NASA Aeronautics Noise Interests

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- Ran Cabell, Steve Rizzi, Mike Doty
  - Assistance in adapting the slides for today's presentation

“Aeronautics” is the First “A” in NASA

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

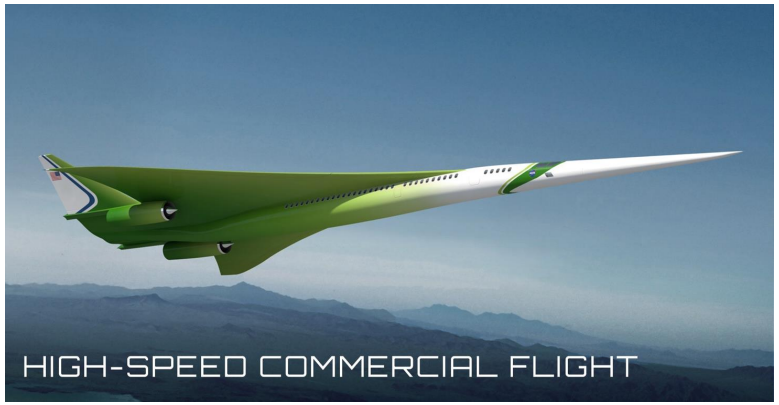
NACA

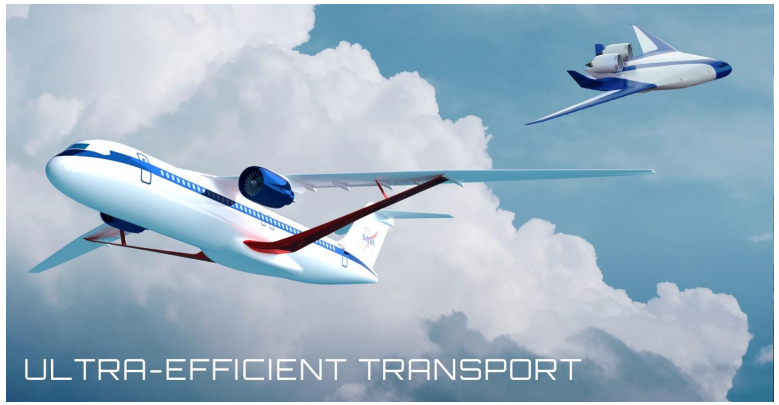
National Advisory Committee for Aeronautics
March 3, 1915

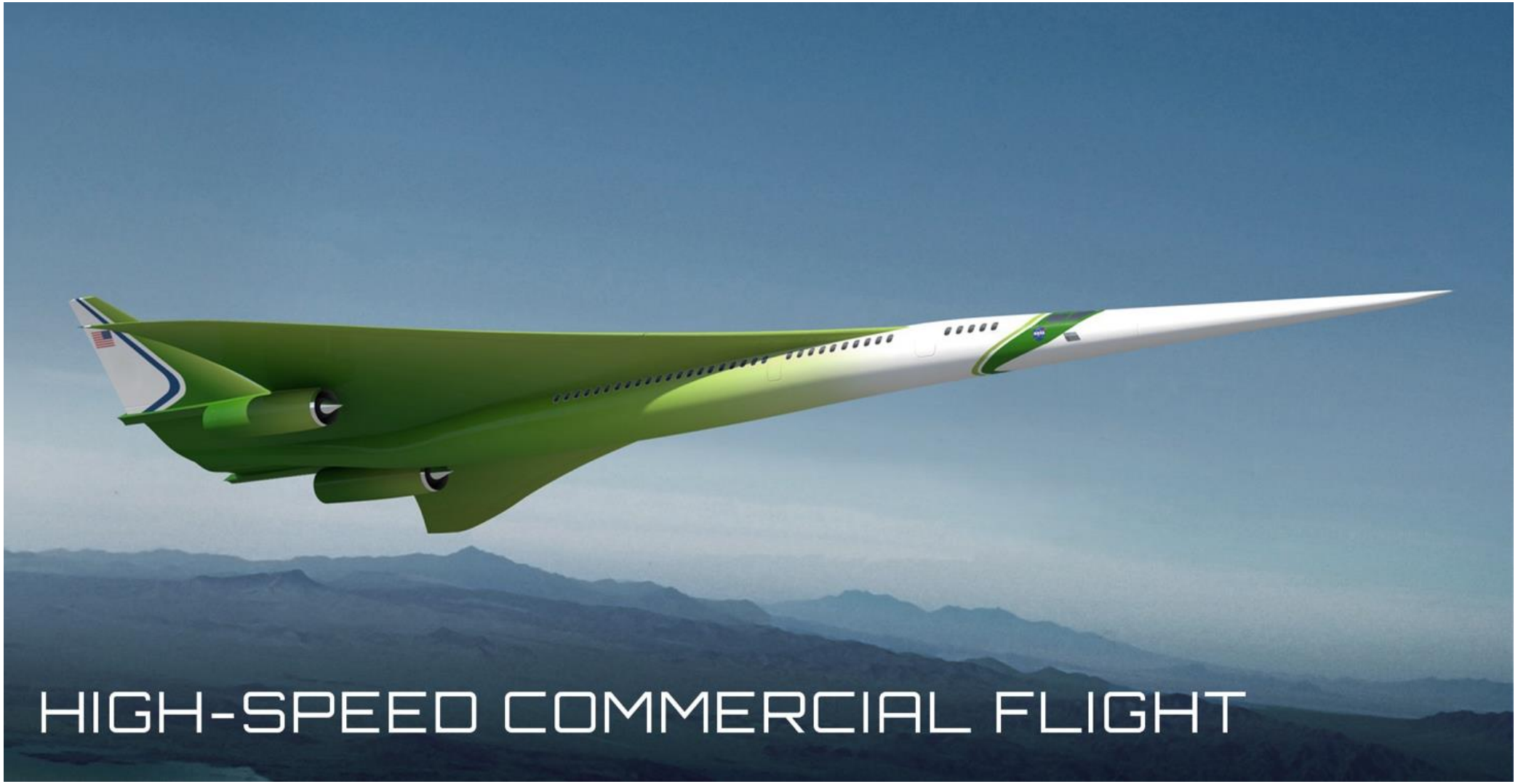
7,500 NACA employees
$300 million in NACA research facilities
(Langley, Lewis Field, Ames)
NACA research process

