NASA Advisory Council Aeronautics Committee Report

Ms. Marion Blakey
Chair
National Institute of Aerospace
July 27th, 2017

Aeronautics Committee Membership

Ms. Marion Blakey

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Rolls Royce North America

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Vice Chair,
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of Technology

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The Boeing Company

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University

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Tebogo

NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

6 Strategic Research and Technology Thrusts

T1 Safe, Efficient Growth in Global Operations

- Enable full NextGen and develop technologies to substantially
- Reduce aircraft safety risks

T2 Innovation in Commercial Supersonic Aircraft

- Achieve a low-boom standard

T3A ST / T3B VL Ultra-Efficient Commercial Vehicles

- Pioneer technologies for big leaps in efficiency and environmental performance

T4 Transition to Alternative Propulsion and Energy

- Characterize drop-in alternative fuels and pioneer
- Low-carbon propulsion technology

T5 Real-Time System-Wide Safety Assurance

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

T6 Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications

Areas of Interest Explored at Current Meeting

Topics covered at the Aeronautics Committee Meeting held on July 25, 2017 at NASA Headquarters, Washington, DC:

- ARMD FY18 Budget *
- New Aviation Horizons Planning and Management Status *
- University Leadership Initiative *
- Airspace Technology Demonstrator Overview *

* All topics have related findings provided by the Aeronautics Committee

Global Growth in Aviation: Opportunities and Challenges

Global Air Passengers by Region (% of Total)

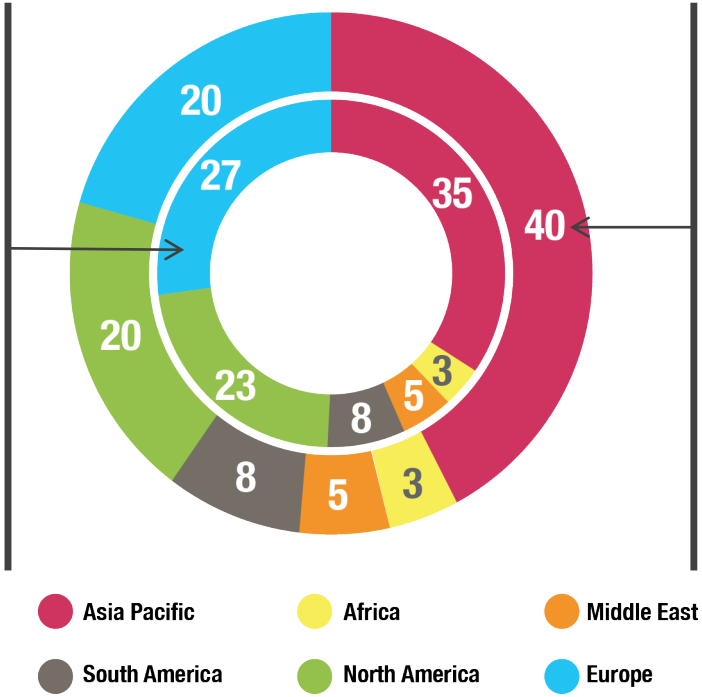
2014 Global Aviation Industry

3.3B Passenger Trips

North America and Europe combined is half of all Passenger Trips

58M Jobs

$2.4T GDP



2034 Global Aviation Industry, est.

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

U.S. well positioned for competition in this enormous market – great technologies and great conventional configuration products

But…

Real and Growing International Competition for the Future of Aviation

We are not the only game in town anymore

…U.S. must win the future through transformative technologies and configurations that will deliver revolutionary performance, or…

Bombardier C Series –
Most efficient in its segment

COMAC C919 – First Flight

Irkut MC-21 – First Flight

New international product competition will mature and pressure US market leadership from below…

…Europe will race to beat U.S. to transformative products…

… And China may surprise us.

FY 2018 Budget

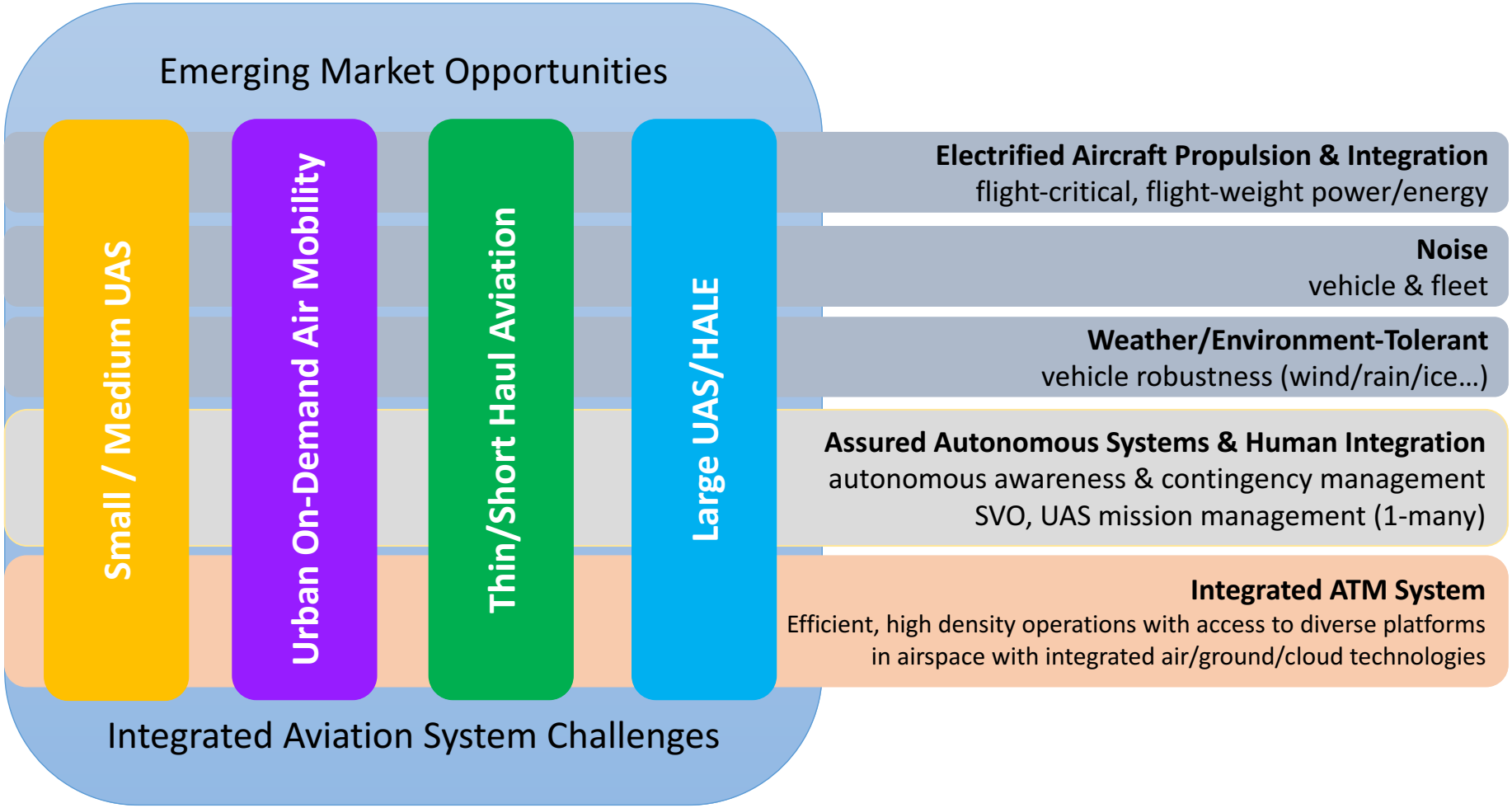
$ Millions	Enacted FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Aeronautics	**$633.8**	**$660.0**	**$624.0**	**$624.4**	**$624.4**	**$624.4**	**$624.4**
Airspace Operations and Safety	147.1		108.7	107.7	107.1	107.8	109.7
Advanced Air Vehicles	254.9		232.7	223.8	233.2	236.7	241.8
Integrated Aviation Systems	128.3		173.5	178.5	167.8	139.2	132.9
Transformative Aeronautics Concepts	103.5		109.2	114.5	116.3	140.7	139.9

