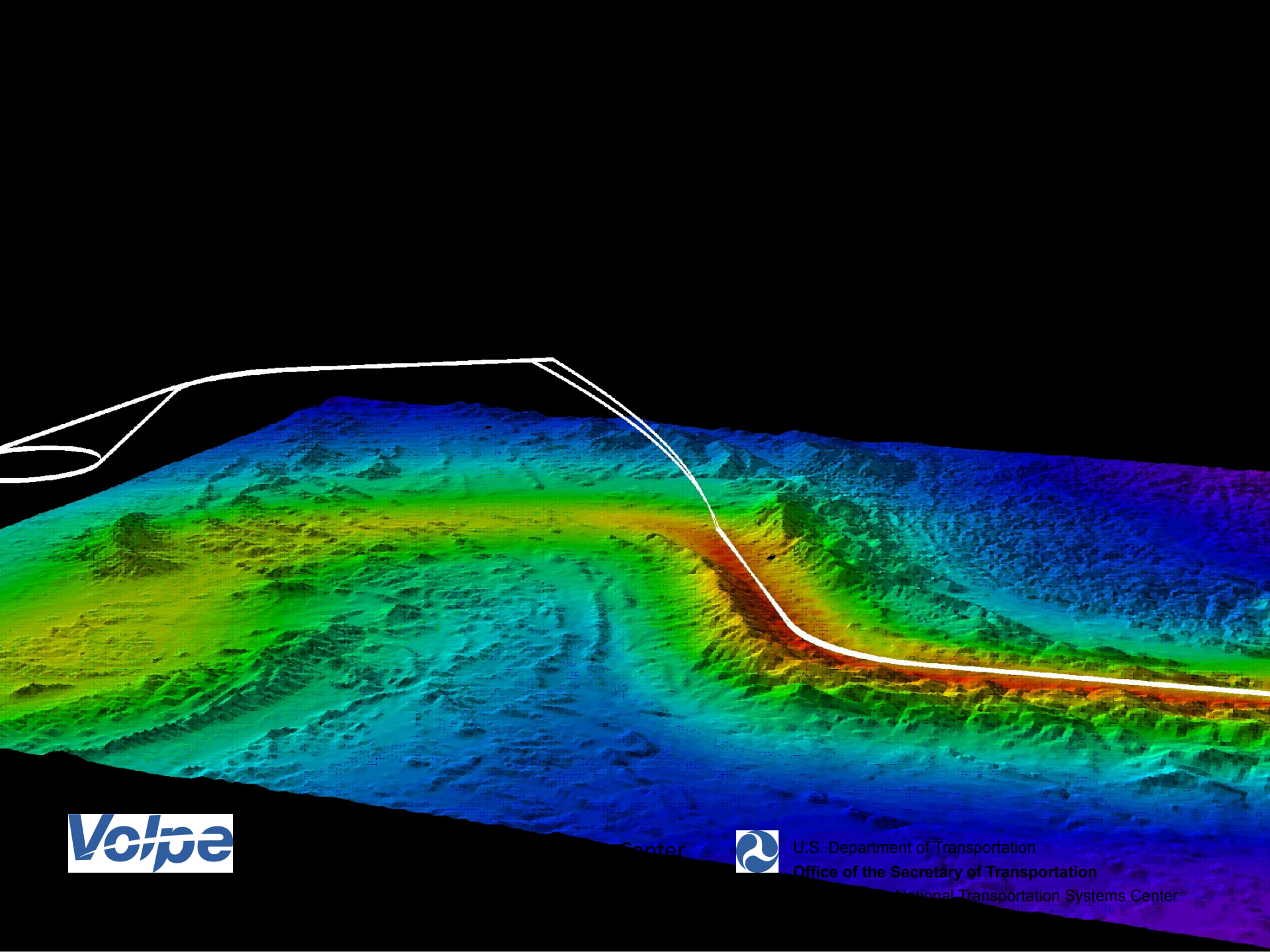


Volpe

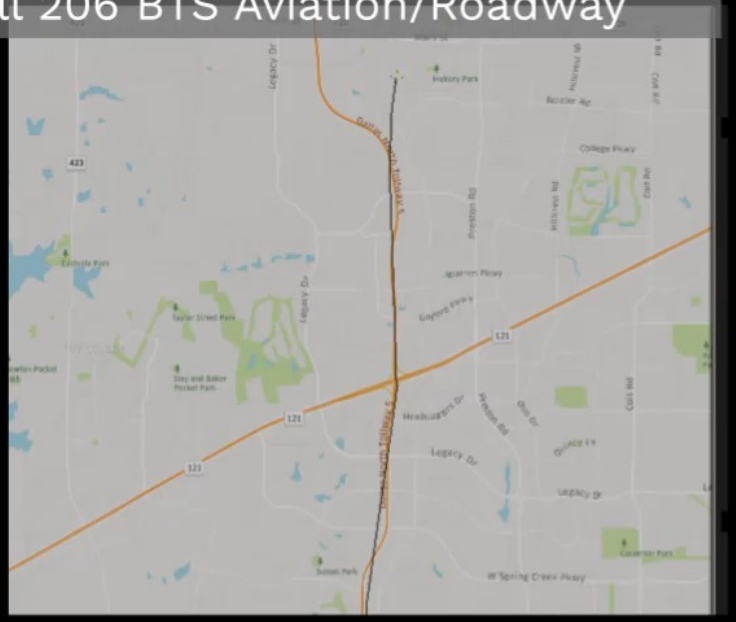
U.S. Department of Transportation
**Office of the Secretary of Transportation**
National Transportation Systems Center

