operational facilities and NASA centers.
- Research engineers experienced in air traffic operations analysis, technology development, and field evaluations

## Dallas Love Field

182,949 flights in 2014  
41<sup>st</sup> among US airports  
(per ASPM/ATADS)

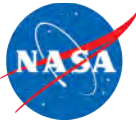


## Southwest Airlines

More than 1.1M flights in 2014  
2<sup>nd</sup> among US air carriers  
(per BTS)

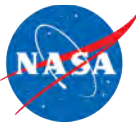






- NASA is planning a series of “tech demos” of evolving air traffic management technologies
  - Integrated concepts where appropriate
  - Leveraging some of the most advanced infrastructure (e.g., ADS-B, RNAV/RNP precision routing, etc...)
  - “Live” air traffic evaluations, beginning in 2014
  - New technology “suites” tested every two years
- Transfer of technologies to the FAA and industry once concepts are validated in live traffic tests

# ATM Technology Demonstration 1 (ATD-1)



ATD-1 is an integrated set of NextGen technologies that provides an efficient arrival solution

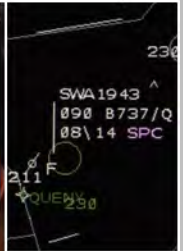
**FIM**

Flight Deck Interval Management for Arrival Operations



**CMS**

Controller-Managed Spacing in Terminal Airspace



**TMA-TM**

Traffic Management Advisor with Terminal Metering



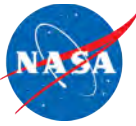
## **Time-Based Flow Management (TBFM)**

- Generates conflict-free arrival scheduling based on airport conditions, airport capacity, and required spacing.
- Involves metering of terminal area traffic flows to avoid downstream congestion.

## **Uses speed adjustments instead of vectoring to precisely maintain aircraft spacing through:**

- Controller Managed Spacing (CMS) decision support tools on controller displays.
- Flight Deck Management (FIM) guidance capabilities to pilots using ADS-B (automatic dependent surveillance – broadcast) information.