- **Integrated Aviation Systems Program funds the design and build of the Low Boom Flight Demonstrator as part of the New Aviation Horizons Initiative**
- **Continues to robustly fund UAS related investments**

Emerging Markets - Integrated Challenges

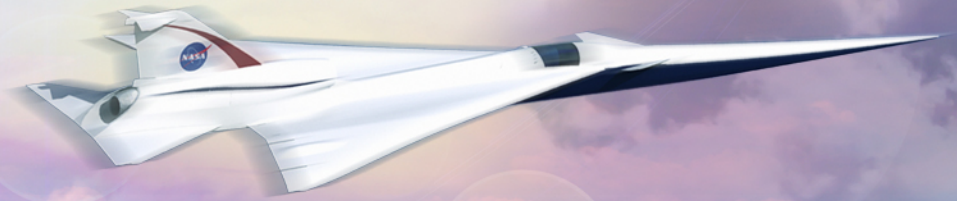
NASA ARMD Programs pivoting to address complex challenges

ARMD has developed a holistic understanding of the challenges for enabling the enormous potential of emerging aviation global market opportunities



NASA Aeronautics is smart business for our nation

- NASA reduces risk for industry to adopt
- Advanced technologies make U.S. aircraft competitive and attractive to domestic/international airlines
- U.S. aviation industry, government, non-traditional industry join forces
- Partners key to NASA's aeronautics strategic vision
- Partnering advances U.S. technology leadership



Committee Finding for ARMD AA – FY18 ARMD Budget

The Committee believes that aeronautics is and will continue to be a strong factor for the U.S. economy. The Committee finds that NASA provided an excellent overview of the Aeronautics portfolio and is appropriately supporting the spectrum of what is needed by both the traditional and emerging aviation communities. NASA is making excellent progress on its Low Boom Flight Demonstrator X-plane and the committee endorses NASA's work in the NAH X-planes initiative and sees concrete benefits to the U.S. industry. The Committee continues to urge NASA to be aggressive in addressing the airspace integration, autonomy and other key needs for emerging aviation users.

New Aviation Horizons Initiative

The NAH Initiative is focused on maturing and advancing aeronautics technologies through flight research for the benefit of domestic stakeholders.

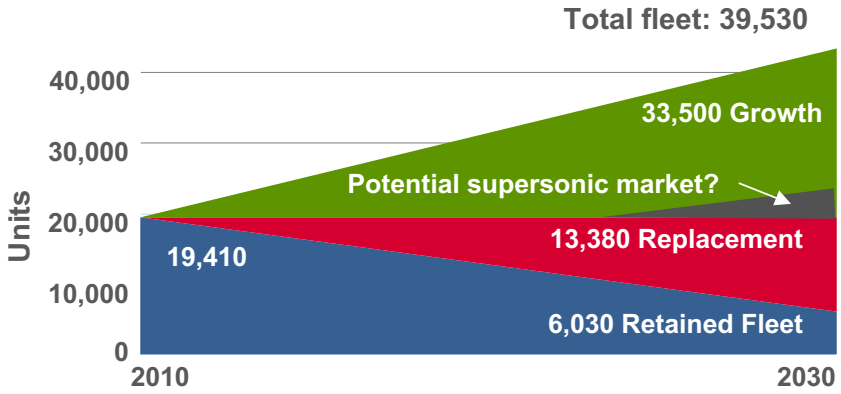
The centerpiece of the NAH Initiative is an ambitious plan to build large-scale experimental aircraft – X-Planes – that will flight test:

- New technologies
- Systems and
- Advanced aircraft and engine configurations

Other key elements of the NAH Initiative include the following:

- Partnerships with industry and academia
- Support accelerated delivery to the US aviation community of advanced design and analysis tools
- Enable US industry to implement flight-proven transformative technologies that solve tomorrow's aviation challenges
- Inspire the next generation of scientists and engineers through education and outreach