# Outline

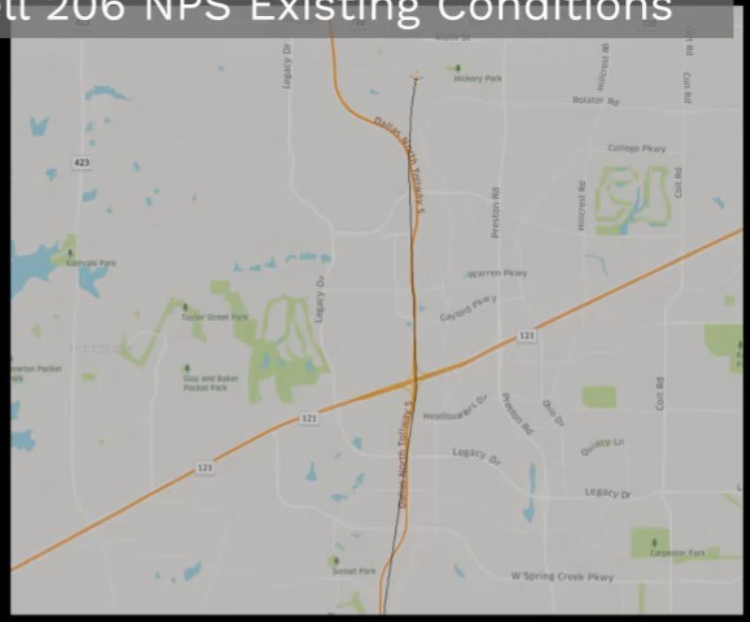
- Acoustic Animation
  - Modeled Vehicle Characteristics
  - Acoustic Animation Properties
- Background Noise
- Acoustic Simulation Technology
- Source Noise Modeling
  - Acoustic Repropagation Technique
- Multimodal Transportation Modeling
- Acoustic Modeling To-Do List
- Looking Towards the Future
  - Vehicle Technologies to Foster Acceptability

*The U.S. Department of Transportation does not implicitly endorse the Uber Elevate Project. Research conducted by the Volpe Center is to gain better insight of potential future Urban VTOL transportation modes.*

