Activities of the NASA Urban Air Mobility Noise Working Group (UNWG)

Stephen A. Rizzi
Senior Researcher for Aeroacoustics
NASA Langley Research Center
stephen.a.rizzi@nasa.gov

Quiet Drones 2022
Second International Symposium on Noise from UAVs, UASs, and eVTOLs
June 27-29, 2022

Outline

- What is the UAM Noise Working Group?
- Preliminary UAM Community Response Test Plan
- UNWG Subgroup Efforts Toward Community Response Test Plan

UAM Noise Exploratory Meeting (April ’18)

- Positive interest in forming a focused working group to define and address noise goals for UAM vehicles.
- Participants should include stakeholders across industry, government agencies, academia, and community groups.
- Focus efforts on reducing or eliminating the barriers associated with community noise.
- Key topics of interest include:
  Tools & Technologies (Subgroup 1 – NASA led)
  Ground & Flight Testing (Subgroup 2 – NASA led)
  Human Response & Metrics (Subgroup 3 – NASA led)
  Regulation & Policy (Subgroup 4 – FAA led)

~ 70 attendees at Exploratory Meeting

UNWG Scope

The UNWG shall focus its efforts on noise issues of UAM vehicles and operations with representative attributes including†

- *electric vertical takeoff and landing (eVTOL) vehicles that can accommodate up to 6 passengers (or equivalent cargo),*
- *possible autonomy,*
- *missions of up to 100 nautical miles at altitudes up to 3000 ft. above ground level,*
- *flight speeds up to 200 knots, and*
- *payloads between 800 and 8000 pounds.*

† Note that these attributes are not intended to serve as strict definitions. They were adopted from market definitions made by the NASA Aeronautics Emerging Aviation Markets (EAM) Tiger Team in 2017.

UNWG High Level Goals

- **Document noise reduction technologies available for UAM and identify knowledge gaps for each of the four areas of interest (UNWG subgroups).**

- Assess prediction capabilities for benchmark problems based on an open set of reference vehicle designs using available data.

- Define measurement methods/procedures to support noise regulations and assessment of community noise impact, and coordinate with UAM vehicle manufacturers on development of low noise approach and takeoff procedures for piloted and automated operations.

- Assess metrics for audibility and annoyance of single-event vehicle operations using available predicted and measured data.

- **Examine fleet noise impacts through prediction and measurement**, and characterize effectiveness of supplemental metrics for audibility and annoyance.

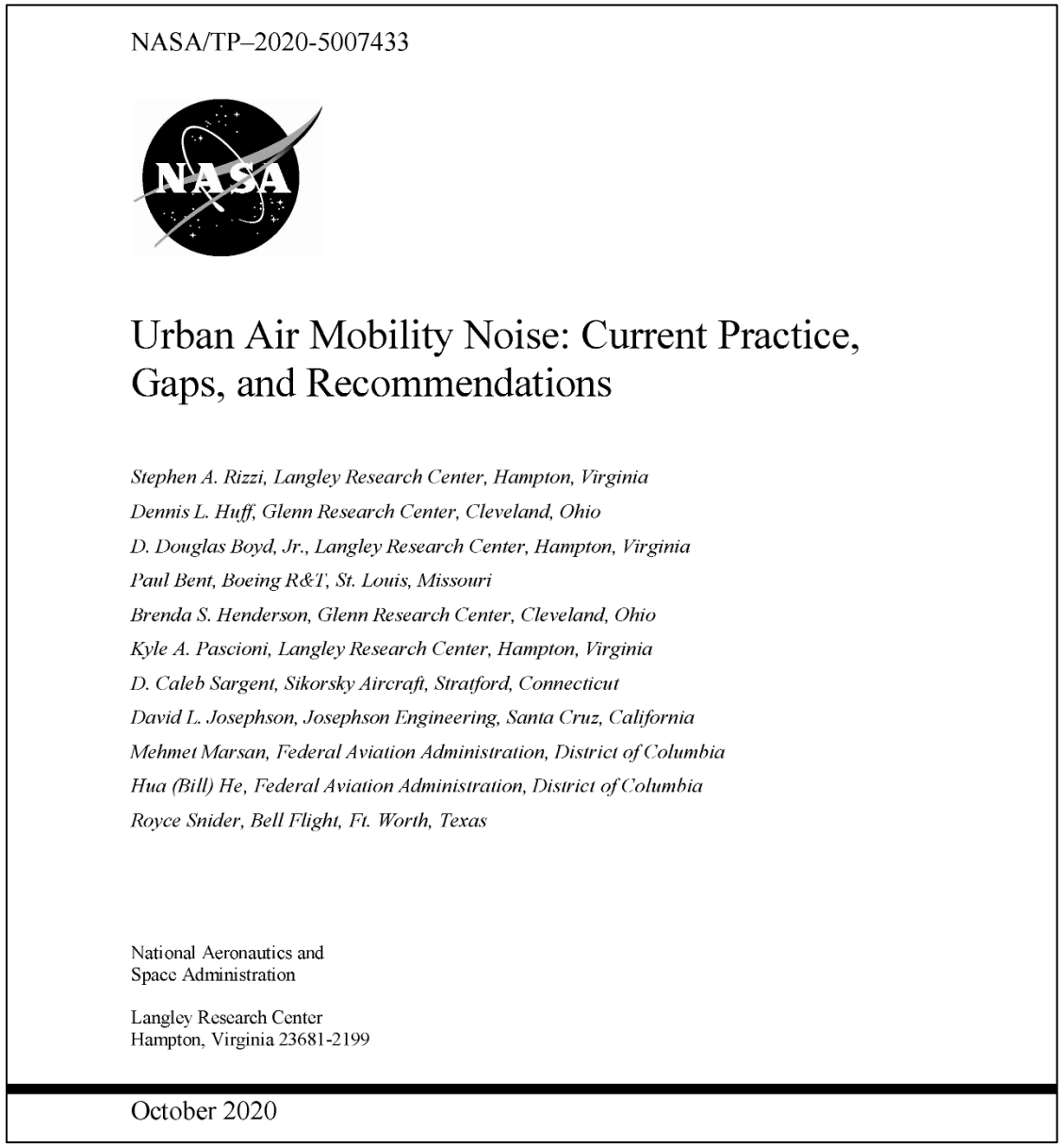
- Promote UAM integration into communities through mitigation of fleet noise impacts, and engagement with the public.