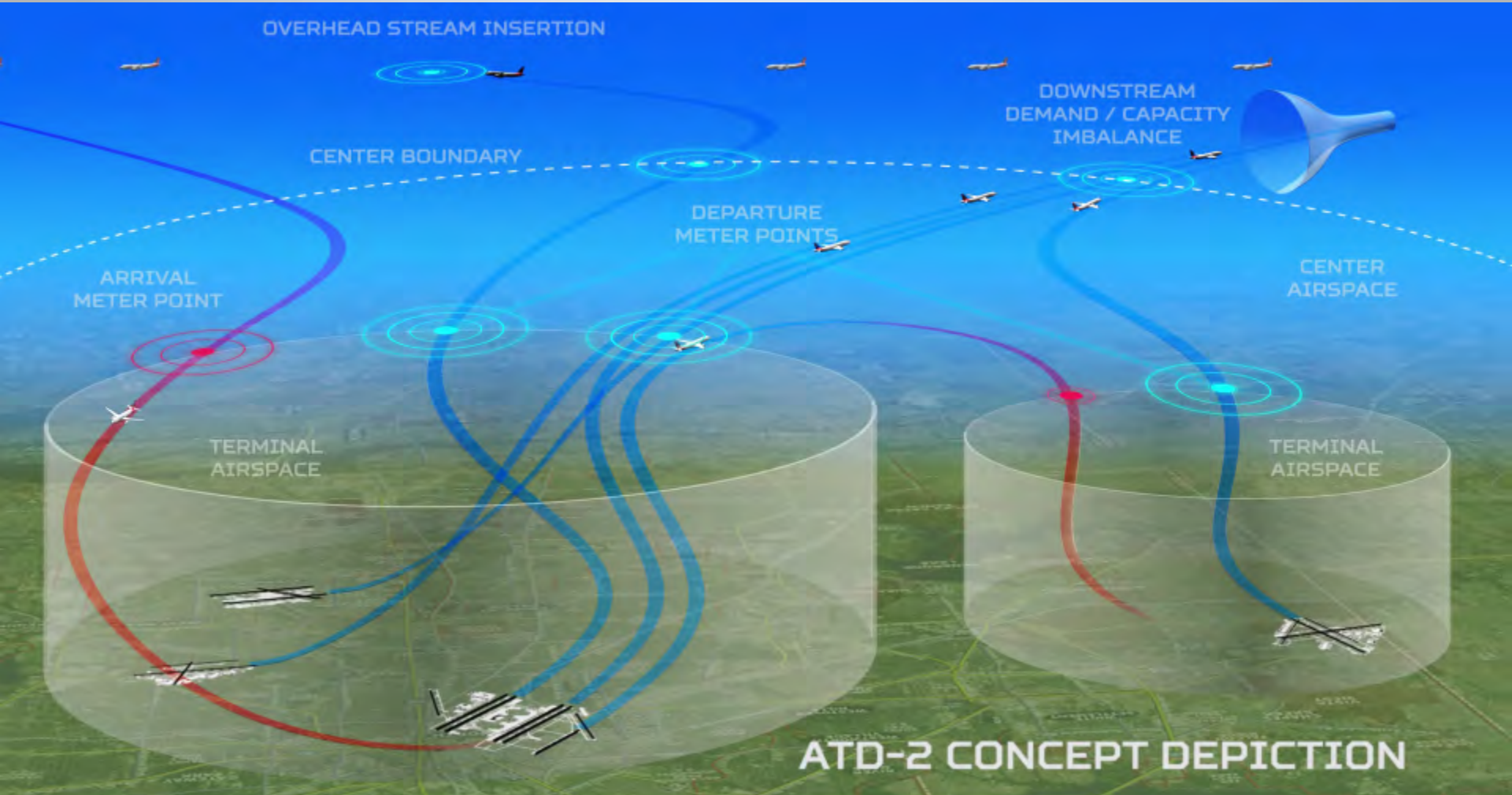
# NAS Delays Due to Weather

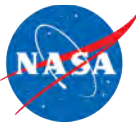


- 24-hr delay video
- This animation shows a typical day of air traffic in the national airspace system during convective weather and the scope of the air traffic delay problem. The dots represent actual flights. The gray flights are on time. The flights with blue streaks are delayed between 15 minutes to 2 hours. The flights with red streaks are delayed 2 hours or more.



# Airspace Technology Demonstration 2 (ATD-2)





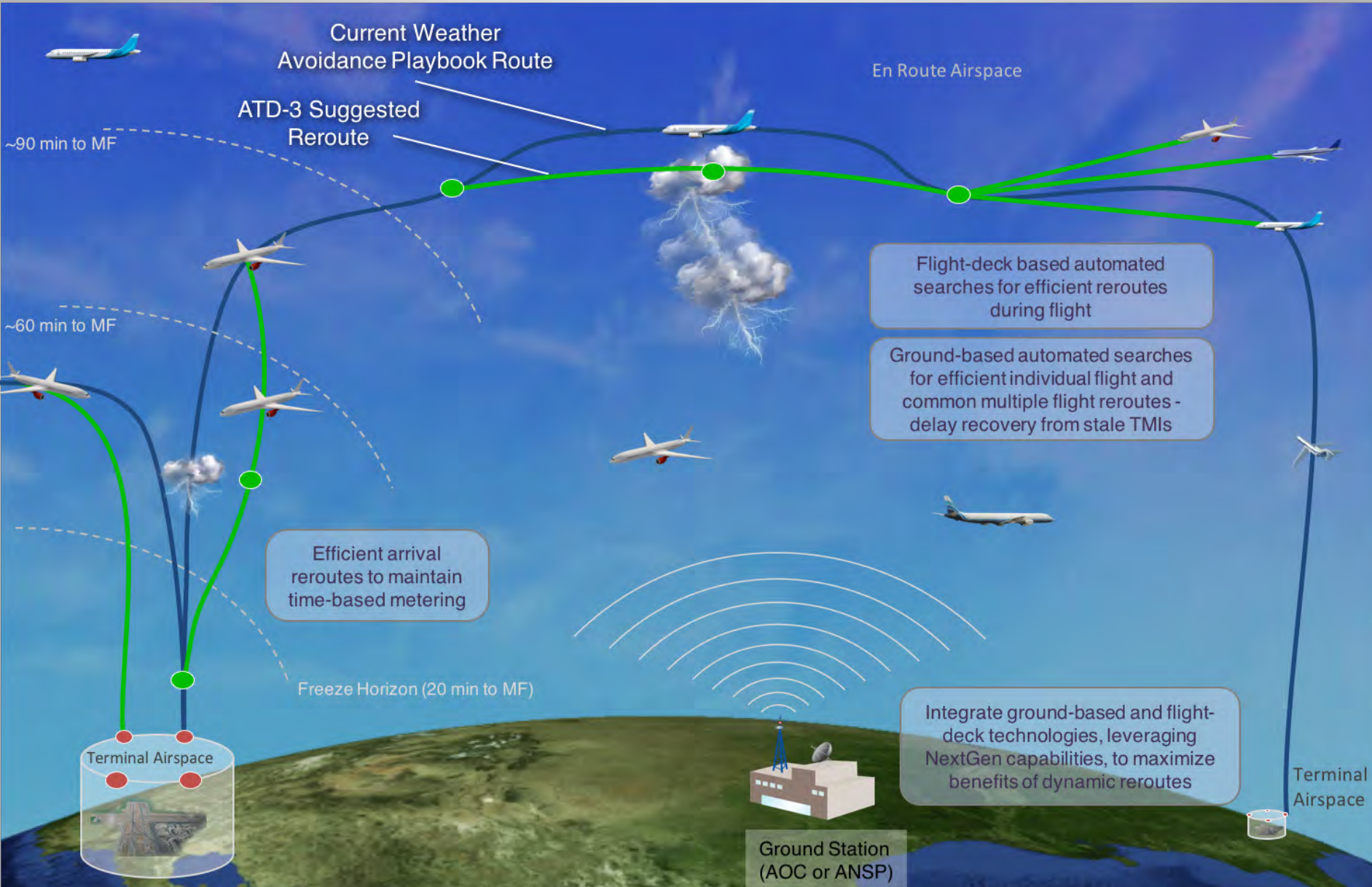
## **Data exchange and airport/airspace integration**