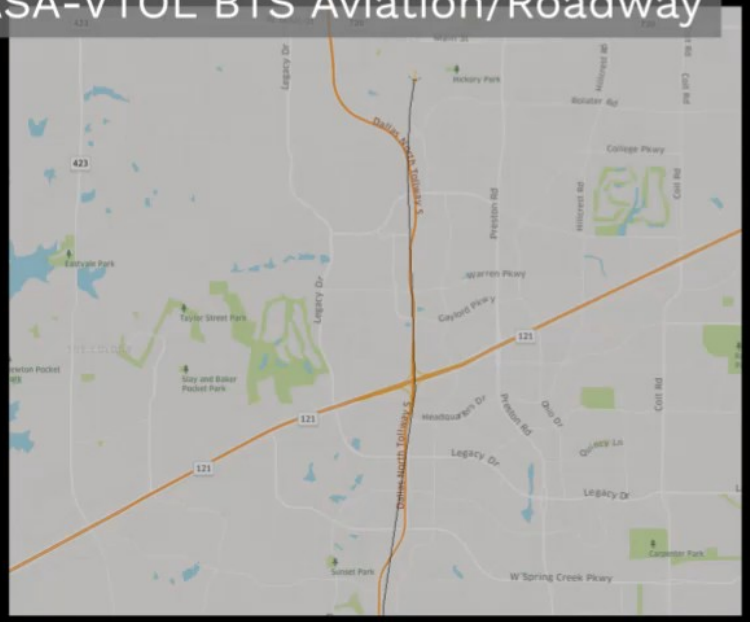
Bell 206 BTS Aviation/Roadway



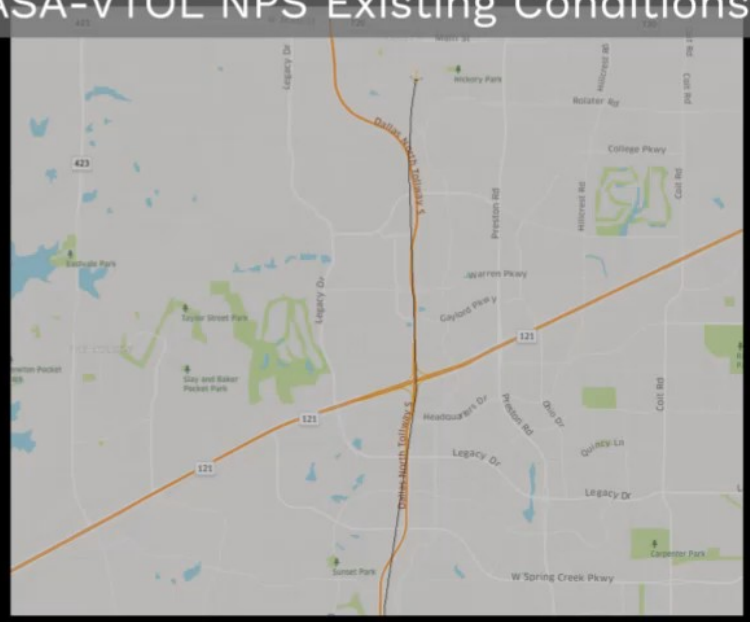

Bell 206 NPS Existing Conditions




NASA-VTOL BTS Aviation/Roadway

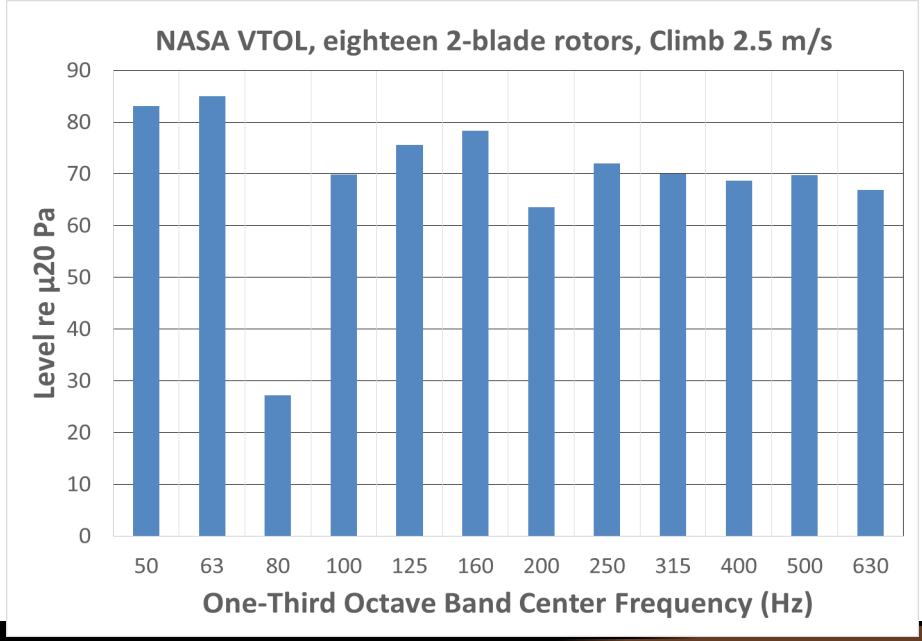



NASA-VTOL NPS Existing Conditions




# Modeled Vehicles

- Bell 206 (TH-57), conventional helicopter
  - Empirical flight test data for multiple operating states
  - Flight condition data: 40-120 kts, -14 to 13o FPA, -1700 to 1250 ft/min ROC
- NASA-VTOL notional vehicle with eighteen 2-blade rotors
  - Single Spectrum, 10 Harmonics 50Hz-630Hz, Climb 2.5 m/s
  - Rotor blade only
  - ANOPP PAS modeling
  - Reference 30m distance
  - Extended to 10Hz & 10kHz
  - Modeled as an Omnidirectional Source




**Caveat!** Single spectrum used for all modes of operation. For modeling illustrative purposes only!

Source: NASA

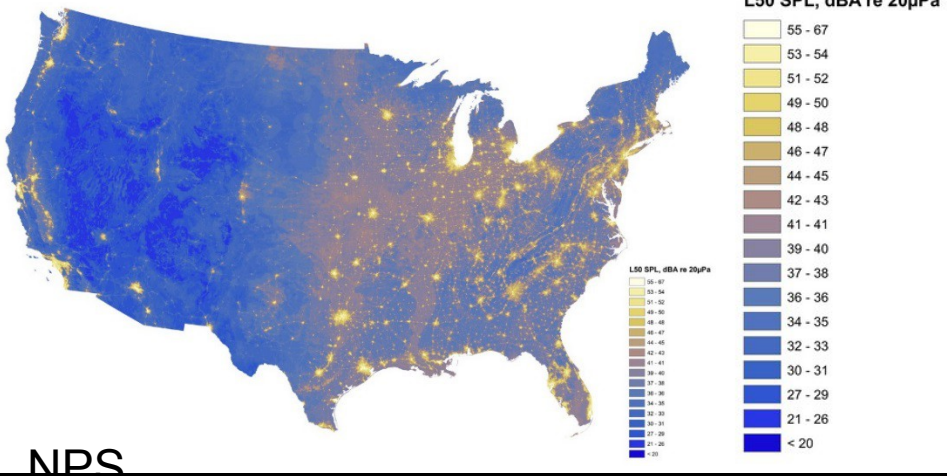
# Acoustic Animation Properties

- Background Data:
  - BTS – Roadway noise only
  - NPS – Existing Conditions, includes airports & roadways
- Flight profiles adapted for each vehicle
  - Helicopter: 110kt cruising speed at 800 ft AGL
  - VTOL: 60kt cruising speed at 800 ft AGL
- Results
  - Display propagated vehicle acoustics + background levels
  - Straight ray propagation
  - Flat, uniform acoustically soft ground