UNWG White Paper

Published as NASA/TP-2020-5007433

Available for download via the NASA Technical Report Server (NTRS):

https://ntrs.nasa.gov/search?q=20205007433



NASA/TP–2020-5007433

Urban Air Mobility Noise: Current Practice, Gaps, and Recommendations

Stephen A. Rizzi, Langley Research Center, Hampton, Virginia
Dennis L. Huff, Glenn Research Center, Cleveland, Ohio
D. Douglas Boyd, Jr., Langley Research Center, Hampton, Virginia
Paul Bent, Boeing R&T, St. Louis, Missouri
Brenda S. Henderson, Glenn Research Center, Cleveland, Ohio
Kyle A. Pascioni, Langley Research Center, Hampton, Virginia
D. Caleb Sargent, Sikorsky Aircraft, Stratford, Connecticut
David L. Josephson, Josephson Engineering, Santa Cruz, California
Mehmet Marsan, Federal Aviation Administration, District of Columbia
Hua (Bill) He, Federal Aviation Administration, District of Columbia
Royce Snider, Bell Flight, Ft. Worth, Texas

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

October 2020

National Academy of Engineering Report†

The report states –

> ***"Public acceptance of advanced aerial mobility, particularly noise aspects and its psychological factors, is perhaps one of the biggest challenges along with safety."***

The report contains the following recommendation –

> **Recommendation: Research should be performed to quantify and mitigate public annoyance due to noise, including psychoacoustic and health aspects, from different types of advanced aerial mobility operations. NASA should facilitate a collaboration between relevant government agencies—including FAA, Department of Defense, National Institutes of Health, academia, state and local governments, industry, original equipment manufacturers, operators, and nonprofit organizations—to prioritize and conduct the research, with responsibility allocated per a coordinated plan and accountability for delivery incorporated. The research should be completed in 2 years.**

† National Academies of Sciences, Engineering, and Medicine 2020. Advancing Aerial Mobility: A National Blueprint. Washington, DC: The National Academies Press. https://doi.org/10.17226/25646

Regarding UAM Community Noise

One of the UNWG high level goal states –

> ***"Examine fleet noise impacts through prediction and measurement, …."***

with a white paper recommendation –

> ***"Until early entrants are fielded, and community noise studies can be performed, laboratory studies be performed to help inform how different the annoyance to short-term exposure of UAM vehicle noise is from that of existing aircraft noise sources."***

Although not explicitly stated in the white paper, this recommendation implies that community noise studies will/should be performed following early entrants' entry into service. It is now time to start planning for those studies.

What follows is a preliminary UAM community response test plan with a summary of some UNWG efforts that support it.

UAM Community Response Tests

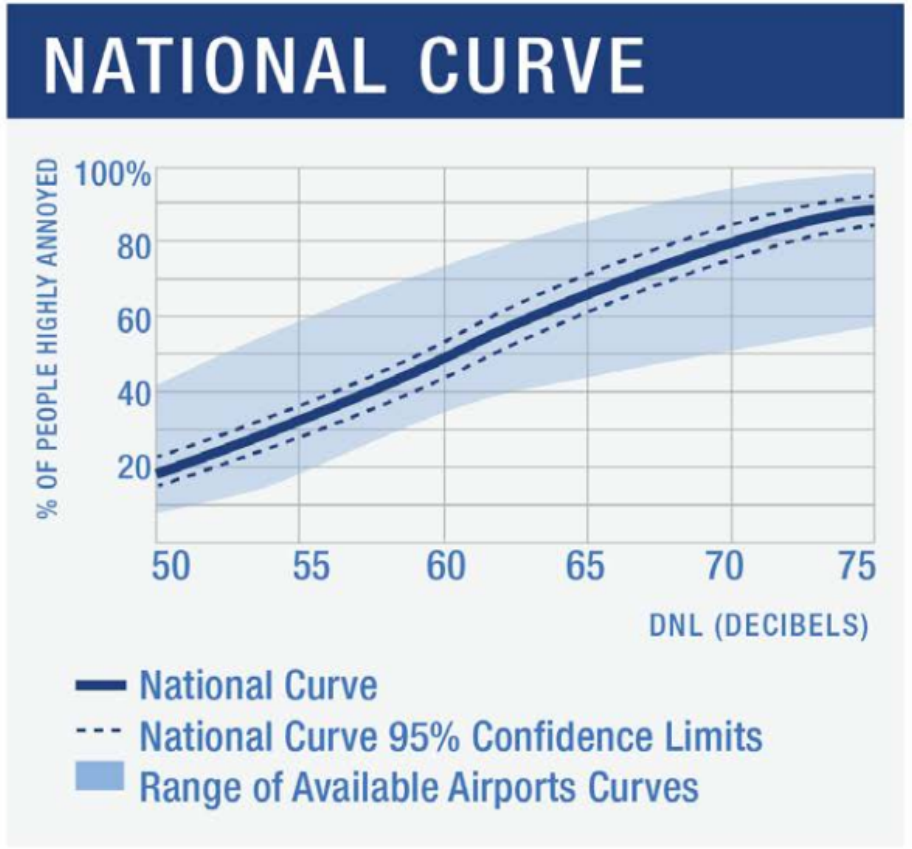
- Goal: Acquire community response data that can be used by the FAA to inform future national noise policy

- Approach:
  - Develop test plan for FAA-led UAM community response tests to be conducted in the late 2020s
    - Draft set of candidate test objectives
    - Solicit feedback from stakeholders and update as needed
  - Plan and execute research activities in preparation for tests
    - Leverage current NASA-led UAM research
    - Address gaps with new cooperative NASA-FAA research activities