Emerging tech: low-boom supersonic flight over land



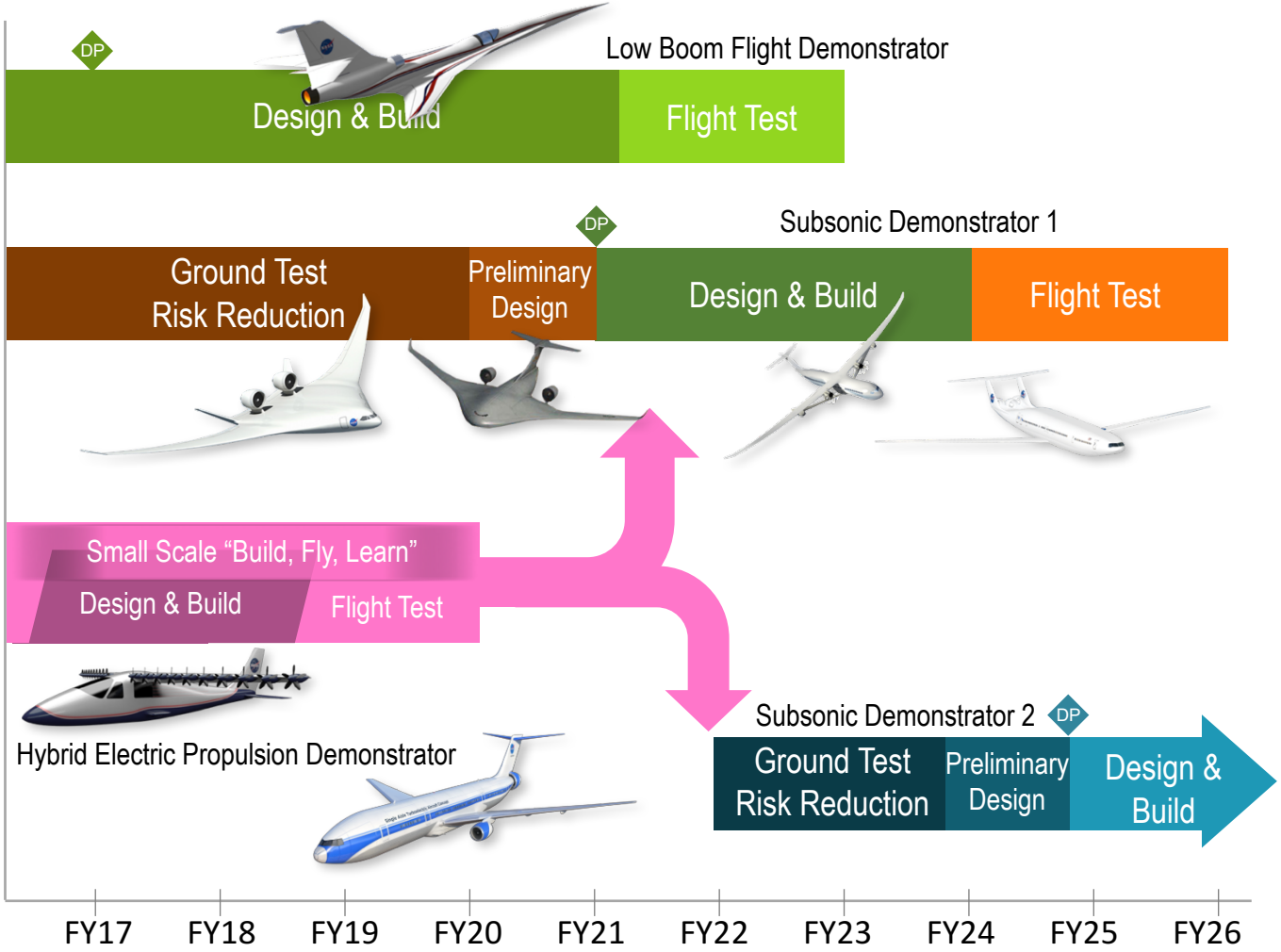
Initial market is supersonic business jets (350+ aircraft) followed by supersonic commercial transports as technology matures. Supersonic civil aircraft market could grow to an estimated 1250 – 1700 aircraft where the US could potentially dominate the design & manufacture of these aircraft.

US economic benefit from manufacturing and employment alone would be on the order of $20B - $60B per year (assume 100 a/c per year). The economic benefit to business and leisure passengers is difficult to quantify, but would be substantial on a global scale.

Low-boom flight demonstrator will pave the way for the development of a noise design standard for overland flight and new generations of supersonic civil aircraft.

FY 2018 President's Budget Request

New Aviation Horizons Flight Demo Plan



Enables Low Boom Regulatory Standard and validated ability for industry to produce and operate commercial low noise supersonic aircraft

Validated ability for U.S. Industry to Build Transformative Aircraft that use 50% less energy and contain noise within the airport boundary

Validated HEP Concepts, Technologies And Integration for U.S. Industry to Lead the Clean Propulsion Revolution

NAH – Where Are We Today?

- Lockheed Martin Aeronautics Company has completed preliminary design review for a Low Boom Flight Demonstrator aircraft (June 2017)

- NASA completed 5 contracts to guide the develop of ultra-efficient subsonic transport demonstrator plans through requirements definition (May 2017)

- NASA Aeronautics is ready to adapt plans to various funding levels and authorization language

NASA's Low-Boom Supersonic Tech is Ready for Flight

FIELD STUDIES

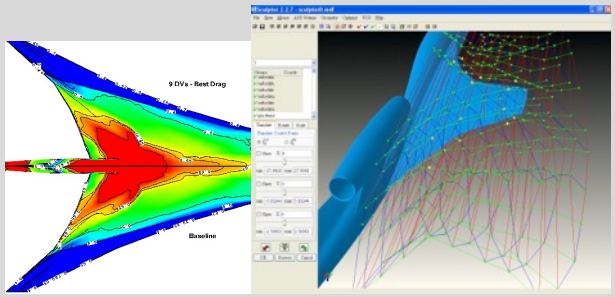
Field studies show the potential for acceptable low boom noise.