National Aeronautics and Space Administration
October 1, 1958

Transformations for Sustainability, Greater Mobility, and Economic Growth



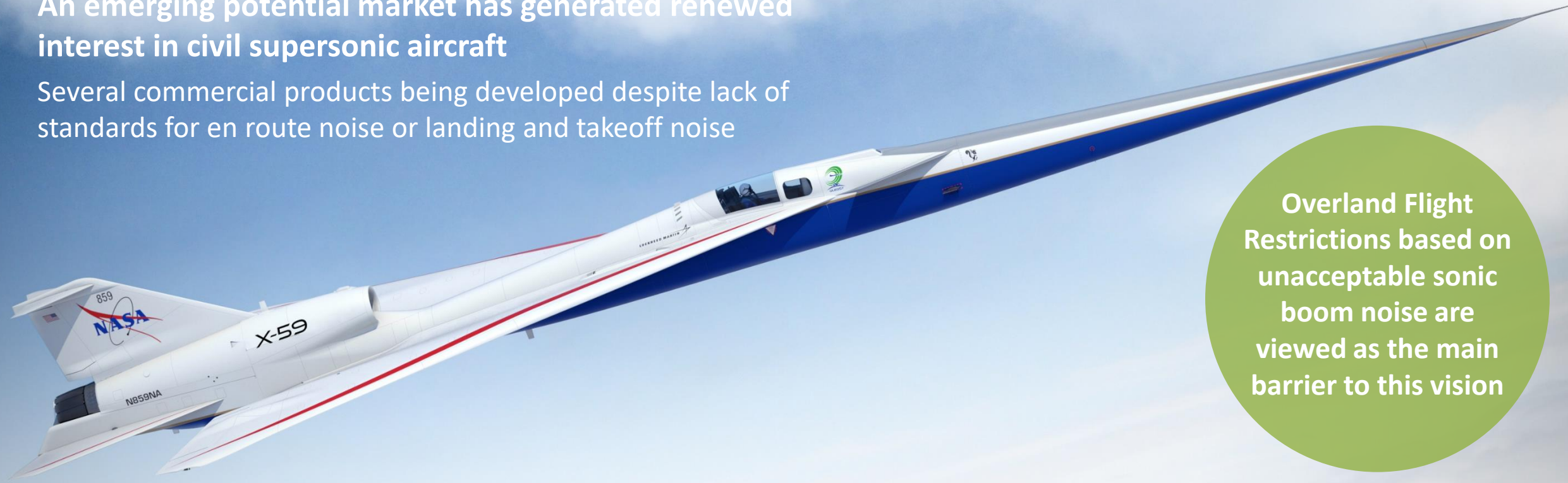



HIGH-SPEED COMMERCIAL FLIGHT

The vision for commercial supersonic flight

An emerging potential market has generated renewed interest in civil supersonic aircraft

Several commercial products being developed despite lack of standards for en route noise or landing and takeoff noise



Overland Flight Restrictions based on unacceptable sonic boom noise are viewed as the main barrier to this vision

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 will be efficient, affordable, and environmentally responsible

Image Credit: Lockheed Martin

Overcoming the barrier to overland flight

Support development of en route certification standards based on acceptable sound levels

- **New environmental standards are needed to open the market to supersonic flight**
- **An en route noise standard is the biggest challenge**
  - Requires proof of new design approaches
  - Must replace current prohibitions
  - No relevant data exists to define limits
  - Standard must be accepted internationally

Image Credit: Lockheed Martin

NASA is building the X-59 research aircraft

Image Credit: Lockheed Martin

- **Flights will confirm that a full-scale supersonic aircraft can produce just a gentle sonic “thump”**
- **Key data will be gathered on public perception of quiet supersonic flights in several cities across the nation**

Length

99.7 feet long

Width

29.5 feet wingspan

Cruise Speed

Mach 1.4

Cruise Altitude

55,000 feet

Quesst Mission Overview

Phase 1: X-59 Aircraft Development

- Detailed Design
- Fabrication, Integration, Ground Test
- Checkout Flights
- Subsonic Envelope Expansion
- Supersonic Envelope Expansion

Phase 2: Acoustic Validation

- In-flight and ground measurements
- Validation of X-59 signature and prediction tools
- Development of acoustic prediction tools for Phase 3

Phase 3: Community Response

- Ground measurements in communities
- Community response surveys
- Multiple campaigns across U.S.
- Data analysis and database delivery

