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# Comparison of two community noise models applied to a NASA urban air mobility concept vehicle

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# Outline

- Concept Vehicle, Trajectory and Operating States
- Source Noise Data Generation
- AEDT Modeling
- Advanced Acoustic Modeling
- Results
- Concluding Remarks
- Acknowledgements

# Analysis Goals

- Demonstrate modeling tool interoperability
- Assess model applicability, capabilities and limitations
  - Integrated (Aviation Environmental Design Tool, AEDT)
  - Simulation (Advanced Acoustic Model, AAM)
- Utilizing the same source noise model assess:
  - Source noise directivity effects
  - Propagation modeling fidelity differences
  - Consider individual receptors and grid area
  - Demonstrate AAM advanced techniques: acoustic visualization and time varying loudness metric

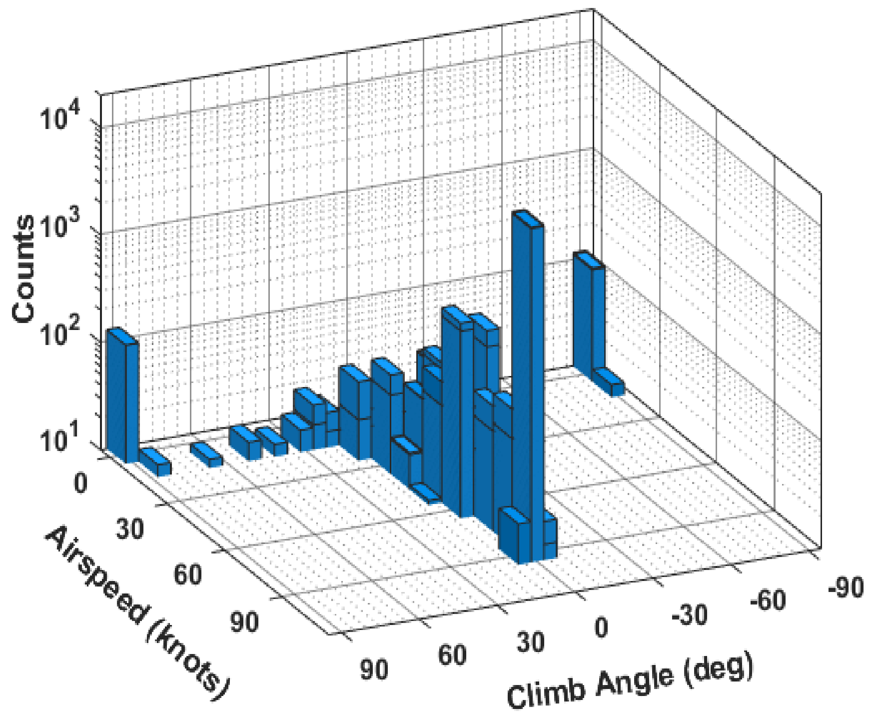
# NASA Quadrotor Reference Vehicle*

- 6 passenger payload
- All-electric variant
- 3-bladed rotors
- Gross weight = 6469 lbs
- $V_{max}$ = 109 kts (KTAS)
- Operational limit: 85% $V_{max}$

* *Silva et al., "VTOL urban air mobility concept vehicles for technology development," AIAA Aviation Forum, AIAA-2018-3847, 2018.*