UAM Community Response Tests

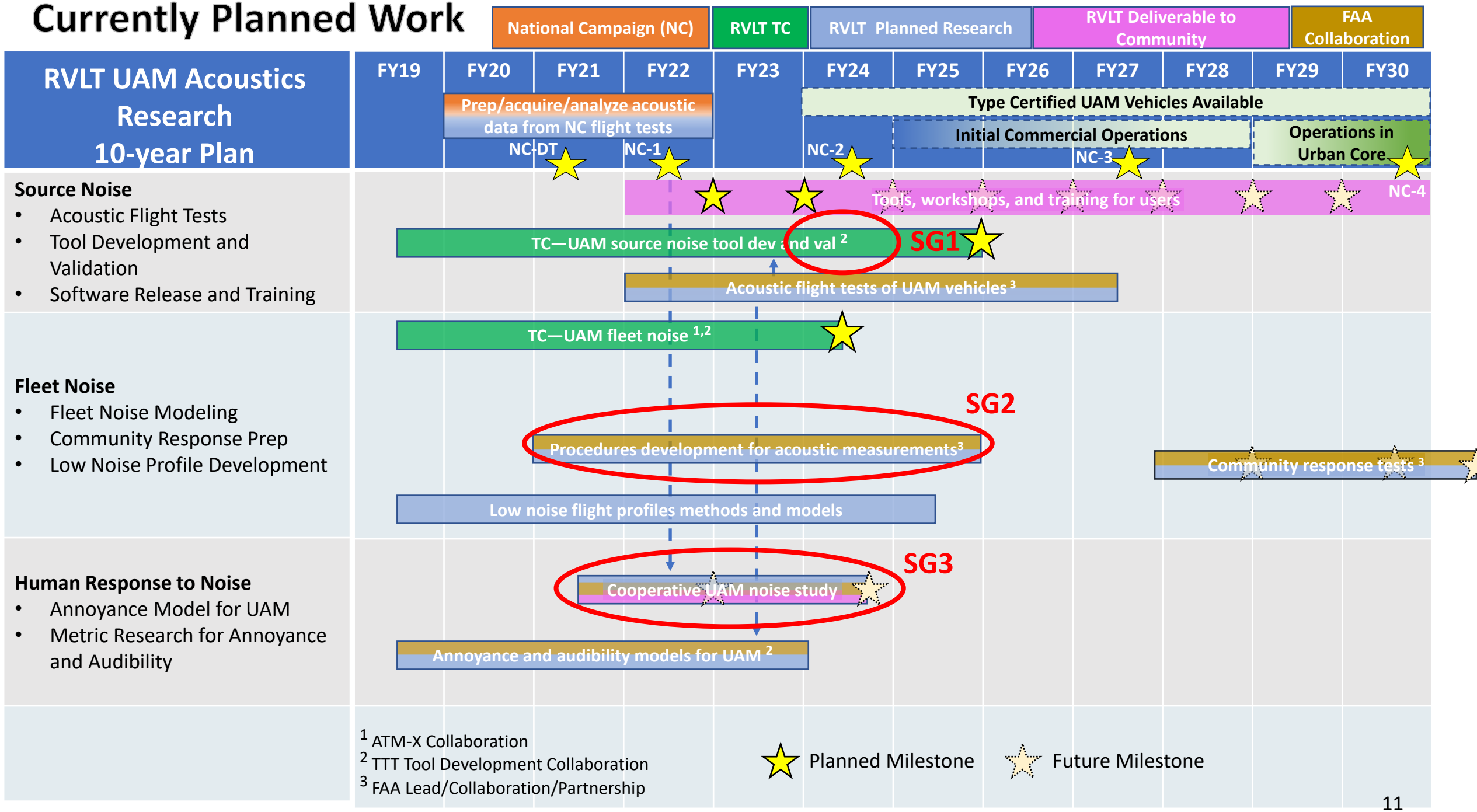
- Desired outcome: acquire community response data that can be used by the FAA to inform future national noise policy

- Types of community response tests
  - Low Boom Flight Demonstrator-like staged test
    - The only option for supersonic research due to current ban on commercial operations over land
    - Provides single event and short-term annoyance (due to a single flyover or collection of flyovers)
  - **Observational study**
    - Need certificated vehicles flying over populations for long periods of time
    - Goal is to assess long-duration community response
    - FAA Neighborhood Environmental Survey is the gold standard for this type of test