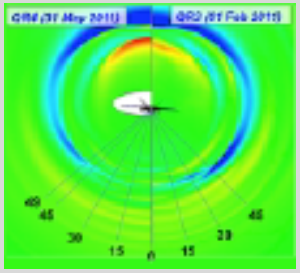
Low-Boom Flight Simulation using F-18 Dive Maneuver

Sonic Boom Acceptability Studies using Ground Simulators and in the Field

MODELING TOOLS

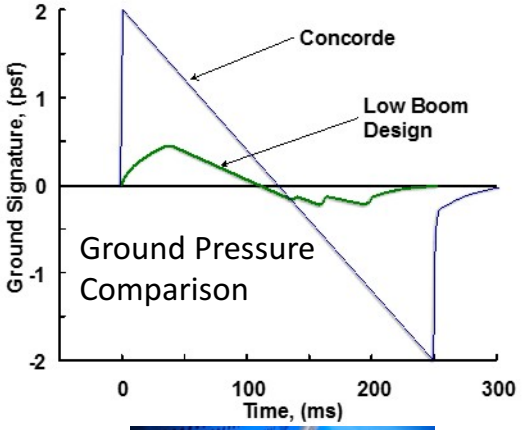
New advances in modeling tools allow us to design new low-boom configurations.

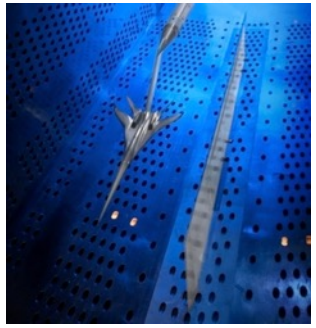




GROUND TESTING

Extensive wind tunnel tests indicate that these new designs show the low-boom characteristics that we predict.





Low Boom Flight Demonstrator

40+ years of NASA led investment and technical progress
has created an opportunity to overcome the sonic boom restriction

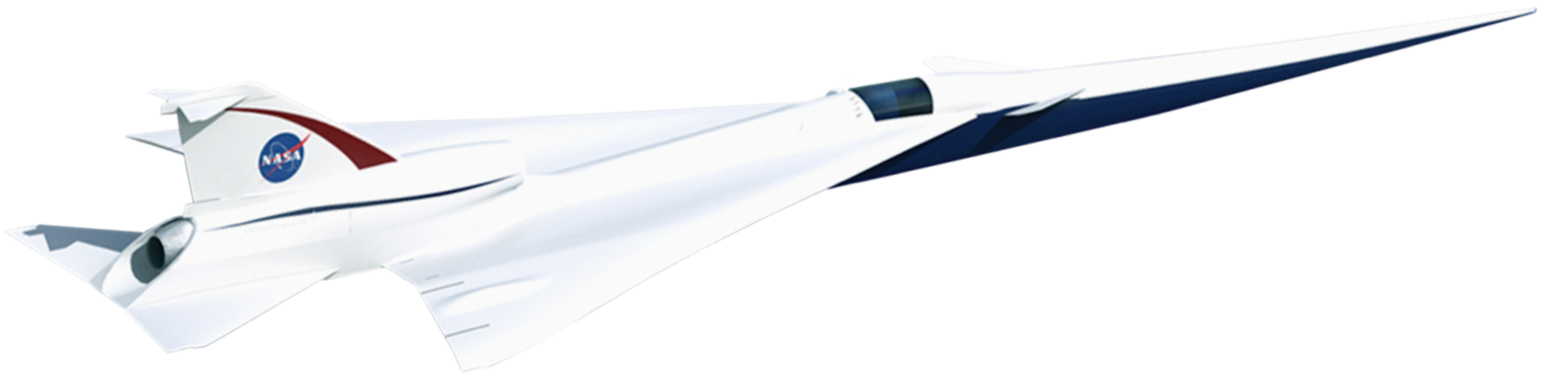
Outcome Elements

- Demonstrate that noise from sonic booms 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 over land flight

LBFD Project Goals and Objectives designed to support
ARMD Technical Challenges and NASA Strategic Outcomes

Committee Finding for ARMD AA - New Aviation Horizons (NAH)

The Committee strongly supports the Aeronautics budget for X-planes and recognizes that NASA has worked very hard for the current budget levels. The Committee recommends that NASA should consider opportunities to integrate autonomous operations into the NAH initiative. The Committee also finds that NASA should be careful not to sacrifice other investments in emerging market areas (UAS, Urban Air Mobility, etc) in the event of X-plane cost escalation.