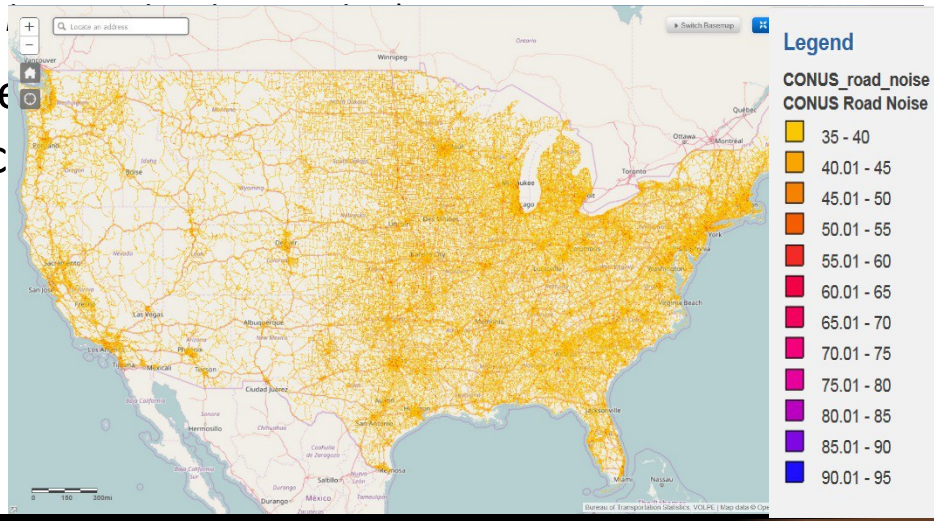
Acoustic Modeling Tools provide the flexibility to design vehicles while considering acoustic footprints, population impacts and operations

# Background Noise Data

- U.S. Bureau of Transportation Statistics (BTS) https://www.rita.dot.gov/bts/press_releases/bts015_17
  - U.S. Roadway Noise & Airport Noise and combined databases
  - A-weighted 24-hour LAEQ (dBA) *(24-hour equivalent sound level (LAEQ) is (logarithmic) average of sound energy over a 24 hour period)*
- U.S. National Park Service (NPS) https://www.nps.gov/subjects/sound/soundmap.htm
  - Existing Conditions (includes airports and all anthropogenic sounds)
  - Natural Conditions (e.g. wind, water, animals, etc. but no human activity)
  - L50 sound pressure level, dBA re 20µPa *(L50 is sound pressure level exceeded half of the time;*
    *conditions are for a typical summer daytime*




NPS




BTS

# Acoustic Simulation Technology

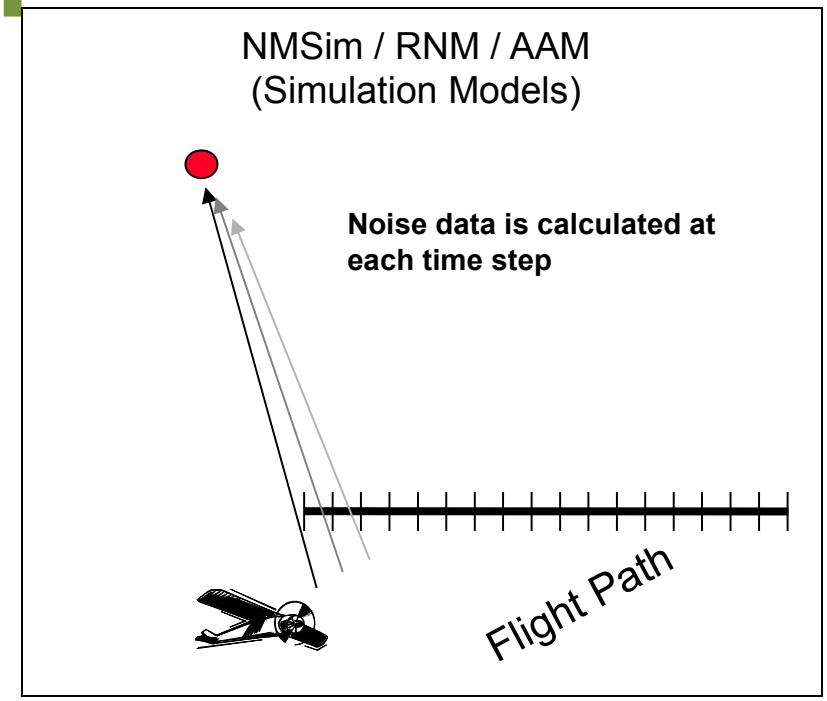
- Advanced Acoustic Model (AAM)
  - AAM V2 is available from NASA Langley (Michael Doty michael.j.doty@nasa.gov)
  - Future versions from Volpe (U.S. DOT) (Juliet Page Juliet.Page@dot.gov)
- Long history of development & validation
  - 1994 - NMSim – Bourne out of a need to understand Narvik measurement data
  - 1996 - Rotorcraft Noise Model Conception (NASA sponsored for XV-15 Tiltotor research)
    - Compatible with ANOPP / WOPWOP, Empirical or Analytical Noise Sources
  - 1998 – 2007 – RNM development (NASA/DOD development)
    - Adopted by DOD as standard NEPA model for Tiltrotors / Rotorcraft, part of NOISEMAP suite
    - 1/3 Octave Band, Narrow Band, Pure tone & phase source modeling
    - Geometrical Theory of Diffraction (Rasmussen) & Curved ray with terrain (Huber/Plotkin)