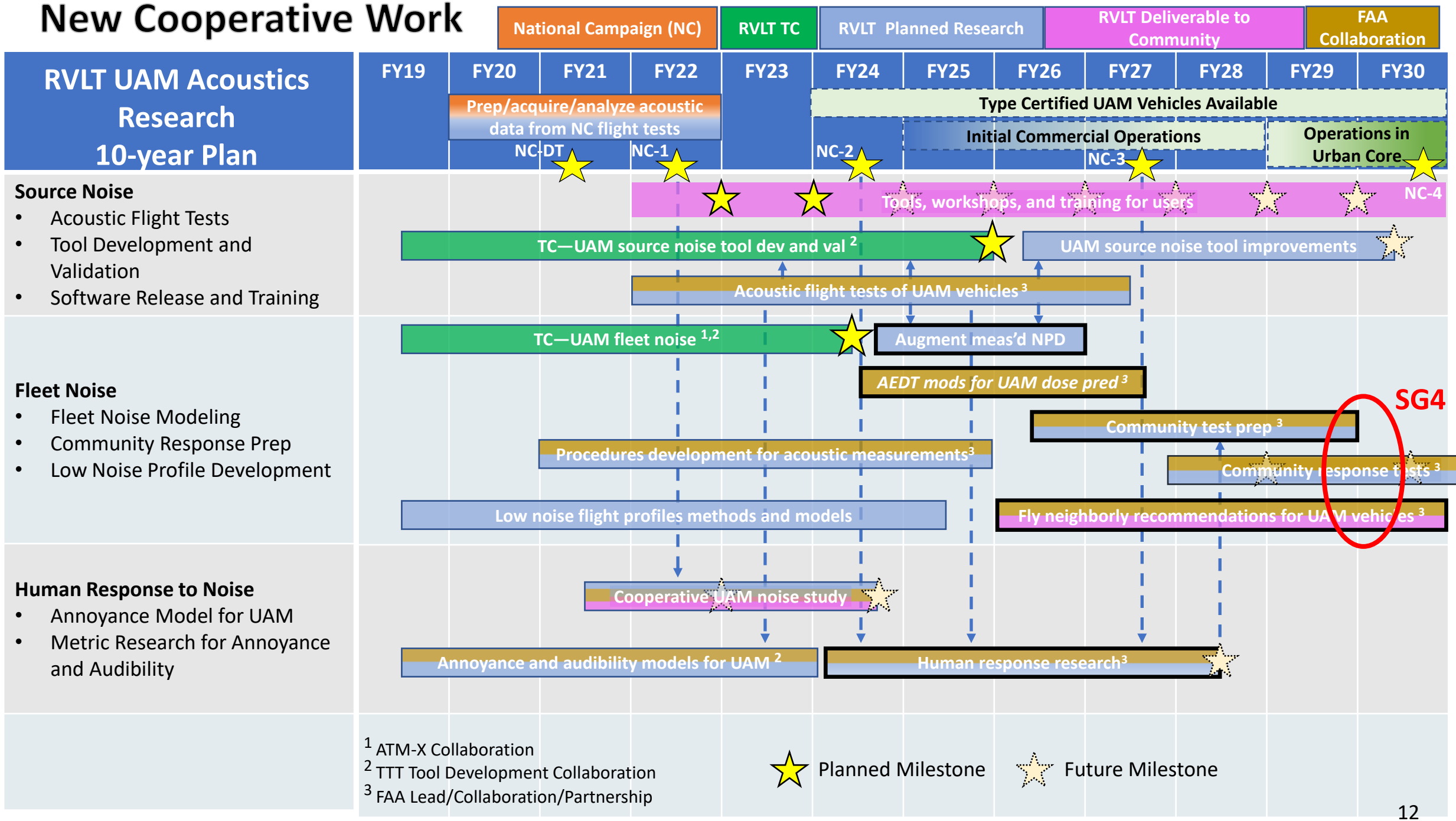


Long-term dose-response curve establishes the relationship between noise (dose) and annoyance (response)

Currently Planned Work

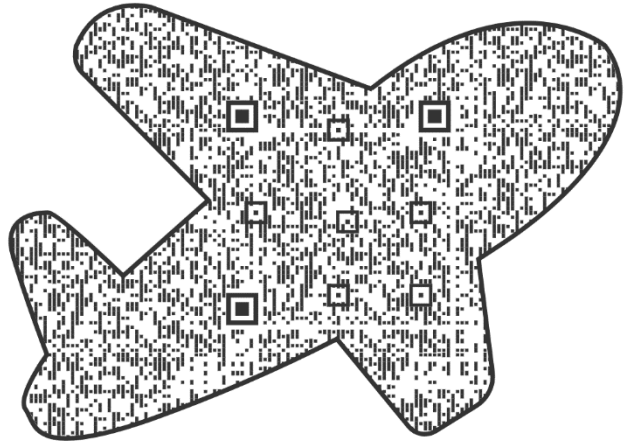


New Cooperative Work



Some Candidate Test Objectives

- Effect of number of operations on annoyance
- Efficacy of currently used LAeq based metrics (e.g., DNL, DENL/CNEL)
- Tempo of operations
- Response differences by setting (e.g., near vertiport vs away from vertiport)
- How does the community react to the introduction of a brand new noise source (e.g., PBN)
  - Habituation – what time frame… weeks, months, ?
  - Managing initial introduction vs steady state
  - Possible longitudinal study
- Changes in average background noise level as a function of operations as an alternative metric
- Differences between AAM and other passenger aircraft when considering
  - Sleep disturbance
  - Treatment of noise sensitive sites
  - …
- Operations
  - How to adapt Fly Neighborly to AAM type vehicles
  - Both directivity and temporal changes in noise with diff operations
  - Dispersion (parallel paths) vs serial when considering many vehicles

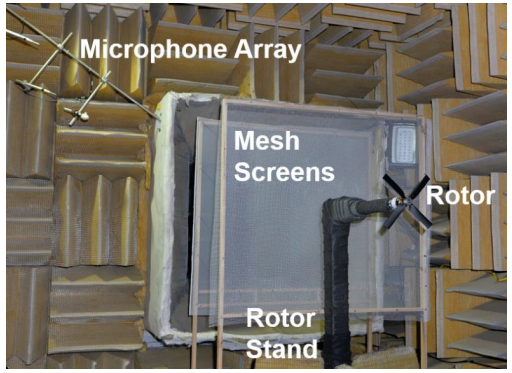


Provide your feedback to larc-unwg@mail.nasa.gov over next 30 days

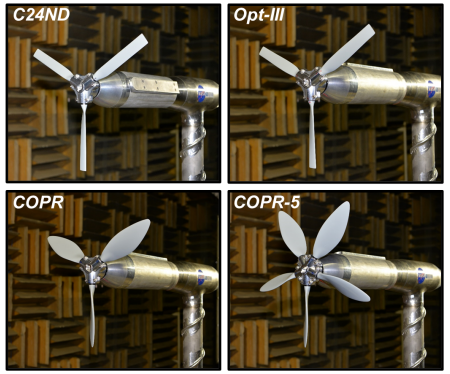
Subgroup 1 – Tools and Technologies

Experimental databases for validation of noise prediction models

- Recent isolated propellers and rotors



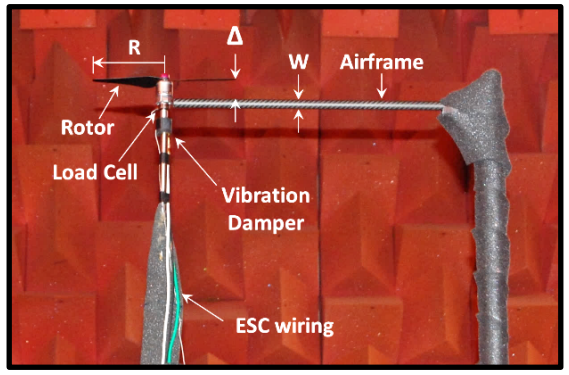
Ideally Twisted Rotor
AIAA-2021-1928



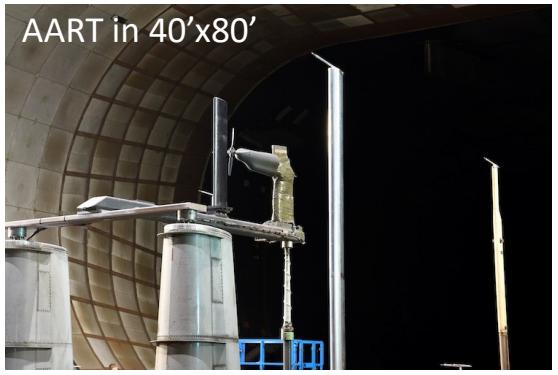
Optimized Proprotor
NASA ATWG Spring 2022