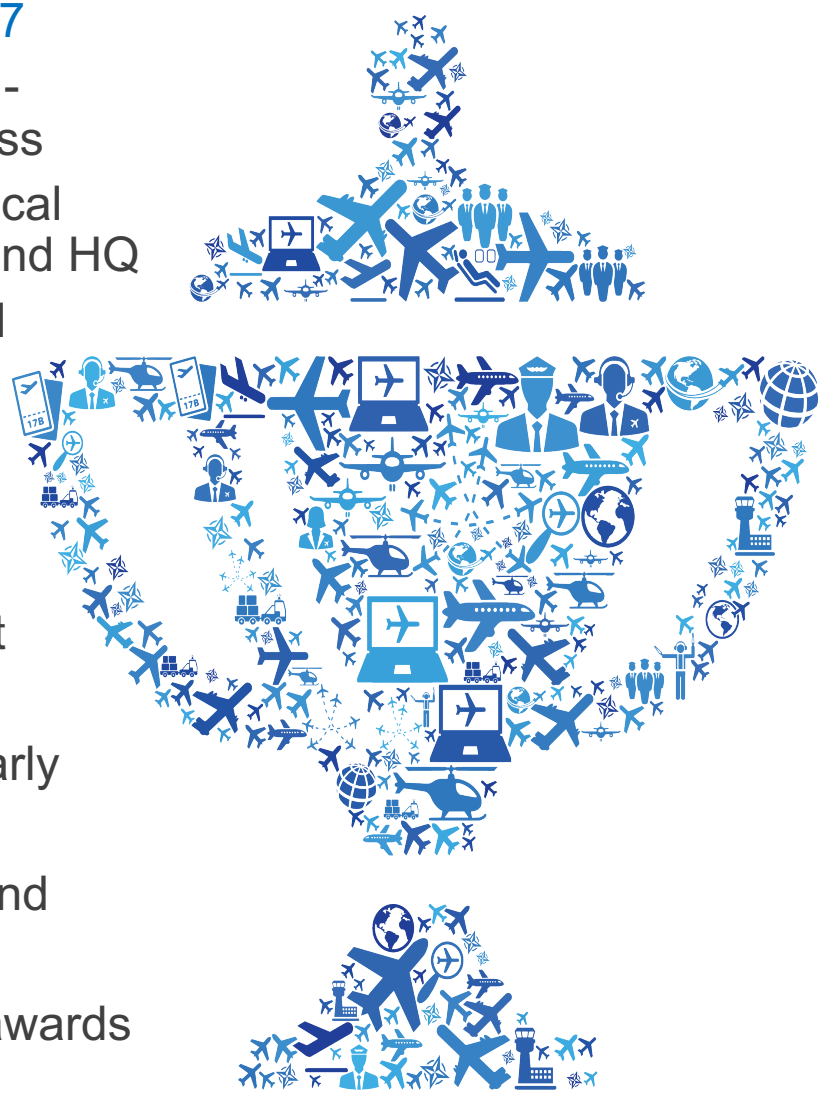


University Leadership Initiative (ULI) – Purpose

- ULI represents a new type of interaction between ARMD and university community, where universities take the lead, build their own teams, and set their own research path
- ULI created to:
  - Promote new, innovative ideas that can support NASA ARMD portfolio and U.S. aviation community
  - Address the most complex challenges associated with strategic thrusts
  - Accelerate progress toward achievement of high impact outcomes
  - Leverage capability of universities to bring together the best and brightest minds across many disciplines

ULI Current Status and Planned Award Schedule

- First ever ULI activities selected April 4, 2017
  - Original solicitation released April 2016 - applied two-step proposal review process
    - Proposals were reviewed by technical experts across four Aero Centers and HQ
    - 83 proposals received in first round
    - 21 invited to submit second round proposal
    - 5 selected for award
    - Awards now completed
  - Kick-off meetings scheduled throughout summer
- Future solicitations – working to achieve yearly release schedule
- Next solicitation planned for FY18 release and award
- Anticipating follow-on solicitations with 1-2 awards (3-5 year duration) every year thereafter



ULI Summary

- Many areas are notably different between ULI and traditional ARMD NRAs. With ULI, universities:
  - Select own research topics and deliverables
  - Provide larger scale, multi-disciplinary solutions
  - Establish own external peer review to assess performance and quality
  - Create university-industry teams across broad disciplines
  - Facilitate technology transfer to U.S. industry, other government agencies, or other NASA programs
  - Emphasize “wearing a bigger hat” – reaching out to schools with underrepresented student populations and to early-career faculty

- ARMD is considering various incentives to encourage practices that will benefit ULI
  - Setting aside a certain number of shorter-duration awards within each solicitation (helps balance year-to-year funding)
  - Rewarding successful technology transition through possible award fees (promotes key ULI success measure)

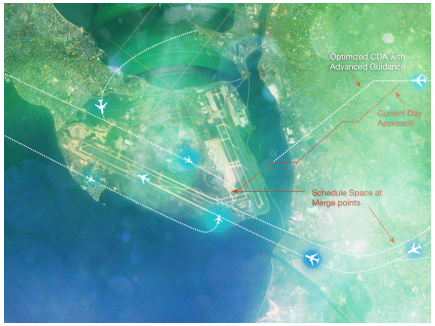
ARMD is excited to begin the ULI activity, and looks forward to taking additional steps to promote its long-term success!

Committee Finding for ARMD AA – University Leadership Initiative (ULI)

The Committee commends NASA for the effort to successfully launch the University Leadership Initiative. The Committee was very impressed with the objective and approach to the initiative, including the competitive award process used by NASA. There was expressed concern about the ability of the U.S. educational system to motivate students to pursue STEM careers. The Committee believes that ULI is a great example of an initiative that can address this issue. NASA has a great reputation worldwide and ULI should be amplified so that more students can take advantage of the opportunities offered.

Air Traffic Management Technology Demonstration (ATD)

Objective
Accelerate the maturation of integrated Airspace Operations and Safety Program concepts and technologies to higher technology readiness levels for transition to stakeholders



Integrated Arrival/Departure/Surface traffic management for metroplex environments (ATD-2)

- Coordinated operation with arrivals, departures and surface provides most efficient operational environment
- Predictable schedules benefit airline planning and operations
- Reduced emissions from less idling and taxiing
- Field test scheduled for September 2017

FY15	FY16	FY17	FY18	FY19	FY20

Arrival Sequencing and Spacing Tools (ATD-1)

- Conflict-free continuous descent approach can happen even in heavy traffic at the busiest airports
- Precise schedules for more efficient and safe spacing between aircraft enabled by controller and flight deck automation tools
- Achieve significant reduction in fuel use and noise around airports
- Deliverables to the FAA include controller tools in 2015 and flight deck automation in 2017

Applied Traffic Flow Management (ATD-3)

- Improved air/ground automation tools reduce the impact of adverse weather
- Continuous searching for more efficient routes for individual flights and groups of flights, saving significant time and money for airlines and passengers
- Efficiently share route improvement options between traffic managers, pilots, dispatchers and controllers
- Transferring developed Multi-Flight Common Route technology to the FAA in 2018