Phase 1 X-59 Aircraft Development

Overall good progress in all aspects of aircraft design/build

- Lockheed Martin internal design, fab, and assembly
- Contracted fabrication and supply
- NASA-developed systems, donor aircraft parts and components
- Current focus is on delivering a safe, robust aircraft that can support the accomplishment of the mission goals

Moved to the flight line

Engine installation

Cockpit systems installation

Quesst Mission - Phase 2 and 3 Status

Acoustic Validation

- Ground Recording System (GRS) being developed by Crystal Instruments, Inc
  - First set of units have been through verification testing at NASA
- Risk reduction tests for Phase 2 logistics and GRS deployment continue
- Progress continues on airborne acoustic measurement systems

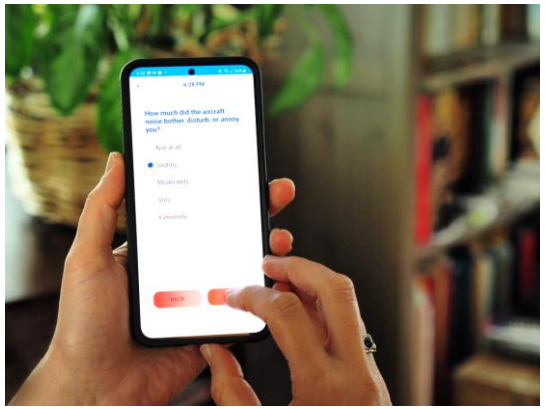
GRS unit

Community Test Planning & Execution

- Significant progress on test, exposure, and survey plans
- Airfield and community selection process ongoing
- Conducting test of survey methods in coming months (no actual flights)
  - Including recruitment approach & survey questionnaires

International Standards Development

- Continued engagement with FAA/AEE, ICAO/CAEP & international research community



Commercial Supersonics LTO Noise & Prediction Uncertainty

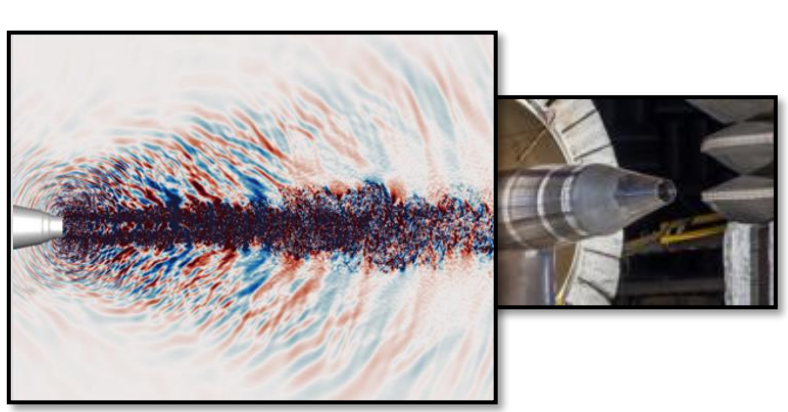
Improvements to noise prediction models used in studies of a supersonic market

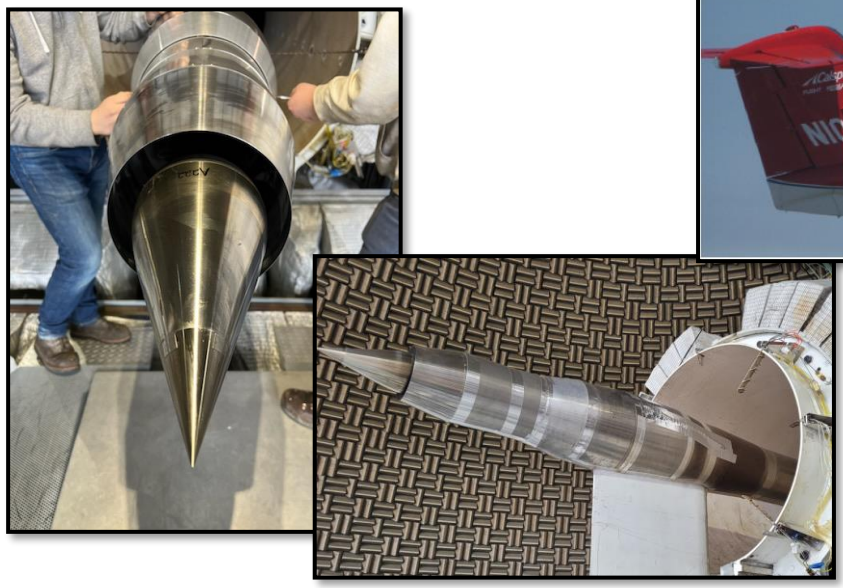
- Models based on current OEM-based aircraft designs for representative near-term aircraft
- Data obtained by physics-based simulations, validated by model-scale tests and flight tests

Recent activities

- Conducted acoustic flight test to acquire far-field noise from jet-noise dominated aircraft (Learjet 25), Sept 2022
- Conducted complementary model-scale rig test using flight test variables (engine conditions, flight speeds), Sept 2022
  - Traces accuracies from simulations through flight.
- Completed external review (with FAA participation) validating NASA simulation methods for fan noise, Feb 2023