# Determination of Operating States

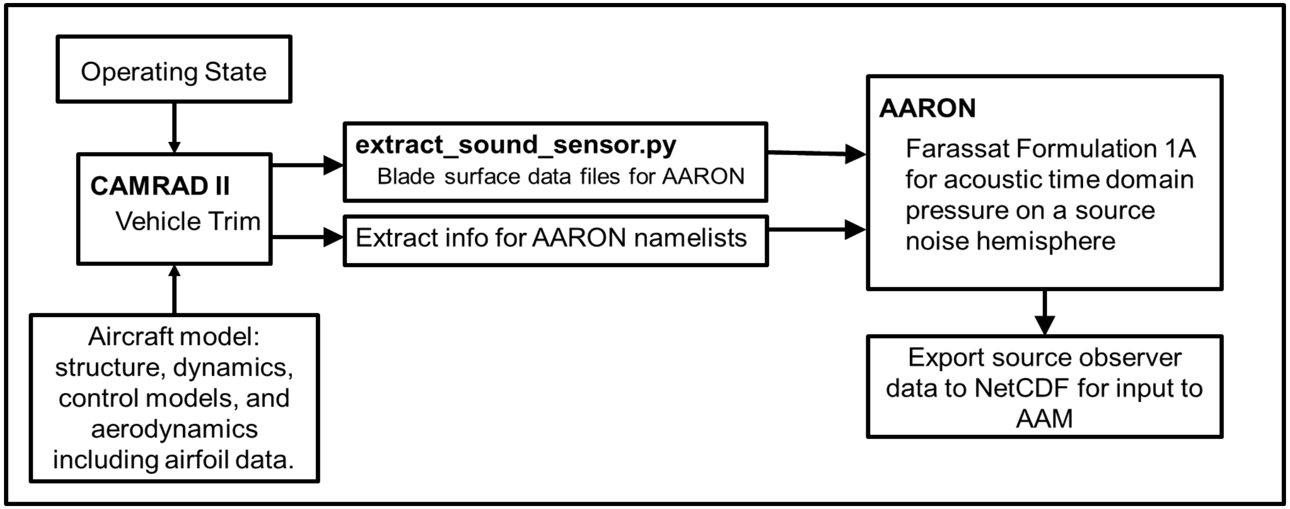
- Examined 16 notional routes* in Dallas Ft-Worth, TX
- Evaluated number of times (counts) each state was used
- Condensation scheme identified 42 unique operating states
- Pairs of airspeed (kts) and climb angle (deg)




* Rizzi, S.A. and Rafaelof, M., "Community noise assessment of urban air mobility vehicle operations using the FAA Aviation Environmental Design Tool," InterNoise 2021, Virtual Meeting, 2021.

# AAM Source Noise Data Generation

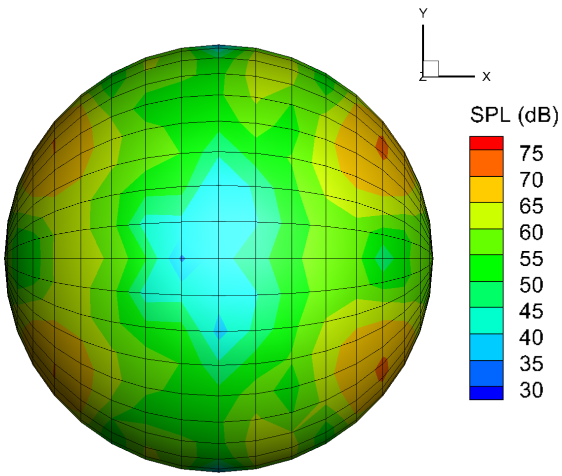
- Determine trimmed condition, blade loading and motions for each operating state using CAMRAD II
  - Constant RPM rotors: 20 Hz BPF
  - Collective pitch control
  - 6-DOF trim (collective controlled pairs + pitch + roll)
- Utilize ANOPP2 AARON tool (F1A)
  - Periodic loading and thickness noise (no broadband noise)
  - Quasistatic operating conditions
- Spectral data fixed radius : 1/3 & 1/12 OB spheres