Cruise and High Lift Propellers
AIAA-2018-3448

- Recent installed propellers and rotors



Rotor-Airframe Interaction
73rd AHS Forum 2017



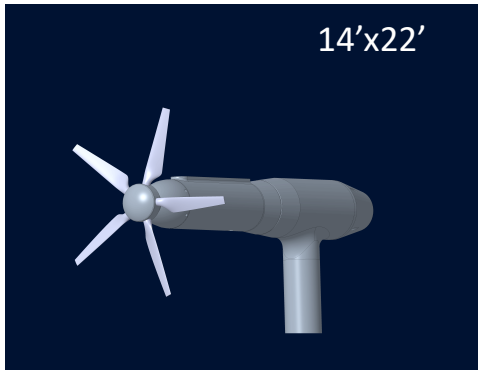
Pusher Configuration
77th VFS Forum 2021

Tractor Configuration
AIAA-2021-0714

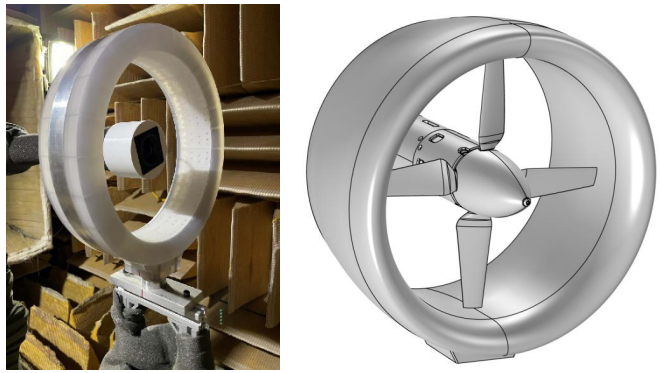
Subgroup 1 – Tools and Technologies

Experimental databases for validation of noise prediction models

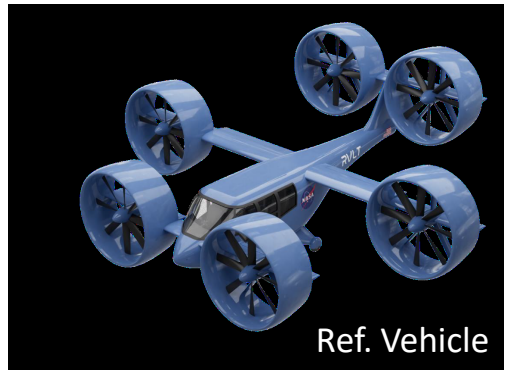
- … more installed propellers, rotors, ducted rotors and tilt



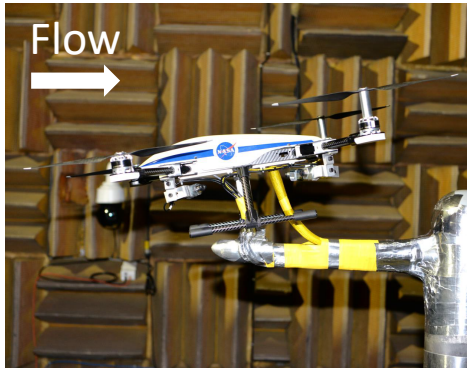
Tilting Vertical Lift Prop Noise
Summer 2022



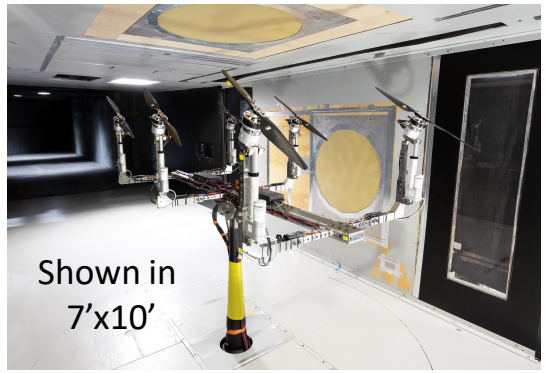
Ducted Speaker & Rotor
NASA ATWG Spring 2022



Tilt Duct Acoustic Test (40’x80’)
FY 23-25



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



Multirotor Test Bed Acoustic Test (40’x80’)
FY 23-25

Tiltwing Acoustic Test (14’x22’)
FY 23-25

Subgroup 2 – Ground and Flight Testing

Develop a research measurement protocol or set of guidelines which can be used to adequately quantify vehicle acoustic emission for the evaluation of community noise impact.

Approach: *Define measurements suitable for the creation of acoustic spheres*

- Ensure sufficient data are gathered to support quantifying community noise impacts
- Activities envisioned to aid all the other SGs: Tools/Technologies, Metrics, Regulation & Policy

- Baseline protocol document has been developed
  - Created topic groups to develop content for each relevant section of the document
  - Define a prioritized list of measurements that would fully define the acoustic environment for the community
  - Working toward defining minimum requirements for acoustic measurements
  - Include rationale for measurement protocols to inform researchers and practitioners about technical impetus for guidance contained in document
  - Living document

Subgroup 2 – Measurement Protocol Outline

Introduction

Measurement Protocol

- Environment:
  - Temperature and Humidity
  - Wind
- Background Noise
- Signal to Noise Ratio Assessment
- Microphone Positions and Orientation
- Ground Impedance
- Terrain and Obstructions
- Time Synchronization
- Signal Processing

Open Items and Discussion Topics

- Array Layout
- Variability
- Additional Considerations within Scope of Subgroup 2

Review current research, existing standards, certification procedures and guidelines. Discuss interrelated items and develop SG consensus on testing topics, including confidence level needs.