➢ **System level prediction uncertainty already showing significant reduction**



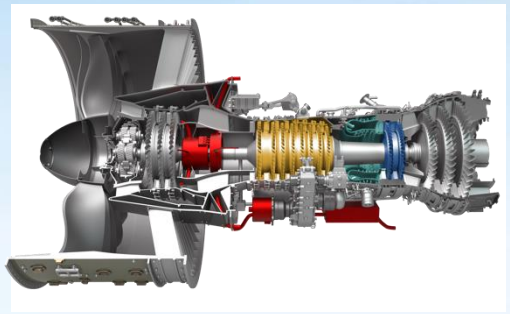



ULTRA-EFFICIENT TRANSPORT

Subsonic Transport Technologies

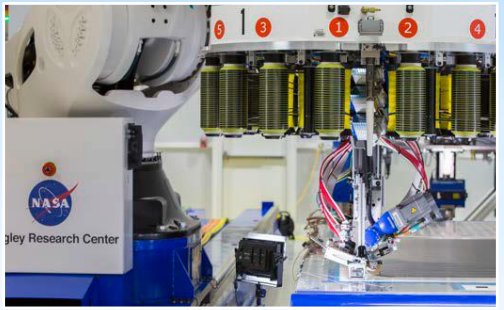
Foundation for the next generation of commercial aircraft

Transonic Truss-Braced Wing
5-10% fuel burn benefit



Small Core Gas Turbine
5-10% fuel burn benefit

Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit



High-Rate Composite Manufacturing
4x-6x manufacturing rate increase

Sustainable Flight Demonstrator (SFD)

Demonstrate technologies in flight for efficiency and environmental performance

Scope

- Partnership with Boeing to design, build, test, and fly an advanced airframe configuration demonstrator aircraft and related technologies to dramatically reduce fuel burn and CO2 emissions

Design

- Boeing's Transonic Truss-Braced Wing (TTBW) configuration utilizes a high aspect ratio, thin, truss-braced wing design

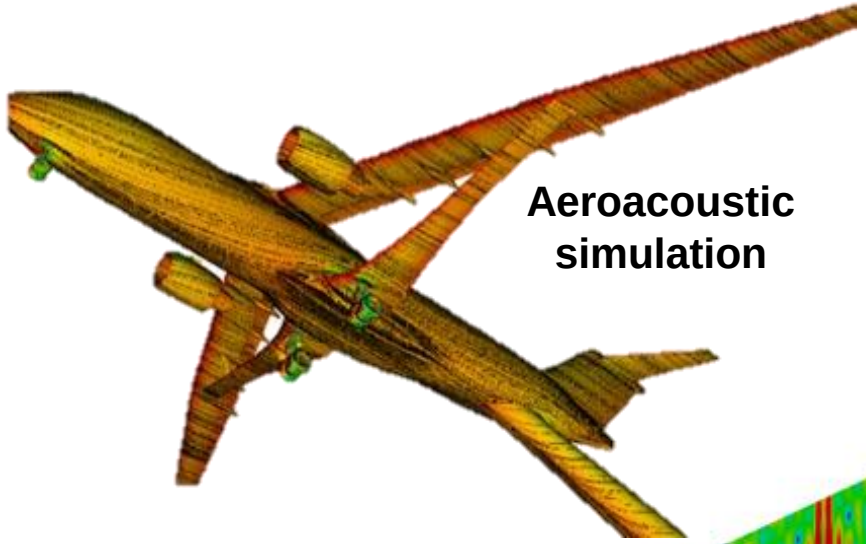
Approach

- Boeing will modify MD-90 aircraft into the SFD Demonstrator aircraft
- Existing wings, aft engines, and fuselage sections will be removed
- TTBW & subsystems, modern turbofan engines, and instrumentation will be added

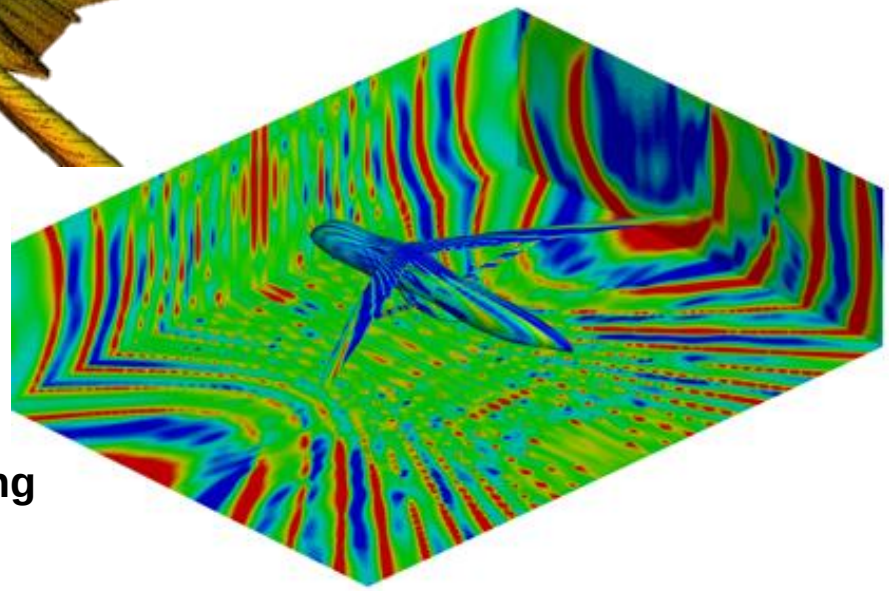
Risk Reduction Contracts August 2021 – September 2022
Design/Build/Fly Funded Space Act Agreement Awarded January 18, 2023 - 1st Flight 2028