- Collaborative decision making enabled by new data exchange among ATC, flight operators, and airports
- On-ramp to the overhead stream via FAA's Time Based Flow Management system

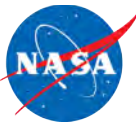
## **Surface modeling, scheduling, and metering**

- Combines pushback estimates from flight operators with trajectory-based airport operations model to provide accurate capacity estimates
- Implements FAA's Surface Collaborative Decision Making concept for surface metering

# Airspace Technology Demonstration 3 (ATD-3)



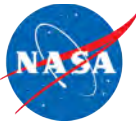




NASA is developing and plans to demonstrate technologies and procedures to identify strategic, user-preferred routes and enable tactical route corrections in domestic en route and arrival airspace to:

- Reduce the impact of unpredictable weather
- Enable continuous searching for more efficient routes for individual flights and groups of flights
- Efficiently share route correction options between traffic managers, controllers, pilots, and dispatchers

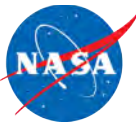
# UAS in the NAS



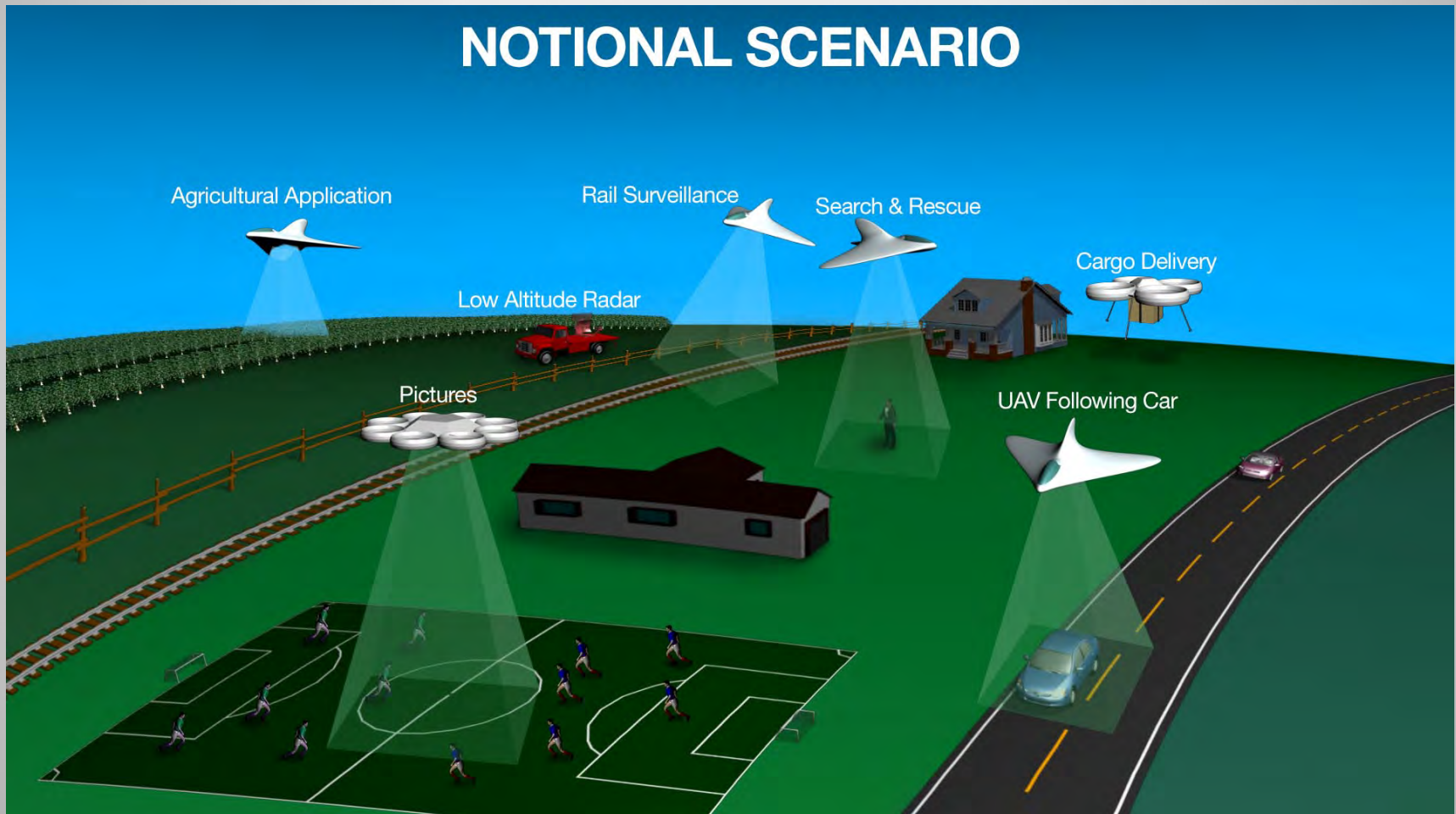
- Conducted a series of experiments to measure the time to transmit aircraft state data, involving NASA Ames, Dryden, and Glenn
- Developed and delivered algorithms that provide the UAS's sense-and-avoid capabilities
- Collected more data on defining the airborne separation standard “well clear” and when to notify the pilot of potential collision situations.