# Source Noise Data Spheres for AAM

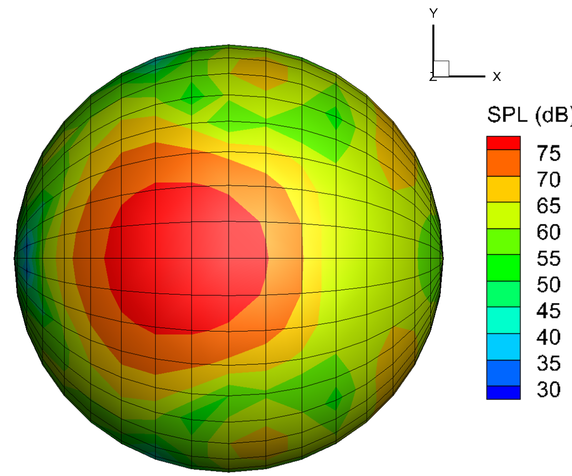
Low speed ascent

20 Hz OTOB



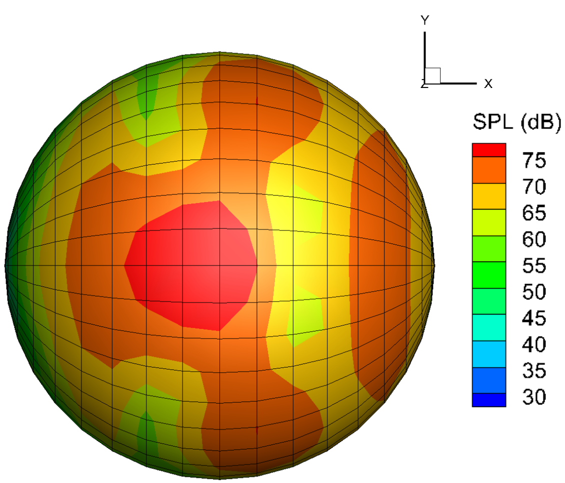

High speed descent

20 Hz OTOB



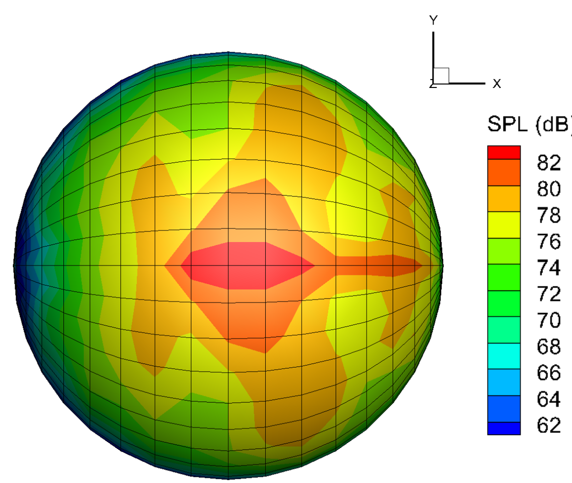

High Speed cruise

20 Hz OTOB




High speed cruise

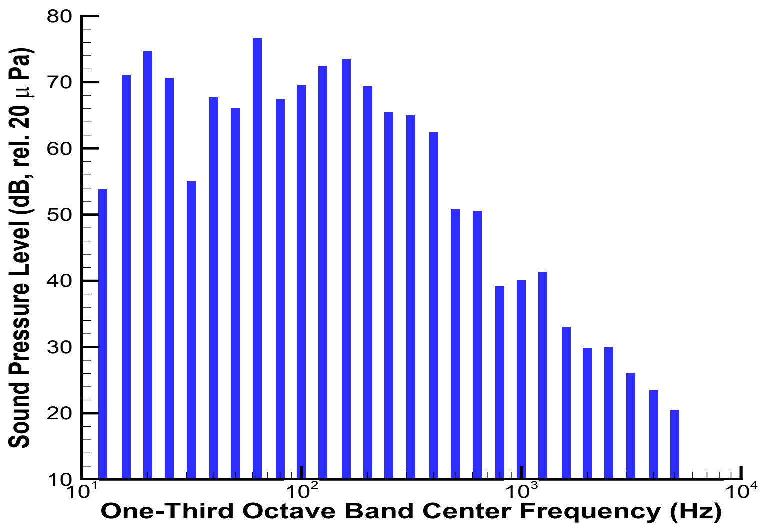
OASPL



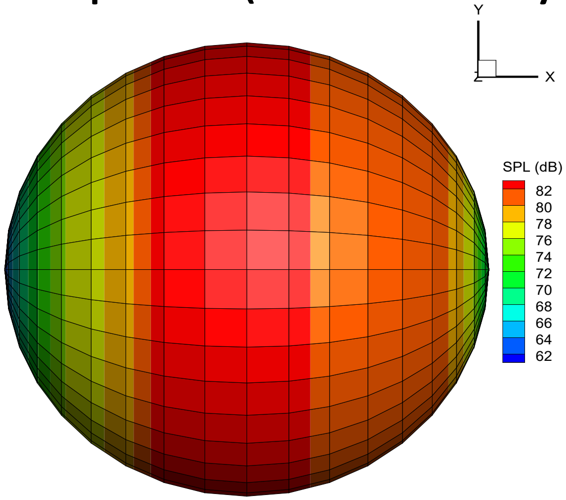

Top View. Nose is pointing to the right

# AAM Modeling

- Three versions of spheres developed
  - Omnidirectional – spectra at point of LmaxA (cal +.33 dB)