TTBW: Acoustic Assessment & Noise Reduction Technology

Computational and experimental work for system noise assessment, improving prediction tools, & assessing noise reduction technologies



Aeroacoustic simulation



Noise scattering by airframe

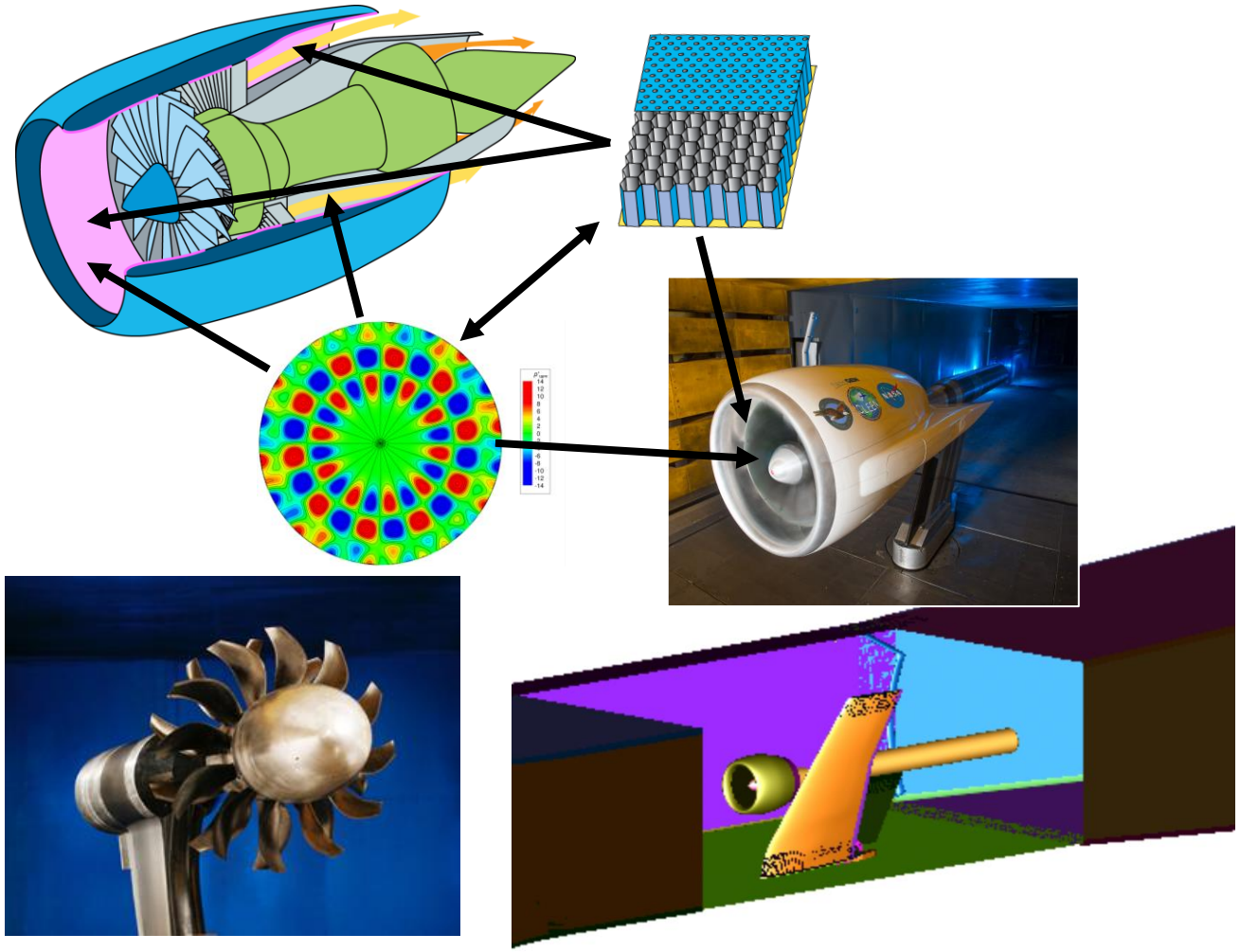
Scope and Partners:

- Steady CFD simulations (validated against wind tunnel data) - NASA
- High resolution unsteady numerical simulations of TTBW - NASA/3DS/AVEC
- Noise scattering tests in LaRC Quiet Flow Facility - NASA
- Development of acoustic scattering tools - Old Dominion University
- Modeling and testing of Slat Gap Filler - NASA & Texas A&M

Reducing the uncertainty of TTBW system noise assessment and identifying noise reduction technologies

Efficient Quiet integrated Propulsors (EQuiP)

Next-generation propulsors technology



Scope

- Predict, model, assess the ability for next-generation propulsor to meet market-driven noise & fuel burn reduction goals *with integration effects*

Benefit

- Accelerate next-generation propulsor development for 5-10% fuel burn reduction & 4 EPNdB noise reduction relative to 2021 best-in-class propulsors

Approach

- Partner with industry & FAA CLEEN to mature/ demonstrate promising technologies
- Initial scope is on propulsor but interested in partnerships for effect of propulsor-on-wing studies