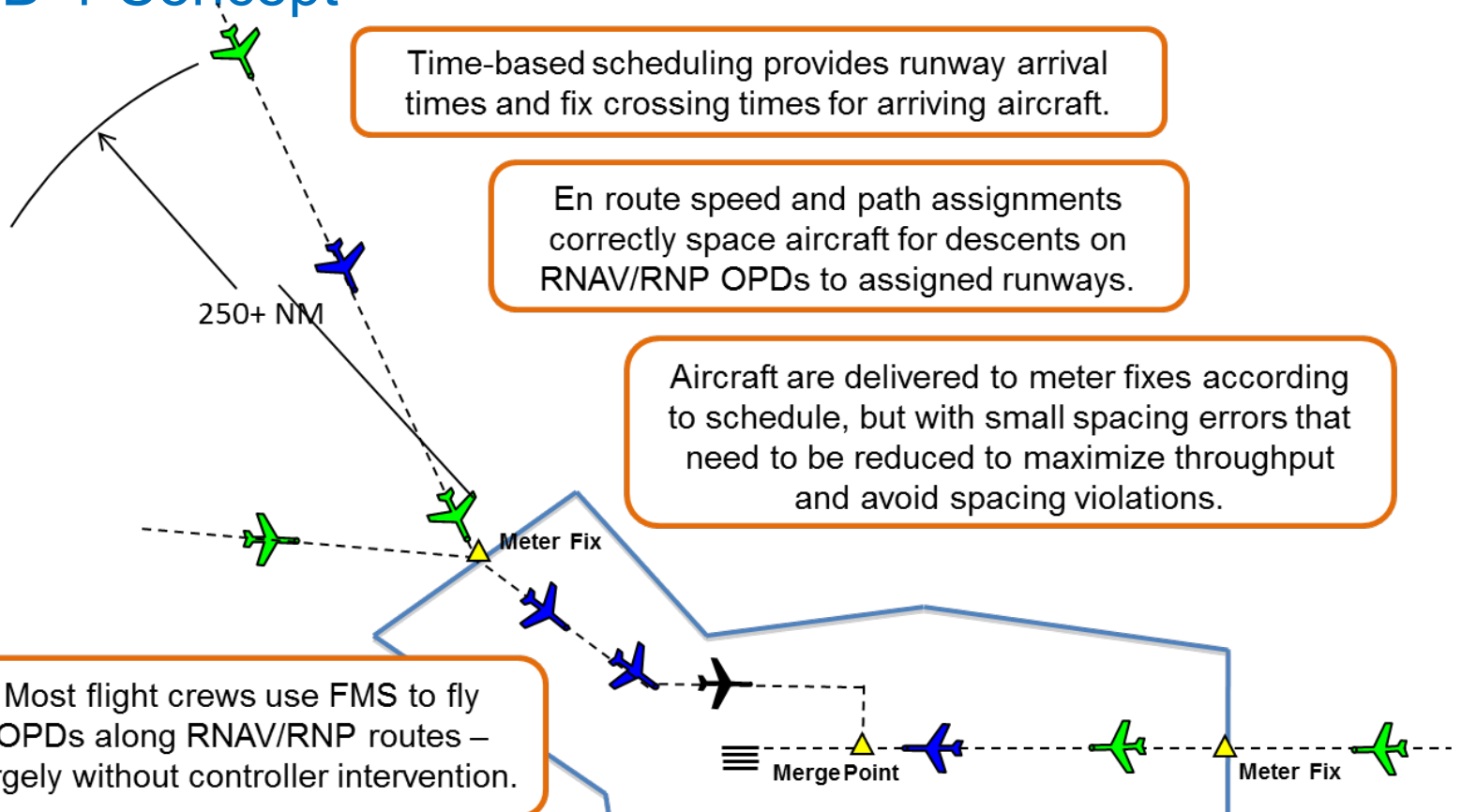
ATD is transferring integrated concepts and technologies to meet the needs of NextGen

ATD-1 Concept

Time-based scheduling provides runway arrival times and fix crossing times for arriving aircraft.

En route speed and path assignments correctly space aircraft for descents on RNAV/RNP OPDs to assigned runways.

Aircraft are delivered to meter fixes according to schedule, but with small spacing errors that need to be reduced to maximize throughput and avoid spacing violations.



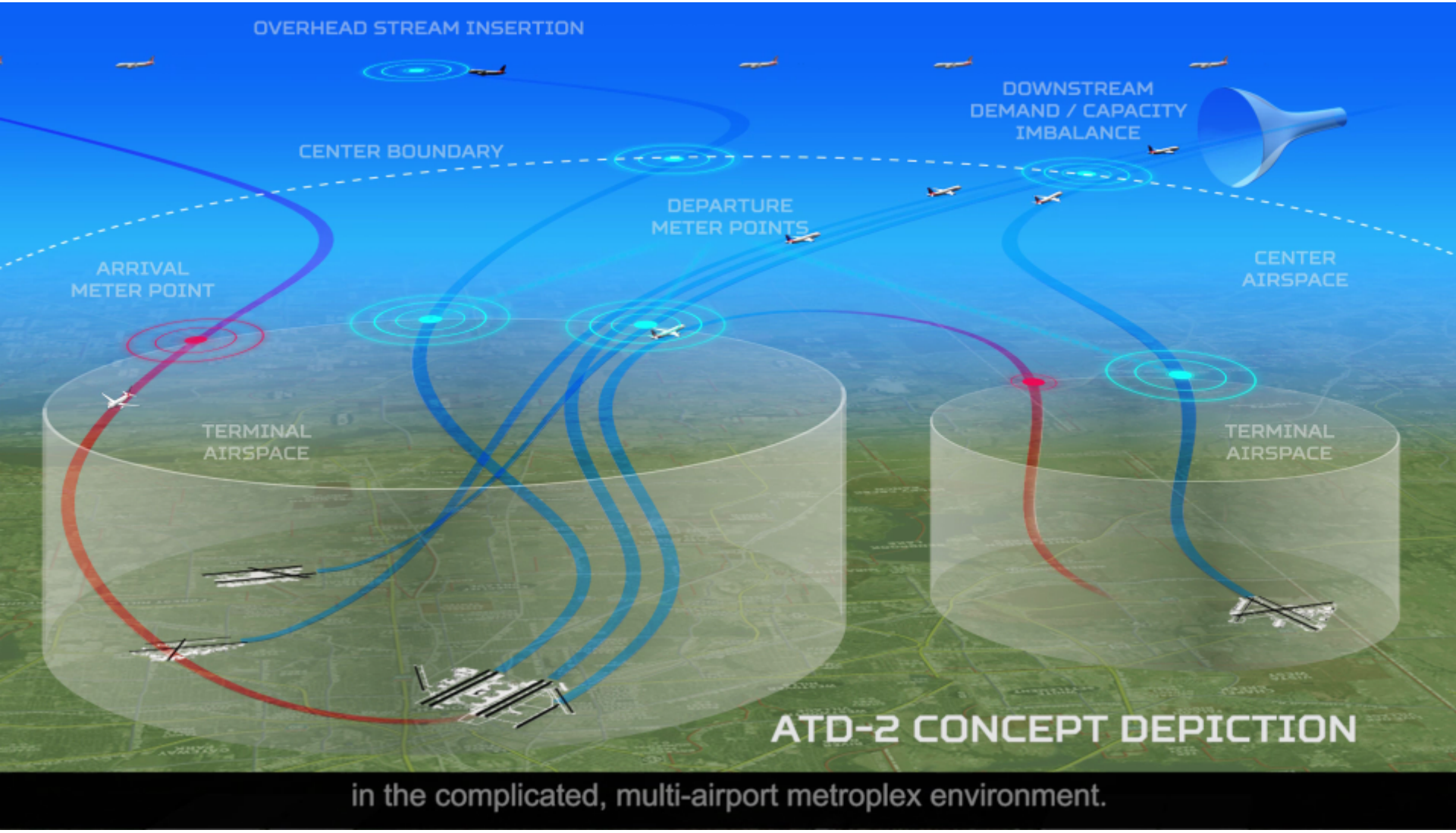
Most flight crews use FMS to fly OPDs along RNAV/RNP routes – largely without controller intervention.