  - Axisymmetric – undertrack spectral directivity (cal +.21 dB)
  - Full 3D based on ANOPP2/AARON modeling (cal +.21 dB)
- Spheres 'calibrated': 90 kt level flight, 1000 ft AGL
  - Spheres adjusted (uniform correction) to match AEDT LmaxA NPD data
  - AEDT NPDs and AAM calibration runs use a 4 Ft AGL receiver
- Analysis specified exact sphere for each point (NCSPEC keyword)




Omni-directional Spectrum

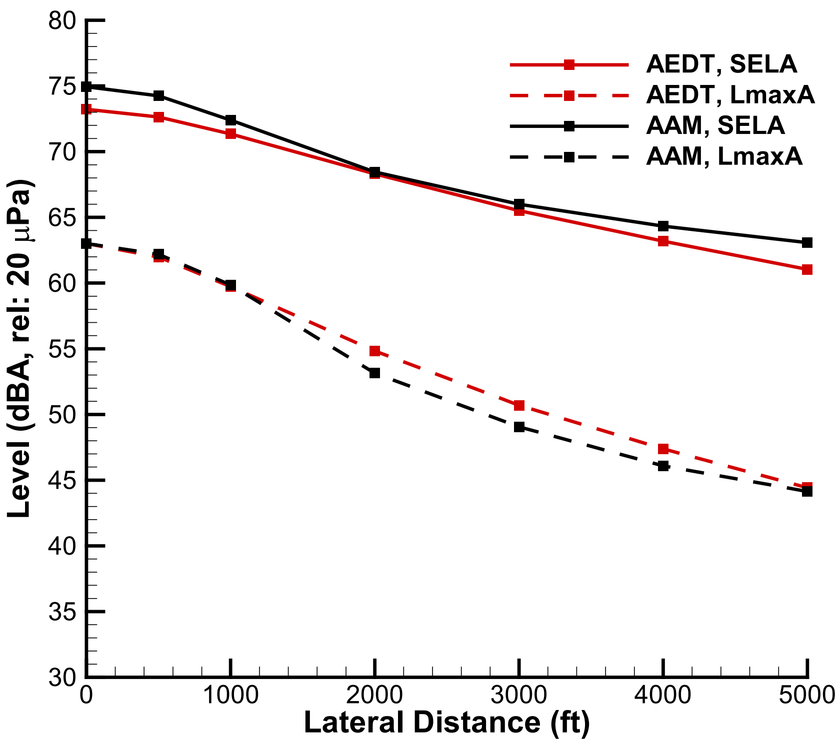



Axisymmetric sphere (90 kt level)