# UAS Traffic Management (UTM)

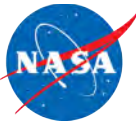


NASA is helping establish infrastructure to enable and safely manage the widespread use of low-altitude airspace and UAS operations.





# Where do we see NASA's benefits today?



NASA's fundamental research can be traced to ongoing innovation.

## Efficient Descent Advisor

### NASA's work on these technologies

- Human-in-the-loop simulations
- Joint flight trials with FAA and airlines
- Automated decision support tools
  - Traffic Management Advisor
  - 3-Dimensional Path Arrival Management
- Trajectory and arrival modeling and solutions

Was transferred for use here

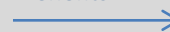


*Transferred to the FAA in November 2011 for phased deployment starting 2014; full deployment by 2020.*



Federal Aviation Administration  
Source: FAA

Benefits



- Fuel-efficient continuous descents
- Potential \$300 million jet fuel savings per year (savings vary per spot fuel costs)
- Reduced delays in congested airspace
- Reduced noise and emissions around airports
- Retained safety
- Reduced controller workload through increased automation

## Precision Departure and Release Capability

### NASA's work on these technologies

- Human-in-the-loop simulations
- Operational field trials
- Automated decision support tools

Was transferred for use here

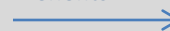


*Transferred to FAA in August 2013 for further development and implementation.*



Federal Aviation Administration  
Source: FAA

Benefits



- Improved precision in departure times even in bad weather and heavy traffic
- Reduced number of "missed" slots in overhead aircraft traffic stream
- More than 50% improvement in number of flights departing within release window
- Reduced congestion system-wide

## Terminal Sequencing and Spacing

### NASA's work on these technologies

- Human-in-the-loop simulations
- Operational field trials
- Automated decision support tools

Was transferred for use here



*Transferred to FAA in February 2014 for further development and implementation.*



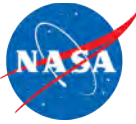
Federal Aviation Administration  
Source: FAA

Benefits



- Improved controller ability to coordinate flight paths of descending aircraft in congested airspace
- Increased capacity for aircraft in same amount of airspace
- Improved traffic flow

# Where do we see NASA's benefits today?



NASA's fundamental research can be traced to ongoing innovation.