Some flight crews use onboard speed guidance to achieve and maintain precise traffic spacing.

Terminal controllers correct residual spacing errors and cope with disturbances and off-nominal events using tools and display enhancements based on 4-D trajectories.

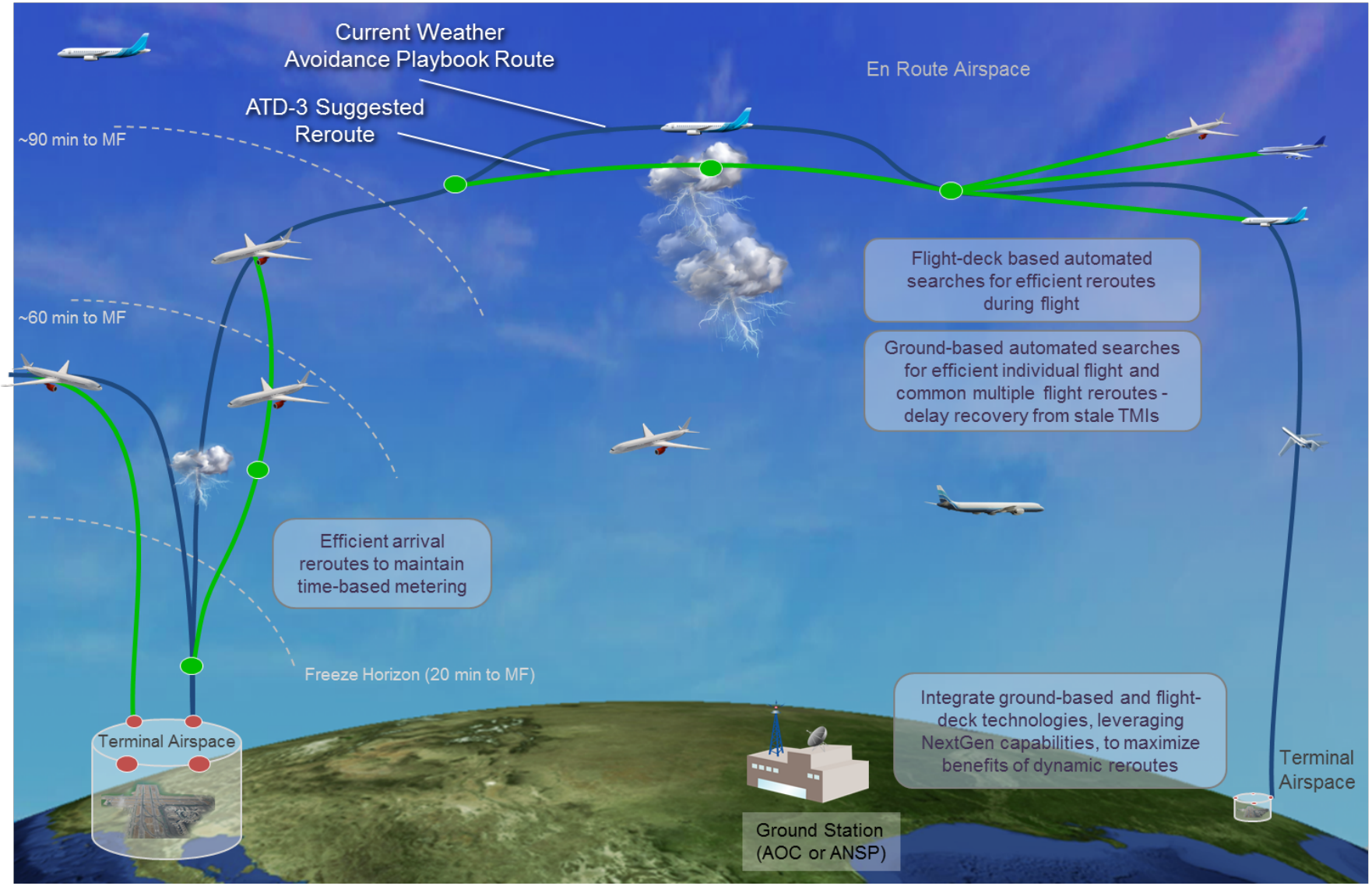
https://youtu.be/6vKA539C2-U
https://youtu.be/ngKazVQN4BI
https://www.youtube.com/watch?v=oHkIEjQ9sZY

ATD-2: Concept



https://youtu.be/yQGtQ8V6bZY

ATD-3: Integrated Concept

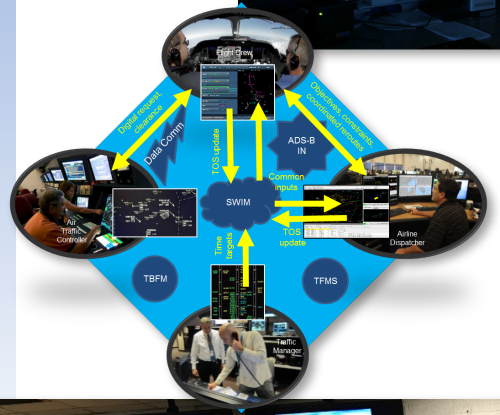


https://youtu.be/Mt2_MuH2W5U

ATD Summary

- Progress against TCs
  - TC 1: ATD-1
    - FIM flight test completed February in Pacific Northwest region
    - Closeout Briefs later in year
  - TC-2: ATD-2 IADS Metroplex Traffic Management
    - Strong stakeholder engagements through multiple venues and activities
    - ATD-2 Phase 1 hardware deployments in progress
  - TC-3: ATD-3 Domestic Applied Traffic Flow Management
    - Stakeholder engagement on DRAW and Air/Ground Integration objectives and requirements
    - Deployments of TASAR and MFCR continue
  - TC-5: TASA
    - Executing on all defined Safety Enhancement Outputs
    - Multiple simulation efforts
- Overall programmatic progress is good

Source: Boeing



Committee Finding for ARMD AA – Airspace Transportation Demonstration (ATD)

The Committee finds that NASA should further highlight to the public the contributions it is making to NextGen. The ATD's are providing tangible benefits to the airlines and flying public that are not widely recognized, but critical to fulfilling the NextGen vision. The Committee encourages NASA to push toward demonstrating higher levels of automation and autonomy to increase the benefits further.