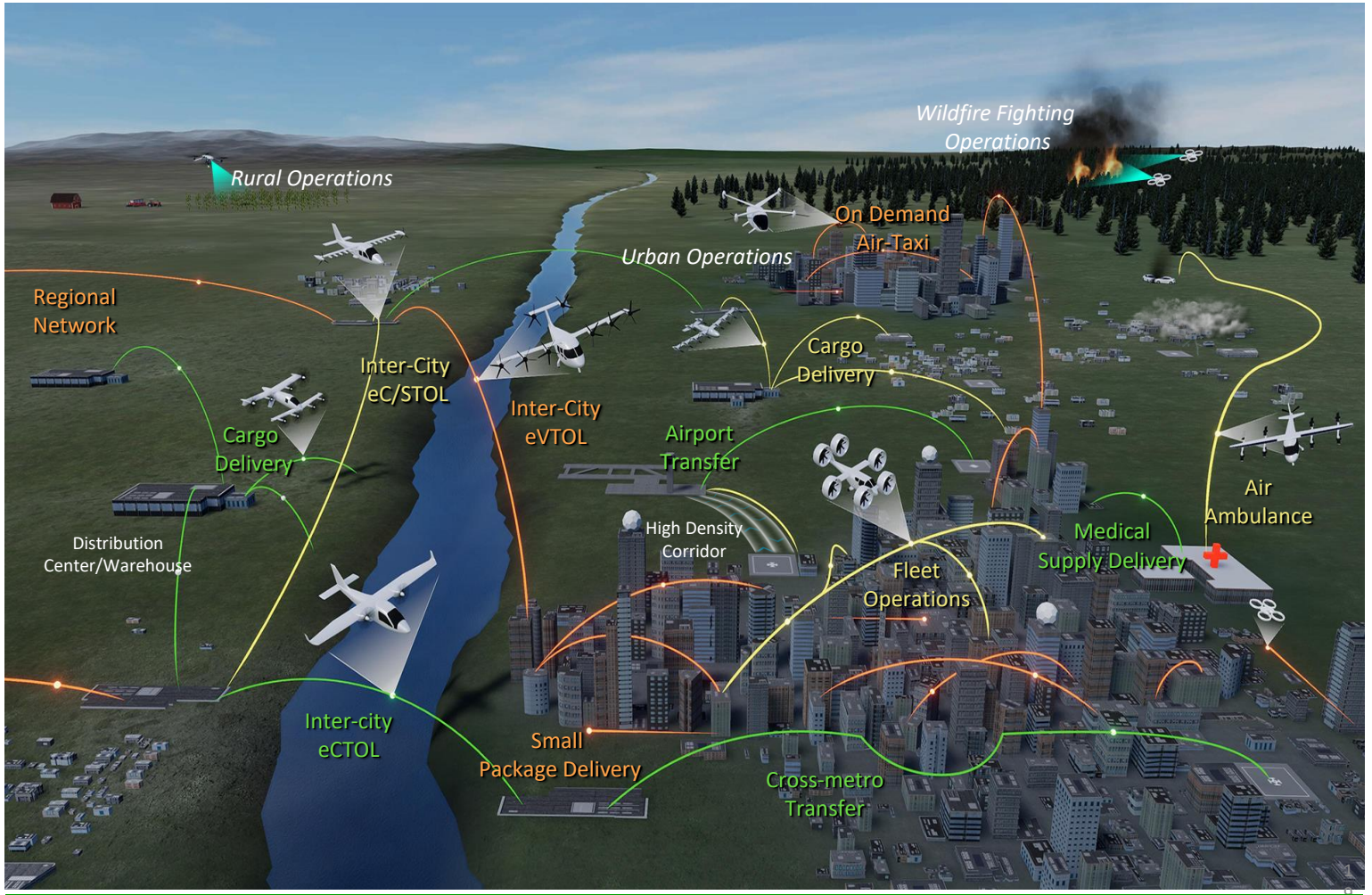
Modern high bypass ratio propulsors have potential for significant efficiency gains regardless of power source, but are a dominant aircraft noise source


METRO
ADVANCED AIR MOBILITY

Advanced Air Mobility (AAM) and Urban Air Mobility (UAM)

- AAM missions characterized by
  < 300-500 nm range
- Rural & urban operations are included
- Missions can be public transportation, cargo delivery, air taxi, or emergency response

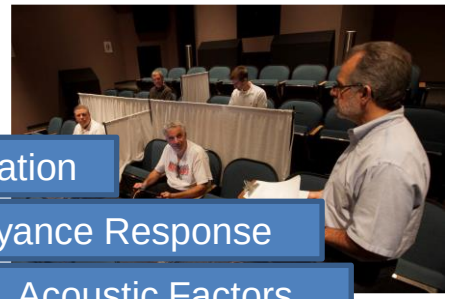
- **Urban Air Mobility (UAM)** is a subset of AAM - a segment projected to have high economic benefit & to be the most difficult to develop
  - requires an airspace system to handle high-density operations
  - requires an advanced urban-capable vehicle
  - vehicle variants can target other missions



Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

Multiple NASA projects support the AAM Mission

UAM Noise Research Approach

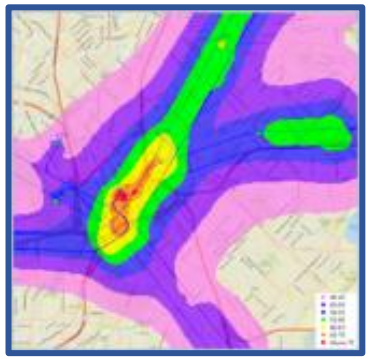


Sound Auralization

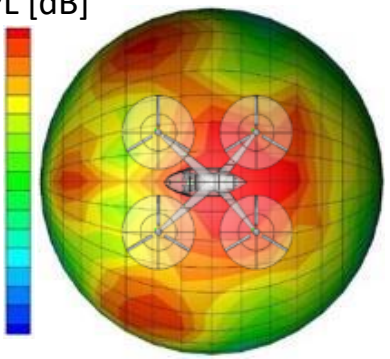
Annoyance Response

Acoustic Factors

Develop and Distribute Noise Prediction Tools



SPL [dB]



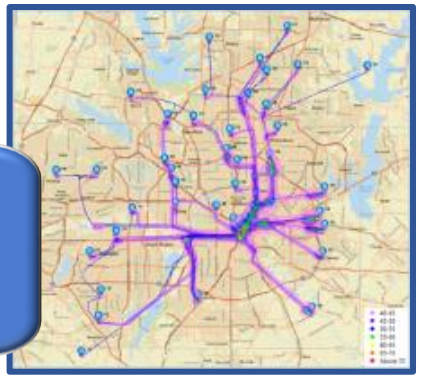
Psychoacoustics Research for Human Response to UAM Noise

Accurately Model and Predict UAM Noise Sources

Photo Credit: Joby Aviation

Obtain Flight and Wind Tunnel Data to Characterize Noise

Methods for Assessing UAM Acoustic Impact in Operations

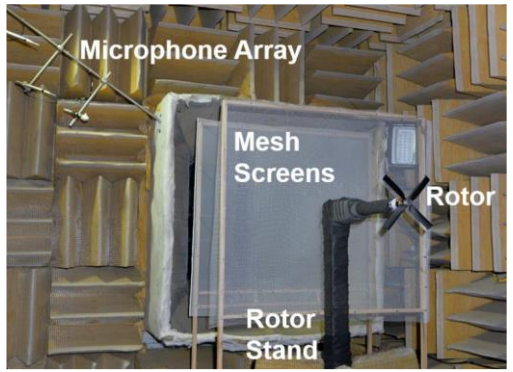


https://ntrs.nasa.gov/citations/20220006729

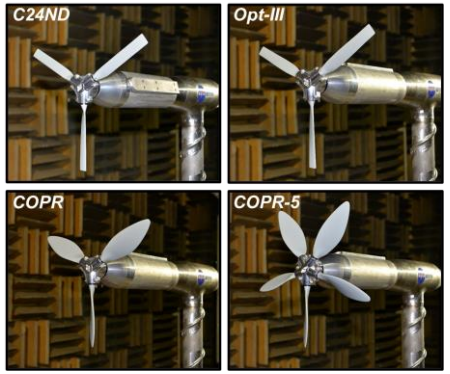
Provide Design Tools and Guidelines for Low Noise Design and Operations

Experimental Databases for Validation of Noise Prediction Models

Recent isolated propellers and rotors



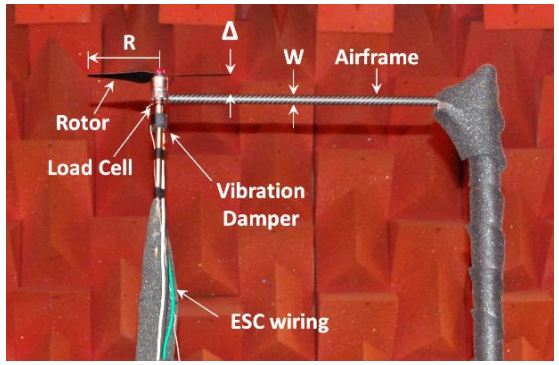
Ideally Twisted Rotor
AIAA-2021-1928



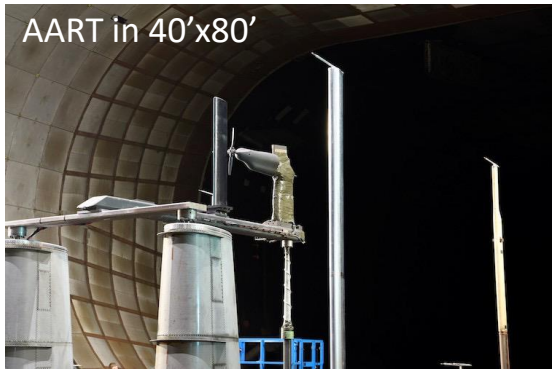
Optimized Proprotor
NASA ATWG Spring 2022

Cruise and High Lift Propellers
AIAA-2018-3448

Recent installed propellers and rotors



Rotor-Airframe Interaction
73rd AHS Forum 2017

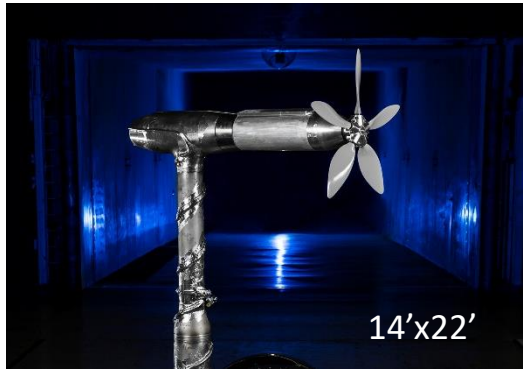


Pusher Configuration
77th VFS Forum 2021

Tractor Configuration
AIAA-2021-0714

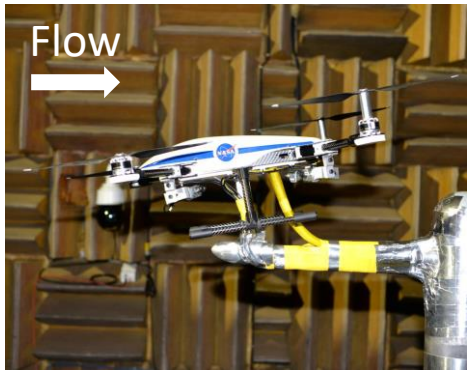
Experimental Databases for Validation of Noise Prediction Models