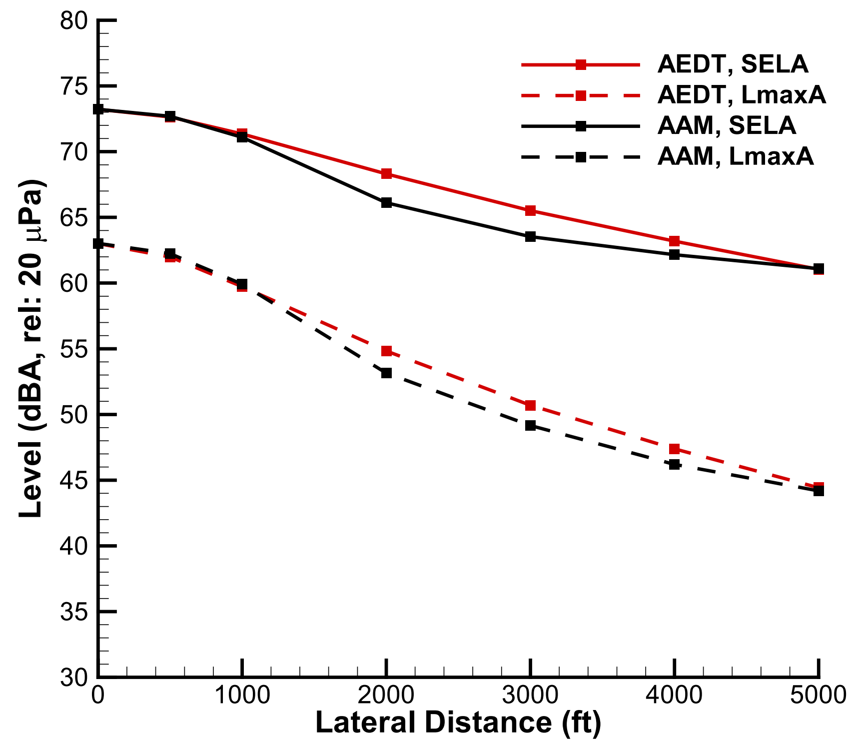
Top View. Nose is pointing to the right

# Lateral Directivity Results: Omni & Axi

- SEL(dBA) and $L_{max}$(dBA) at lateral POIs
- Only slight differences laterally between AEDT and AAM