Reference: Page, et al., "Advanced Acoustic Model Technical Reference and User Manual", SERDP WP-1304-TR, 2009.
Early version: https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Noise-and-Emissions/Noise/WP-1304

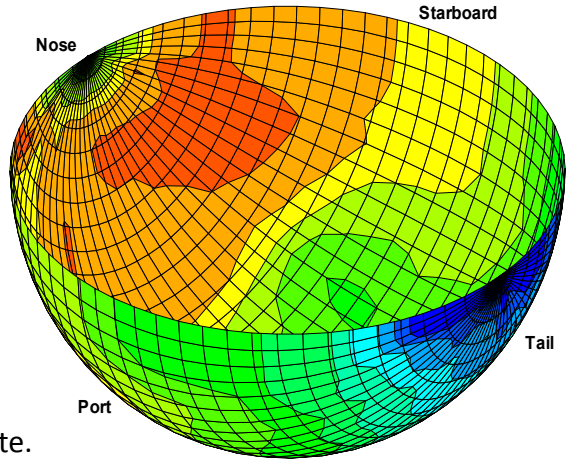
or just **Google "SERDP Advanced Acoustic Model"**

system)

# Time Based Simulation




- Built around point source moving incrementally on track
- Computes noise time history
- Requires 3-D spectral noise sources
- Takes into account:
  - Fixed wing or rotary wing aircraft
  - Source spectrum/directivity
  - Local ground surface
  - Terrain
  - Buildings (shielding)
  - Atmospheric conditions (wind, temp gradients)
- May compute any metric based on spectral time history at receivers

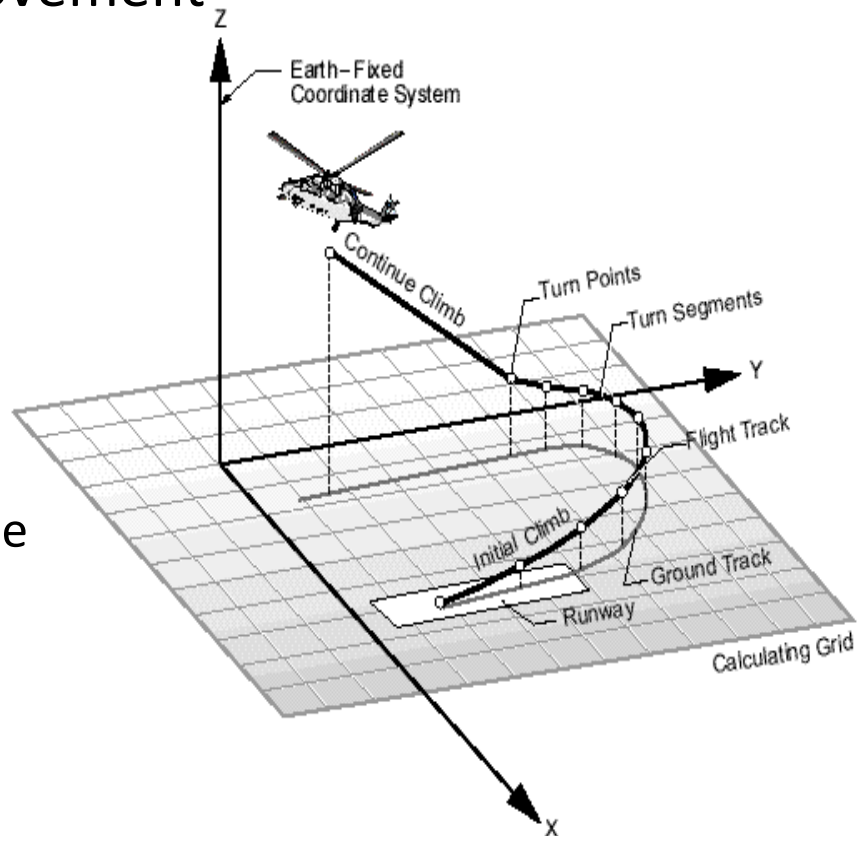



te.

Data in 1/3 OB, NB and/or pure tone & phase formats.
Data may be hemi or full spheres.