Subgroup 3 – Human Response and Metrics

UAM Vehicle Noise Human Response Study

- Motivated by UNWG white paper recommendations to perform laboratory studies to understand the variation of perception of UAM vehicle noise between communities.
- Study Goals:
  - Assemble a wide range of UAM vehicle sounds through cooperation between multiple agencies and organizations for use in human response studies.
  - Create a rich human response database to UAM vehicle noise that can be used for subsequent novel analyses.
  - Provide insights into human response to UAM vehicle noise that would be challenging for any single agency or organization to acquire.
- Study will utilize remote psychoacoustic testing capability

UAM Vehicle Noise Human Response Study Phases

Feasibility Phase (execution planned for late summer 2022)

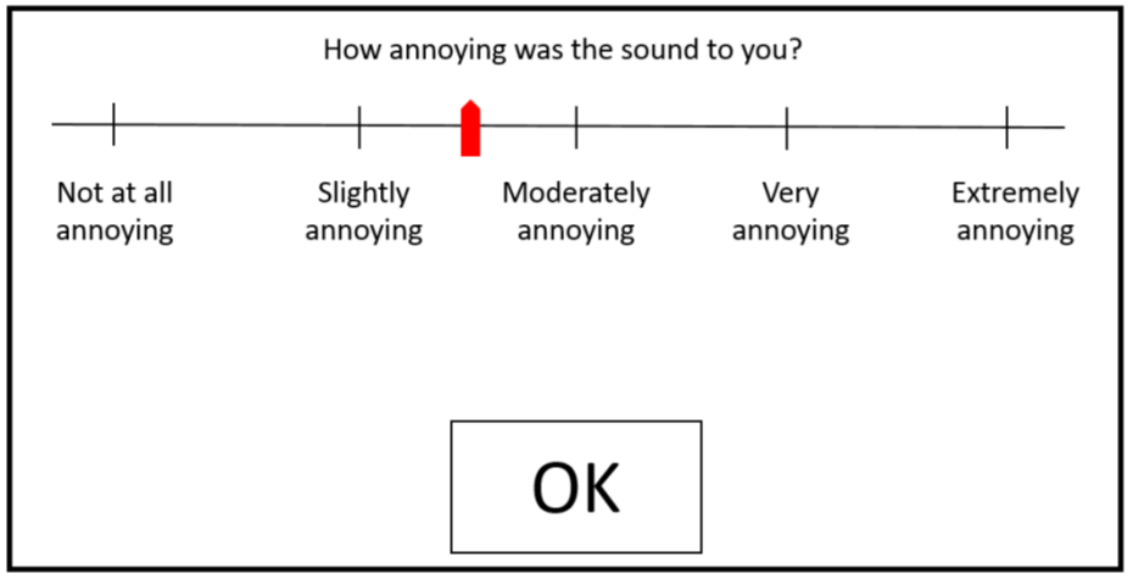
- Objectives:
  1. Identify potential issues with using remote test platform before the Implementation Phase.
  2. Compare results with previous in-person test.
  3. Determine if providing a verbal setting/location context produces annoyance response change.
  4. Rank sounds by their annoyance response.
  5. Compare responses from different geographic locations.

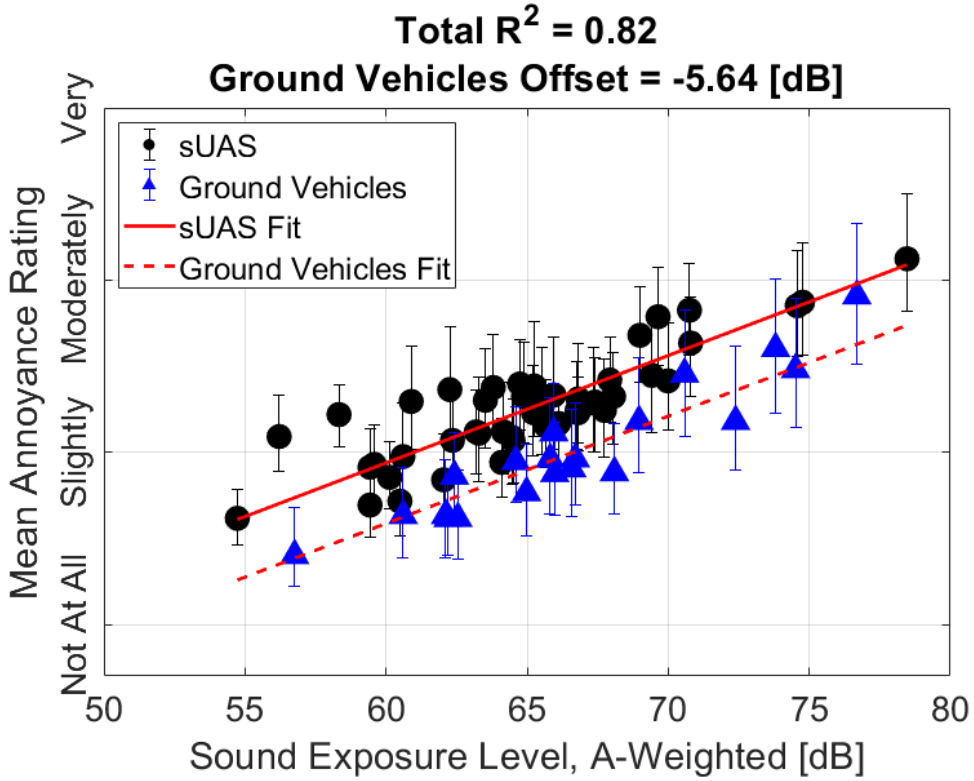
Implementation Phase: UAM Vehicle Noise Perception

- Human response to UAM vehicle noise in different urban soundscapes

Feasibility Test Stimuli

Feasibility Test will compare responses to sUAS and ground vehicle sounds with previous in-person responses[†] to same stimuli





[†] Christian, Andrew W. / Cabell, Randolph. "Initial Investigation into the Psychoacoustic Properties of Small Unmanned Aerial System Noise," *AIAA AVIATION Forum*, Paper 4051, June 5-9, Denver, CO, USA, 2017.