## Traffic and Atmospheric Information for General Aviation

### NASA's work on these technologies

- Human-in-the-loop simulations
- Operational field trials
- Automated decision support tools

Was transferred  
for use here

*Transferred to the State of Alaska's Department of Transportation in 2014 for implementation.*



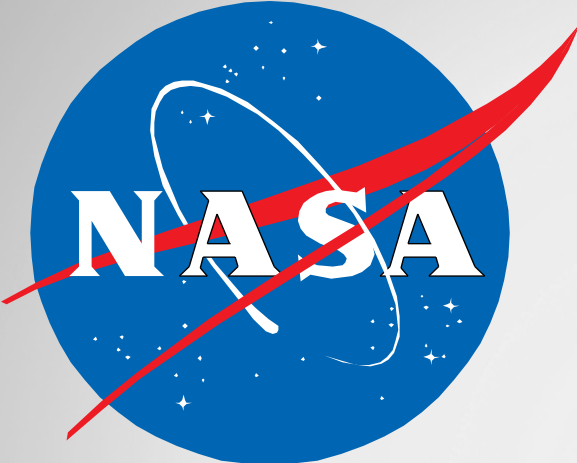
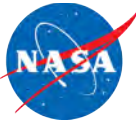
State of Alaska's DOT  
Source: Alaska DOT

Benefits

- Improved situation awareness to general aviation and air taxi pilots
- Better access to data and better interaction with that data on a modern, off-the-shelf mobile device

# How do NASA and the FAA work together?

Our roles are different but our goals to improve efficiency and safety are the same.



Conducts long-term research and development

Conducts regulation and certification

Partners with FAA to ensure new concepts and tools can be adopted into FAA's system

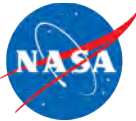
Partners with NASA to access expertise and testing facilities to prove viability of a new idea

Transfers data and tools to the FAA

Takes data and tools from NASA for further verification and validation, certification, and eventual deployment to aircraft and/or airports

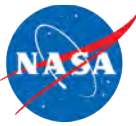



# Collaborating Partners



# Where can I get the latest news?

www.aviationsystems.arc.nasa.gov





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##### NASA ARMD Airspace Operations and Safety Program FY17 Mid-Year Review

May 31, 2017




AOSP Mid-Year Review

NASA Aeronautics Research Mission Directorate (ARMD) Airspace Operations and Safety Program (AOSP) conducted the Mid-Year Review for fiscal year 2017 on May 25-26, 2017, at NASA Ames Research Center.

+ Learn more

##### KARI/NASA Workshop

May 31, 2017



KARI/NASA ATM Research Collaboration

#### FEATURED RESEARCH

##### NextGen is here.

**NASA's ATM Research**  
NASA is conducting air traffic management (ATM) research and development to help achieve the Next Generation Air Transportation System.

+ Learn more

##### NextGen Technologies

Here are a few of the NextGen tools in development by the Aviation Systems Division:

- + ATD-1
- + ATD-2
- + ATD-3
- + DWR
- + EDA
- + FACET
- + PDRC
- + SARDA
- + UTM

##### FY2015 Highlights

Our technical and other highlights for fiscal year 2015.

+ Read More

# Where can I get the latest news?



www.nasa.gov/topics/aeronautics

The screenshot shows the NASA Aeronautics website interface. At the top, there is a navigation bar with the NASA logo and links for Topics, Missions, Galleries, NASA TV, Follow NASA, Downloads, About, and NASA Audiences. A search bar is located on the right. Below the navigation bar is a large banner image of a commercial airplane flying through a blue, cloudy sky. The word "Aeronautics" is displayed in large white text on the left side of the banner. Below the banner is a secondary navigation bar with links for Aeronautics, Overview, Images, Videos, and Media Resources. On the left side, there is a "Follow" section with social media icons for Facebook and Twitter, and a list of categories: Green Aviation, Future Aircraft, Supersonic Flight, Reducing Flight Delays, Unmanned Aircraft, and Aeronautics Research Mission Directorate. Below these categories is a section for "NASA Aeronautics Research Centers" with links to Ames Research Center, Armstrong Flight Research Center, and Glenn Research Center. The main content area features a large video player with the title "ATD3 INTEGRATED TECHNOLOGIES for APPLIED TRAFFIC FLOW MANAGEMENT". To the right of the video player, there are two news articles. The first article is titled "NASA Selects Three Aeronautics Teams to Explore 'Ambitious' Ideas" and includes a thumbnail image of a presentation slide. The second article is titled "Media Invited to Demonstrations of NASA Drone Traffic" and includes a thumbnail image of a drone in flight. On the far right, there is a "Tweets by @NASAAero" section showing a tweet from NASA: "Want to get to know our #NewAstronauts? Join us today for a @Reddit Ask Me Anything at 3:15pm ET: reddit.com/r/AMA".