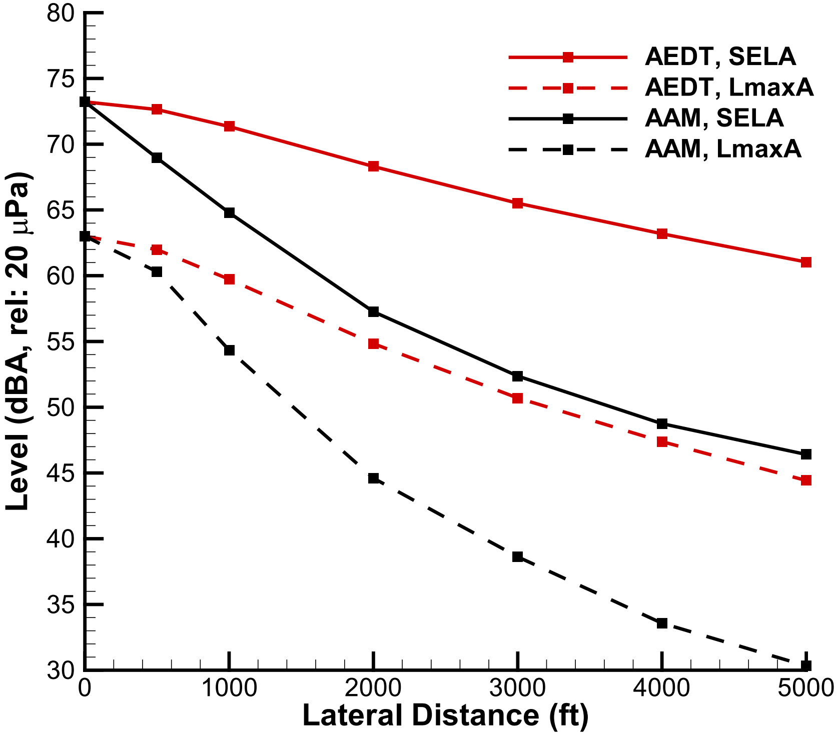

Omnidirectional Sphere vs. AEDT



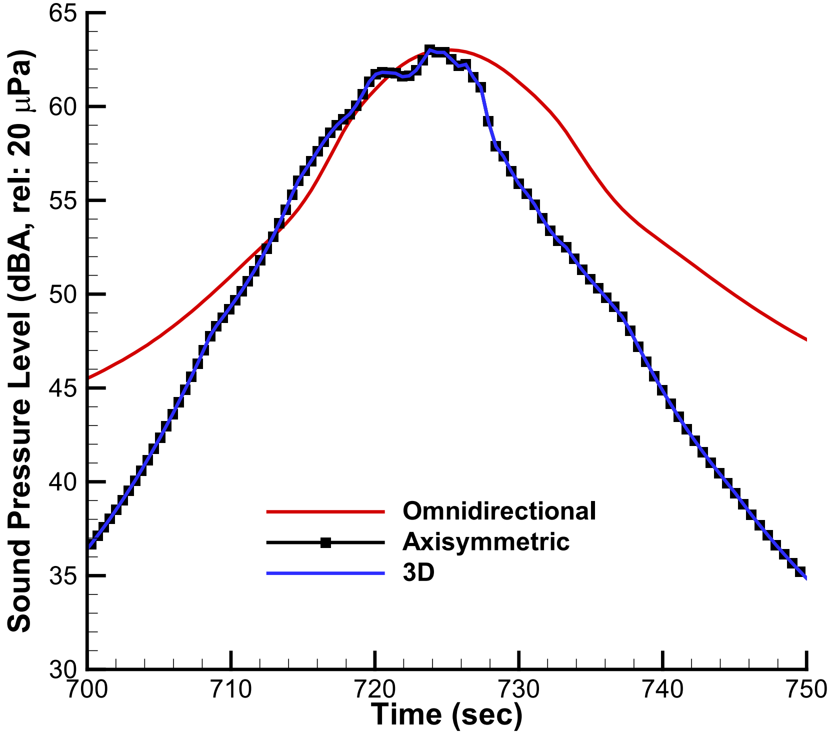

Axisymmetric Sphere vs. AEDT

# Lateral Directivity Results: 3D sphere

- SEL(dBA) and $L_{max}$(dBA) at lateral POIs
- Significant differences between AAM and AEDT laterally
- Time history, undertrack (SPL, dBA): fore/aft directivity apparent