2017 NAC Aeronautics Committee Work Plan

SPRING	SUMMER	FALL
ARMD integrated strategy for UAS **(Completed)**	ARMD FY18 Budget	System Wide Safety Assurance Project
On-Demand Mobility **(Completed)**	NAH Planning and Management Status	Low Boom Flight Demonstrator (LBFD)
Advanced Composites Project **(Completed)**	University Leadership Initiative	Autonomy Thrust
New Administration and Transition Update **(Completed)**	Airspace Technology Demonstrator (ATD)	Hypersonics Update




BACK-UP

Acronyms

- ATD – Airspace Technology Demonstration
- IADS - Integrated Arrival, Departure, and Surface Operations
- MFCR - Multi-Flight Common Route - generates dynamically tailored time- and fuel-saving reroutes and searches for flights that could benefit from these advisories.
- NAH – New Aviation Horizons
- TASA - Technologies for Airplane State Awareness
- TASAR – Traffic Aware Strategic Aircrew Requests - TASAR features a cockpit automation system that monitors for potential flight trajectory improvements and displays them to the pilot.
- T3A ST – Thrust 3A – Subsonic Transport
- T3B VL – Thrust 3B – Vertical Lift

Vision for Commercial Supersonic Flight

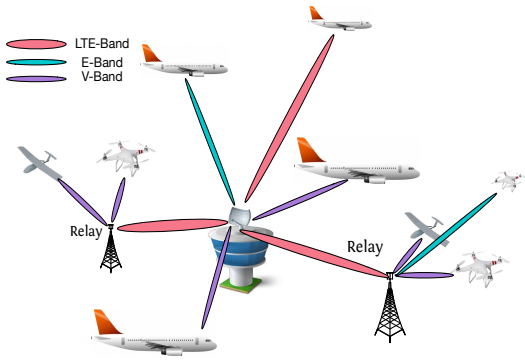
- The emerging potential commercial supersonic transport market has generated renewed interest in civil supersonic aircraft
  - Evidence of this growing interest is shown through Boom and Aerion's willingness to enter the market given restrictions in overland flight and other challenges
- Restrictions dramatically limited market potential for supersonic commercial aircraft
- The vision of the Supersonics Community is a future where fast air travel is available for a broad spectrum of the traveling public.
  - Future supersonic aircraft will not only be able to fly overland without creating an "unacceptable situation" but compared to Concorde and SST will be more efficient and affordable

Overland flight restrictions based on noise are viewed as the main barrier to this vision

Summary of First Round Awards (1/3)

- *Boundless Communications and Networking for Safe, Efficient Future Flight*, PI – David Matolak, Univ. of South Carolina (Thrust 1)
  - Team members: Florida Intl Univ., Boise State Univ., Architecture Technology Corp.
  - Goal: Develop strategies and communication capabilities for improving link/network capacity, reliability, security in support of new ATM applications

UNIVERSITY OF SOUTH CAROLINA



- *Adaptive Aerostructures for Revolutionary Civil Supersonic Transportation,* PI – Dimitris Lagoudas, Texas A&M Univ. (Thrust 2)
  - Team members: Univ. of Houston, Florida Intl Univ., Utah State Univ., Princeton Univ., Univ. of North Texas, Boeing, ATA Engineering, Fort Wayne Metals Research Products Corp.
  - Goal: Explore potential of small real-time geometric outer mold line (OML) reconfigurations to minimize boom signatures and drag in response to changing ambient conditions

TEXAS A&M UNIVERSITY

Summary of First Round Awards (2/3)

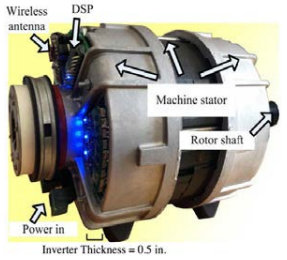
- *Advanced Aerodynamic Design Center for Ultra-Efficient Commercial Vehicles,* PI – James Coder, Univ. of Tennessee (Thrust 3)
  - Team members: Univ. of Illinois, Old Dominion Univ., Penn State Univ., Univ. of Wyoming, Texas A&M Univ., Boeing, Airfoils, Inc.
  - Goal: Develop slotted, natural laminar flow (SNLF) airfoil to reduce wing profile drag and enable N+3 vehicle performance gains

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Slotted Natural Laminar Flow Wing

- *Electric Propulsion: Challenges and Opportunities*, PI – Mike Benzakein, Ohio State Univ. (Thrust 4)
  - Team members: Case Western Reserve Univ., Univ. of Wisconsin, North Carolina A&T State Univ., Georgia Tech, Univ. of Maryland, GE
  - Goal: Provide multi-disciplinary technologies to advance electric power systems, battery and energy storage, thermal management supporting electric propulsion aircraft

THE OHIO STATE UNIVERSITY



Integrated Machine/ Converter Drive System

Summary of First Round Awards (3/3)

- *Information Fusion for Real-Time National Air Transportation System Prognostics under Uncertainty*, PI – Yongming Liu, Arizona State Univ. (Thrust 5)
  - Team members: Vanderbilt Univ., Southwest Research Institute (SRI), Optimal Synthesis, Inc.
  - Goal: Develop capabilities for system-wide, real-time prognostics framework with rigorous V&V for proactive health management of NextGen NAS