# Methodology – Flight Trajectory

- Flight trajectory and vehicle movement defined by the user
  - Vectored Ground Tracks
  - Profiles
  - 3D Integrated Trajectory
  - Vehicle Orientation (6 DOF)
  - Performance physics not modeled
- Flight Operating State incl. Nacelle orientation (tilt rotors)
- Operation Specification
  - Single Events
  - Multiple flights



# Source Noise Modeling

- Empirical Source Characteristics from Flight Measurements
- Propagation Physics: Acoustic Repropagation Technique (ART)
  - Included as part of RNM/AAM distribution, utilizes the same physics modeling
- Wind Tunnel Measurements
- Source data can be Stationary or Moving (AAM can apply Doppler)
- AAM is compatible with ANOPP output
- Source data can be obtained from analytical modeling: PSU-WOPWOP or other computational aeroacoustic tools using Ffowcs-Williams Hawkins or Farassat 1A Formulation

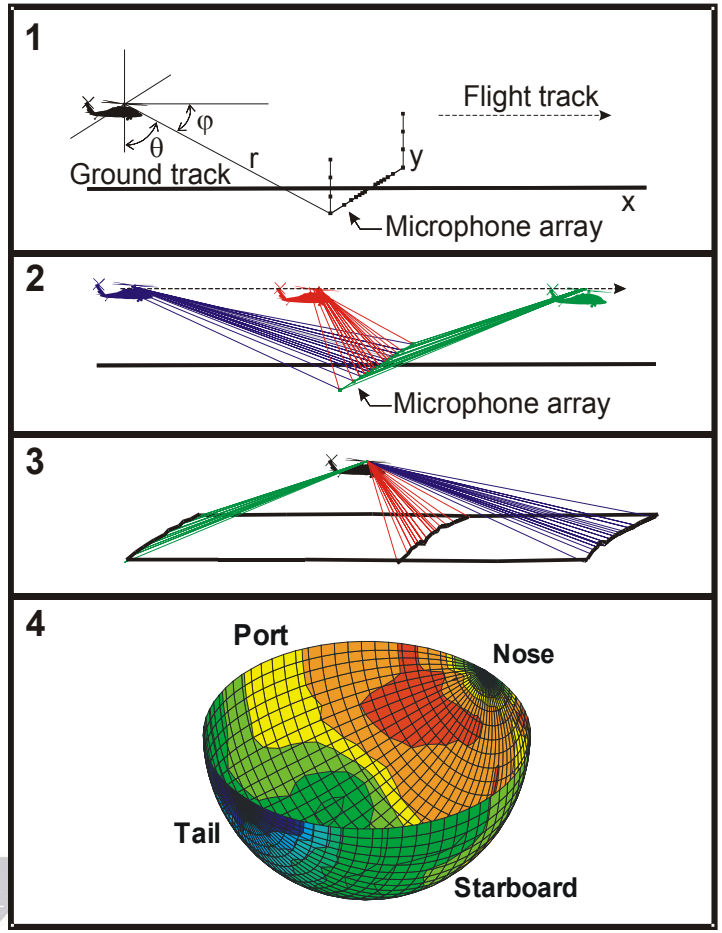
Noise Source Definition:

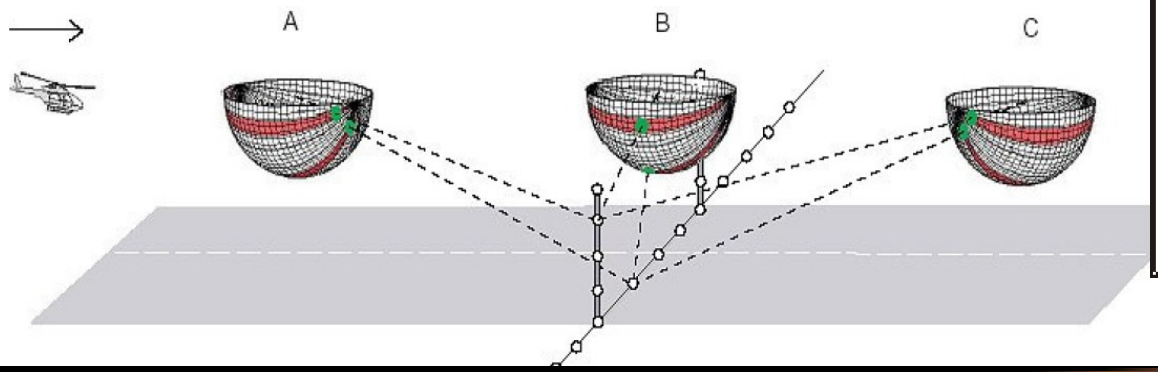
- One-Third OB, NB and/or PureTone/Phase
- One noise sphere per operating state
- Steady or maneuvering states for helos
- NetCDF file format

Wallops NASA-DOT test

# Acoustic Repropagation Technique (ART)

- Used to derive noise spheres from flight measurements
- NASA developing hybrid analytical-empirical techniques for maneuvers
- Array of microphones
- For the last 10+ years for research we only use ground-based microphones to avoid ground effects