Feasibility Test Setting/Location Context

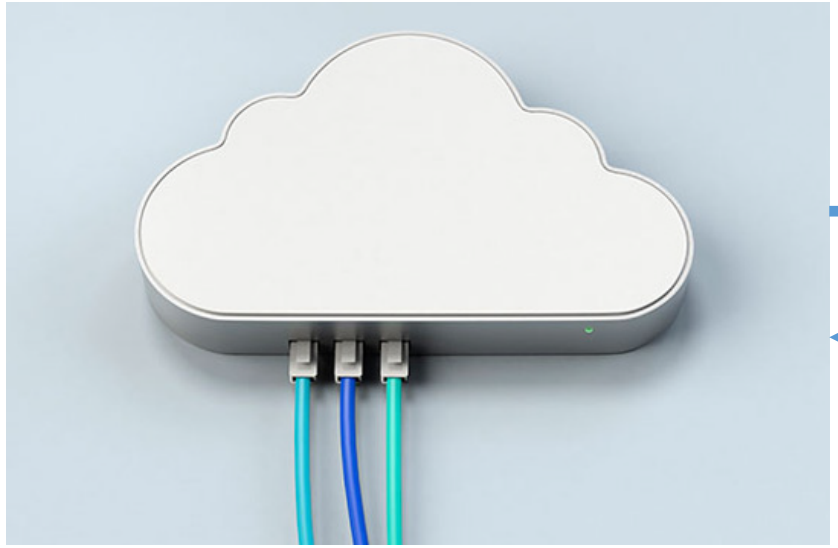
- ICBEN[†] recommendation for community noise testing provides context:
  - "Thinking about the last (. .12 months or so. .), when you are here at home, how much does noise from (. .noise source…) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?"
- Test subjects divided into two groups, with the following question being asked to test subjects after each sound stimulus:
  - For test subjects in no-context group: *How annoying was the sound to you?*
  - For test subjects in context group: *Imagine hearing this sound several times each day while outdoors and near your home, how annoying would this sound be to you?*

[†] Fields, J. M., et al., "Standardized General-purpose Noise Reaction Questions for Community Noise Surveys: Research and a Recommendation," *JSV*, V242 (4), 2001.

Remote Psychoacoustic Testing Platform

- Test platform will require test subjects to use their own computers and headphones.

NASA Approved Cloud Service



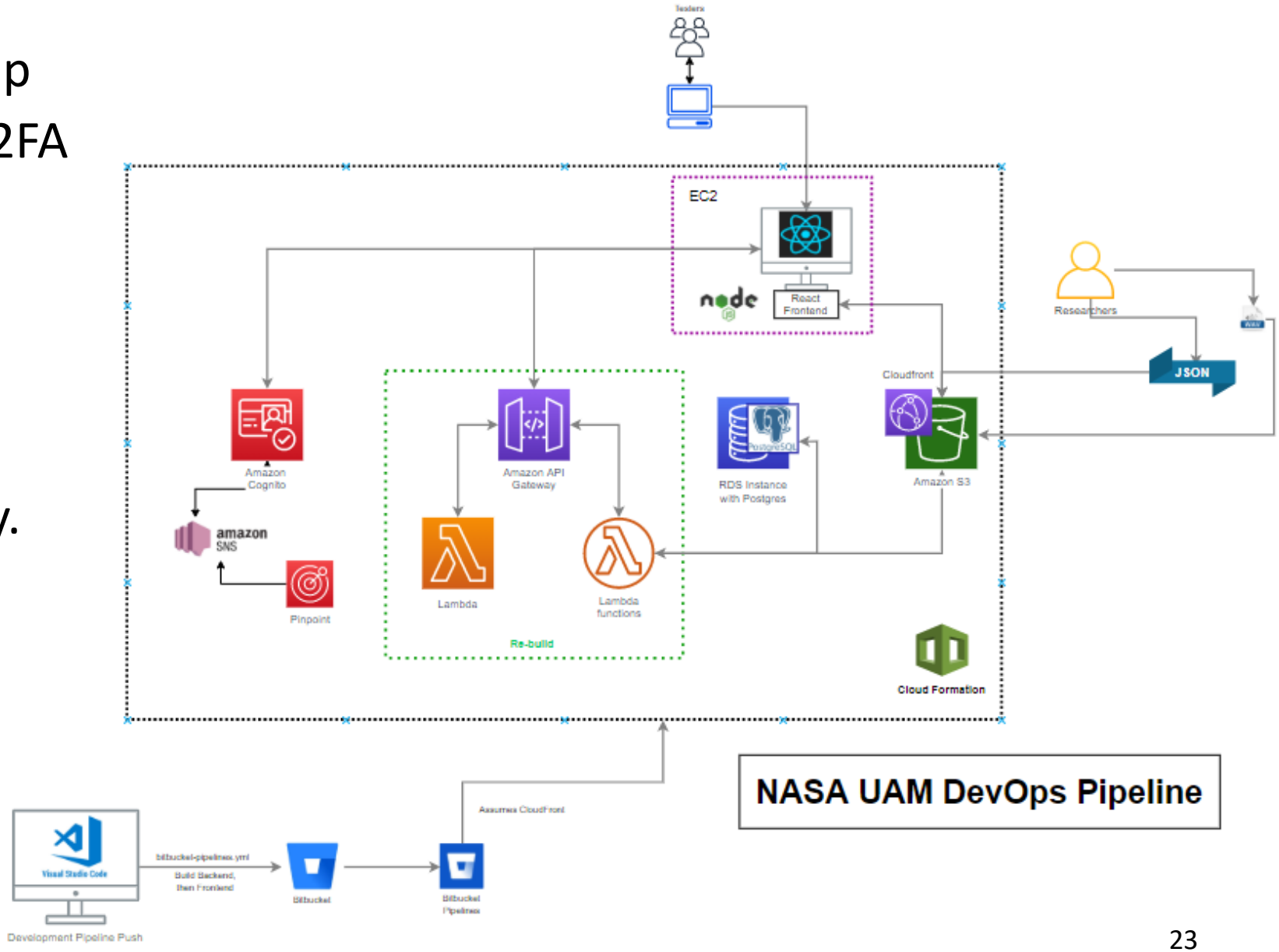
- Feasibility Test application
- Test stimuli, different order for each test subject

Test Subject Computers

- Annoyance response to each sound
- Computer and headphone system used if test subject chooses to provide this information
- Answers to post-test survey questions

Some Remote Test Platform Attributes

- Developed for NASA by Arup
- Login with AWS Cognito & 2FA
- Amazon S3 configured for streaming playback with Cognito token check for access.
- S3 blocks browser from caching any wav files locally.
- Audio streaming quality verified through testing.
- A subjective calibration procedure used to set gain.