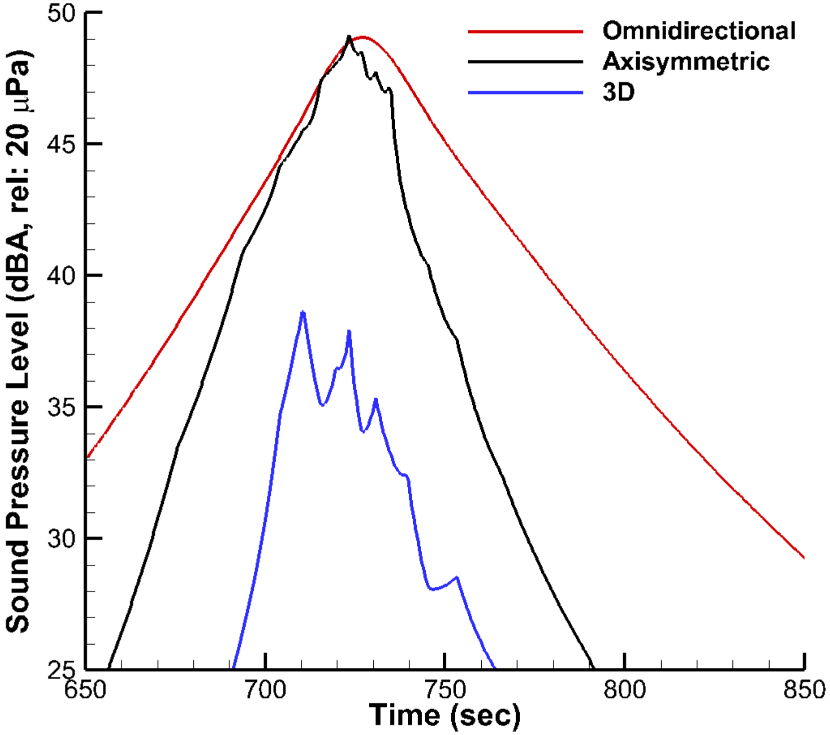

3D Sphere vs. AEDT



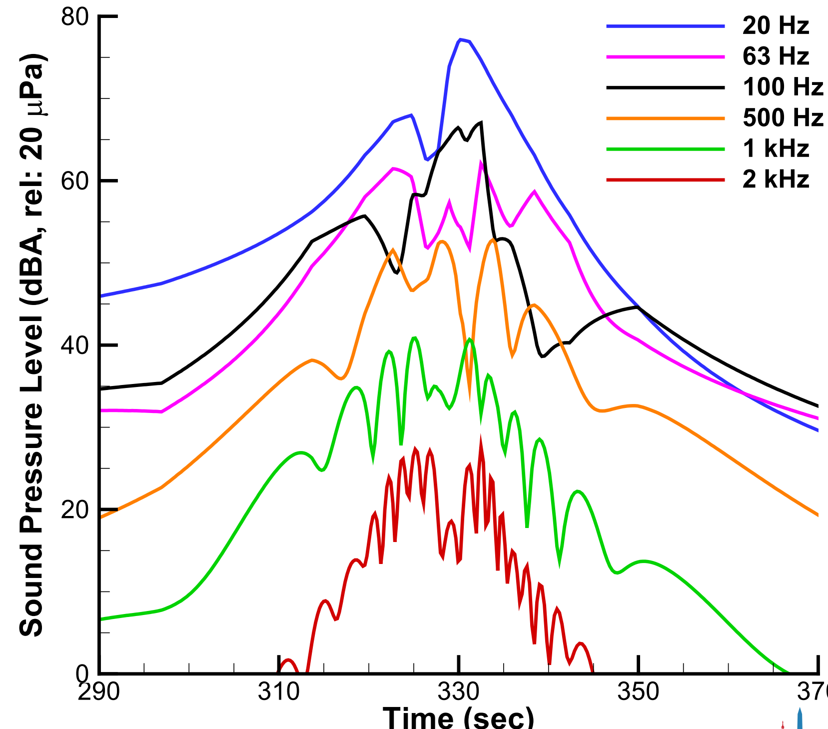

Time history undertrack
for 3 spheres

# Time History: 3000 ft and undertrack

- Omni and Axisymmetric differences due to fore/aft directivity
- 3D time history reflects the lower source emission laterally
- Spectral time history interference due to 4 ft receiver height