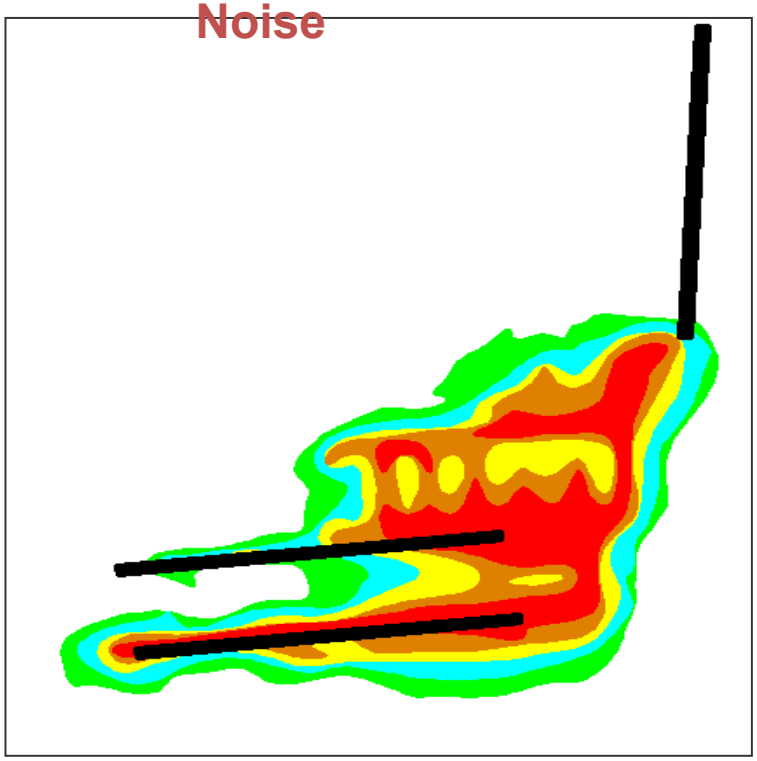


# Multimodal Transportation Modeling

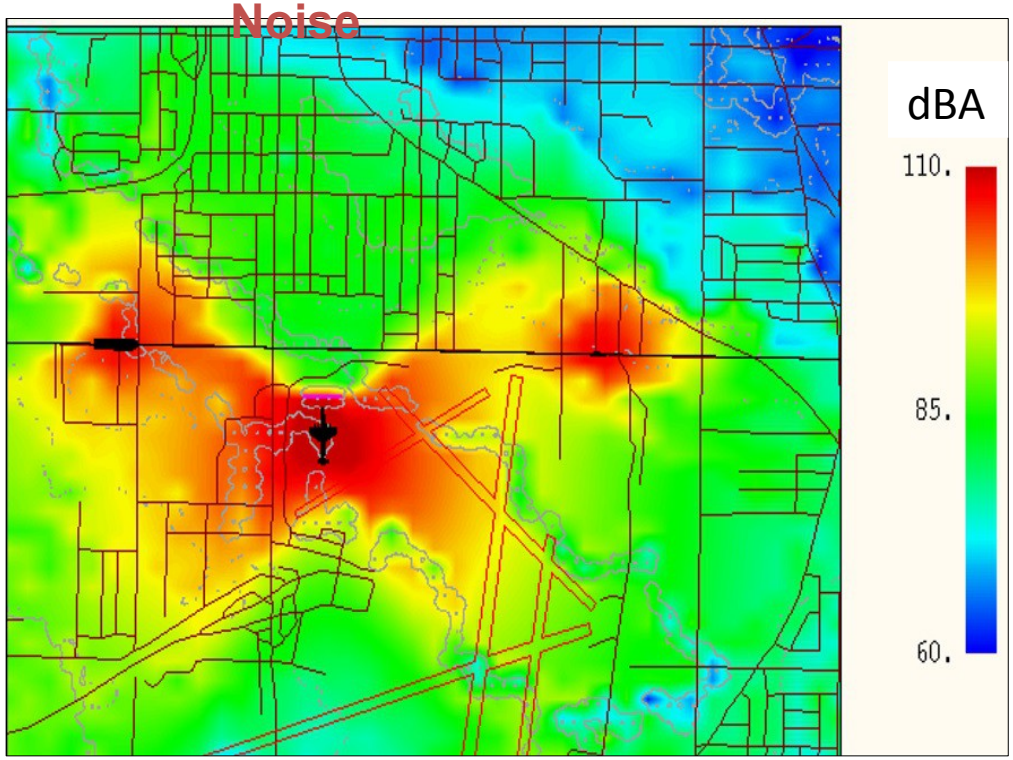
Simulation is ideally suited for assessing complex situations

**Airport Taxiway Noise**



DNL contours, Taxi Operations

**Multimodal Surface Noise**




Screen shot from an acoustic animation.
Engine static test / Semi Truck / Sport bike