… more installed propellers, rotors, ducted rotors and tilt



Tilting Vertical Lift Propeller
Aero Performance - Summer 2022
Acoustic Test – Start June 2024

Ducted Speaker & Rotor
NASA ATWG Spring 2022



Quadrotor – Blade Sets & Standoffs
28th Aeroacoustics Conf. 2022

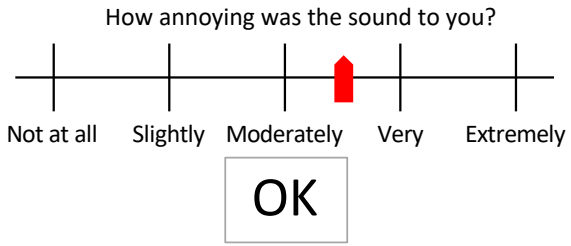
Multirotor Test Bed Acoustic Test
(7’x10’, 40’x80’)
FY 22-25

Tiltwing Acoustic Test (14’x22’)
FY 24-26

Recent and Planned Psychoacoustics Studies

UAM Sound Quality; completed July 2022

- How annoyance varies with sound quality
- Generated test stimuli spanning a range of loudness, sharpness, tonality, fluctuation strength, and impulsiveness



Noise and Numbers; January 2023

- How annoyance varies with number of operations, spacing between operations, and makeup of the fleet

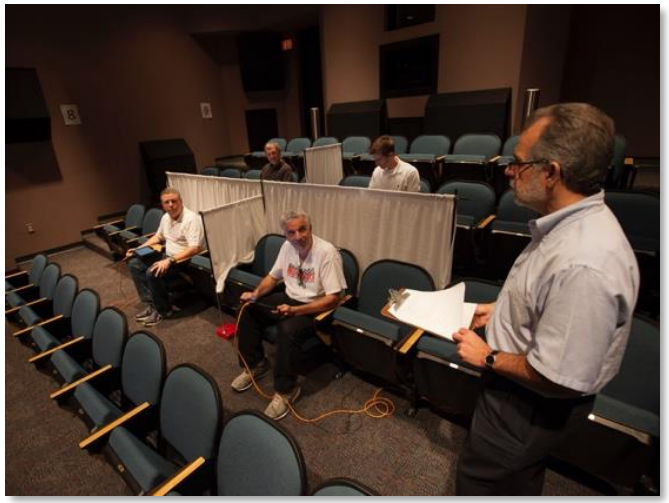
Detection, Noticeability, and Annoyance; Fall 2023

- How annoyance varies in presence of masking noise

Remote UAM Human Response Study

- Verify consistency of remote test platform with prior lab results (Oct 2022)
- Future test objectives may include: annoyance between geographically distinct communities, near vertiports, number of events, different soundscapes, relative to existing aircraft noise sources (2024)

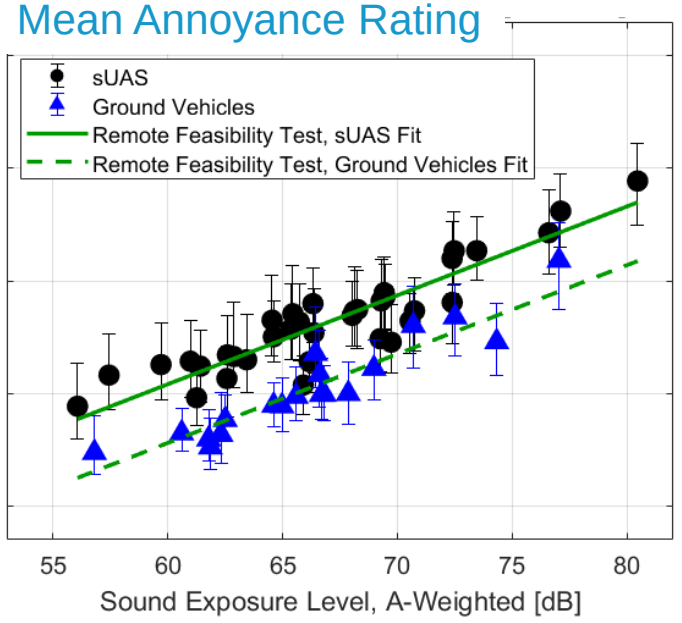
Exterior Effects Room (EER) at NASA Langley



Remote Psychoacoustic Testing

Annoyance Response Prompt for Each Sound

Mean Annoyance Rating



NASA is working on diverse noise issues

- A large variety of flight vehicles pose significant and unique noise challenges
- Acoustics work encompasses many areas, from source noise prediction to community response
- Noise is one of the primary drivers of new research efforts, which presents a tremendous opportunity and responsibility for NASA