Feasibility Test Subject Recruitment and Administration

- Performed by HMMH and Westat with IRB approval
- Screen and recruit potential subjects
  - 80 test subjects – 40 w/ & 40 w/o context
  - Geographic distribution within US - TBD
  - UNWG participants to assist with outreach
- Test subjects shall
  - be naïve listeners with no significant hearing loss (self-reported)
  - use over-the-ear headphones
  - have a quiet listening space with no distractions
  - not be exposed to loud noise one day prior to test
  - have a stable internet connection

Feasibility Test Timeline

May

Request test subject recruitment help from UNWG

Submit Paperwork Reduction Act Clearance Approval Request

June

Begin test subject recruitment

July

Conduct Pilot Test by this time (**UNWG participants can be pilot test subjects!**)

August

Complete pilot test review

Prepare for main test

September

Conduct main Feasibility Test

Continue Implementation Phase planning

Subgroup 4 – Regulation and Policy

Focus on awareness of –

- Noise Standard Developments
  - SAE A-21 ARP 4721 Update and Noise Sphere Guidance Document
  - Joint ISO/TC43/SC1 & ISO/TC20/SC16 Working Group – Noise measurements for UAS
- Regulatory Developments
  - FAA NPRM on Matternet M2 Drone Noise Certification Standards
  - FAA UAS Beyond Visual Line-of-Sight Operations Aviation Rulemaking Committee
  - EASA Regulations (EU) 2019/947 and (EU) 2019/945 Easy Access Rules for UAS
  - ICAO CAEP WG1 (Task N.06 – Emerging Technology Aircraft Noise)
- Policy and Guidance Developments
  - FAA Engineering Brief of Vertiport Design for VTOL operations
  - Recent Environmental Assessments of Drone Package Delivery Operations
  - EASA Guidelines for Design Verification of Drones Operated in the ‘Specific’ Category
- Community Engagement Developments
  - Recent congressional hearings
  - TRB ACRP Report 237 – Primer and Framework for Considering an Airport Noise and Operations Monitoring System

Summary

- There is lots of interesting work is going on in each the four UNWG subgroups.
  - The work supports the UNWG goal of reducing or eliminating the barriers associated with UAM aircraft community noise.
  - Ongoing work is also helping to support UAM community noise testing at end of the decade.

- Please consider getting involved in the UNWG if you are not already doing so.
  - Subgroup meetings are monthly.
  - Next full hybrid UNWG meeting is October 20 at the NASA Glenn Research Center.

UNWG Points of Contact

WG Chairs: Stephen Rizzi (NASA Langley) stephen.a.rizzi@nasa.gov
Brenda Henderson (NASA Glenn) brenda.s.henderson@nasa.gov

Subgroup 1: Tools and Technologies

Lead(s): Doug Boyd (NASA Langley)
d.d.boyd@nasa.gov
Len Lopes (NASA Langley)
leonard.v.lopes@nasa.gov
Co-Lead(s): Jeremy Bain (Joby)
jeremy.bain@jobyaviation.com

Subgroup 2: Ground and Flight Testing

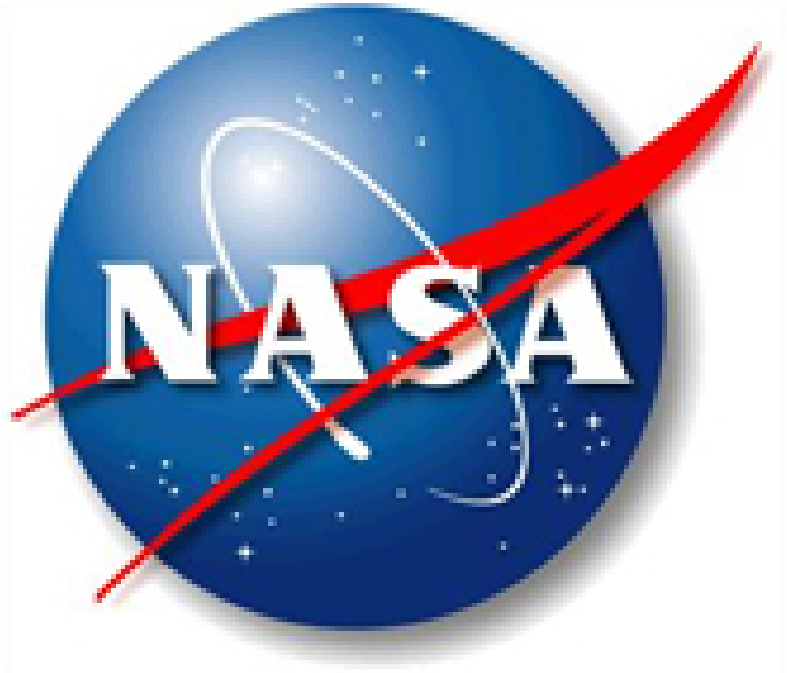
Lead(s): Kyle Pascioni (NASA Langley)
kyle.a.pascioni@nasa.gov
Devin Boyle (NASA Glenn)
devin.k.boyle@nasa.gov
Co-Lead(s): Juliet Page (Blue Ridge Research)
juliet.page@blueridgeresearch.com

Subgroup 3: Human Response and Metrics

Lead(s): Siddhartha Krishnamurthy (NASA Langley)
siddhartha.krishnamurthy@nasa.gov
Co-Lead(s): Yahia Ismail (Supernal)
Yahia.Ismail@supernal.aero

Subgroup 4: Regulation and Policy

Lead(s): Bill He (FAA Office of Environment & Energy)
hua.he@faa.gov
Co-Lead(s): Royce Snider (Bell Flight)
rsnider@bellflight.com



Merci!