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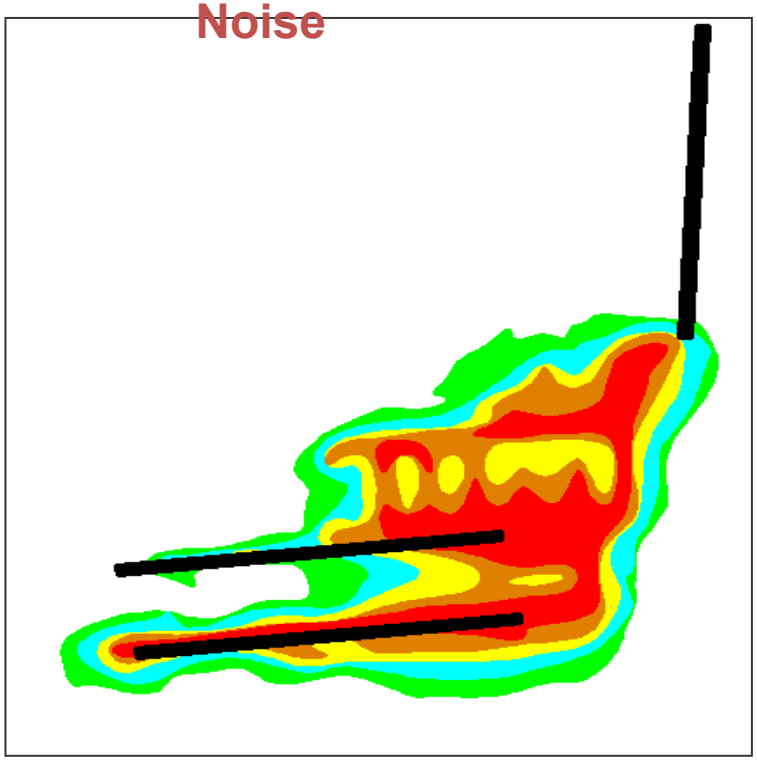

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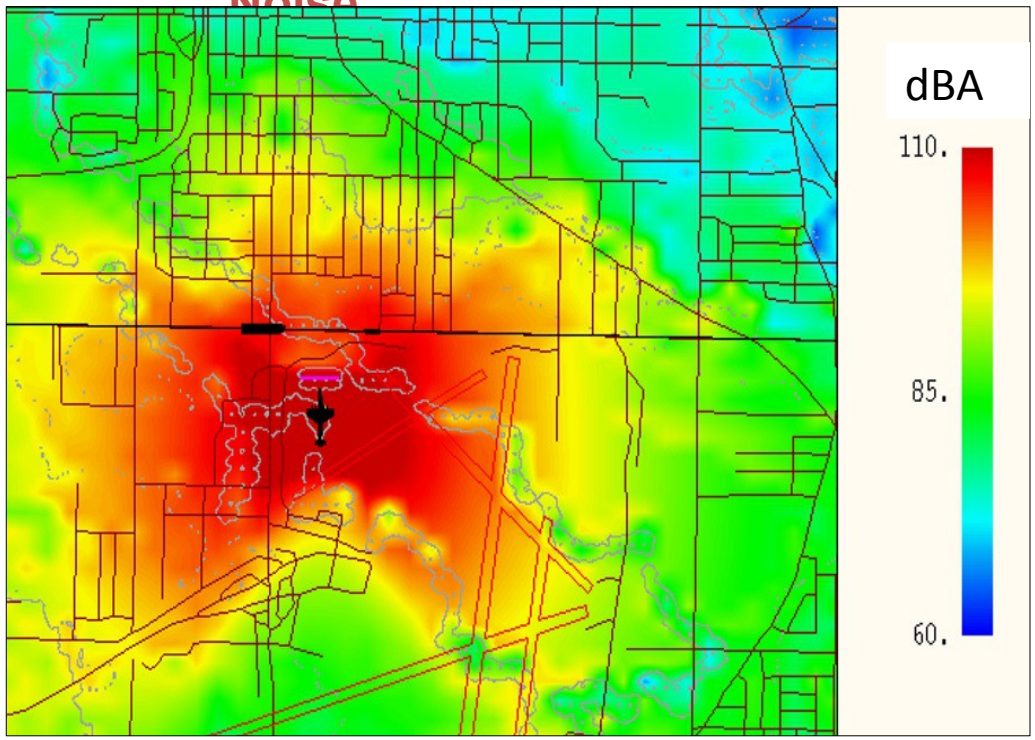


Screen shot from an acoustic animation.
Engine static test / Semi Truck / Sport bike

# Acoustic Modeling To-Do List

- Flexible metric capability needed as psychoacoustic science advances
- Integrate with NASA auralization framework to create "listenable" acoustic animations
- Tighter ANOPP link for fixed wing ve
- Time varying background integratior
- Urban Canyon propagation
- Better building / shielding modeling
  - Acoustic propagation evaluation
  - Physical building model / grid definition
- Acoustic animation software updates
  - Different software platform
  - Higher resolution
  - Vehicle scheduling

# Looking to the Future

We have a solid acoustic foundation from which to analyze unique VTOL designs!

- Many toolsets are available for acoustic analysis
  - Multiple hooks to source modeling tools including computational aeroacoustics ← Need to get these in the hands of vehicle & Ops designers!
  - Capability for singe and multiple event analysis
- Vehicle acoustic technologies to foster acceptability
  - Onboard noise abatement flight ops controls
  - Acoustic self-awareness vehicle technologies (display, route optimizer)
  - Networked route enabled metric non-exceedance technology (noise cost)