Lateral time history for 3 spheres




Time history undertrack, 3D sphere



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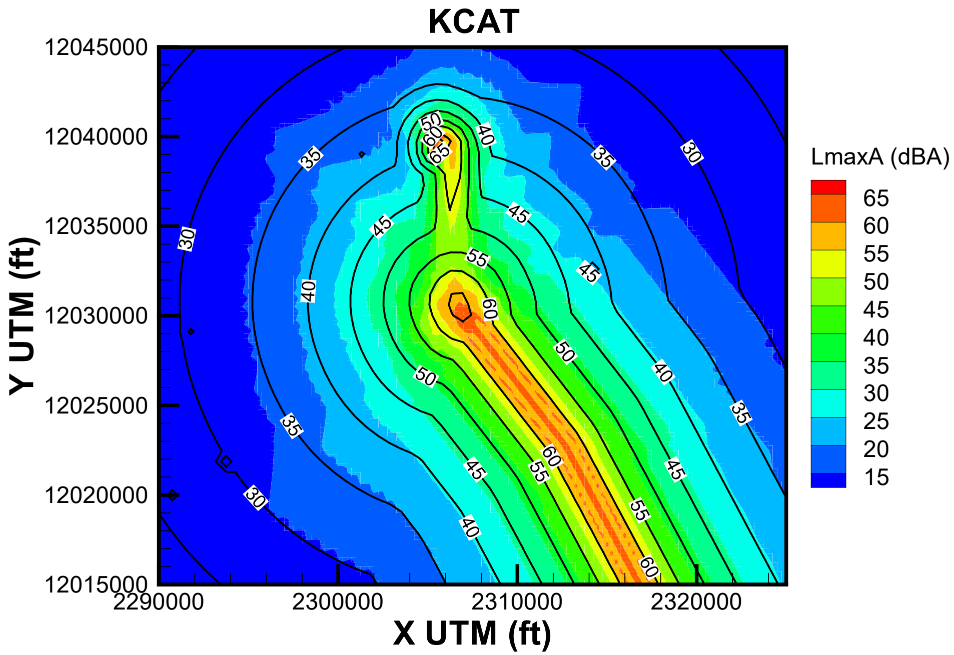
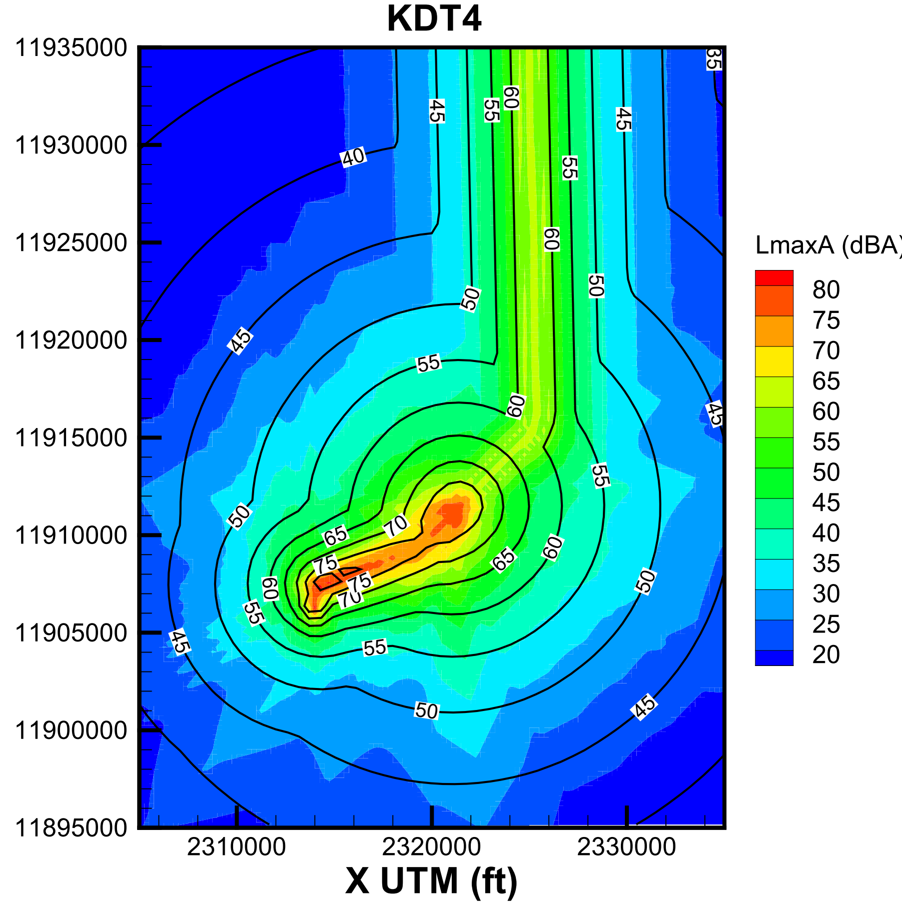
# Comparison of SEL (dBA) Contours



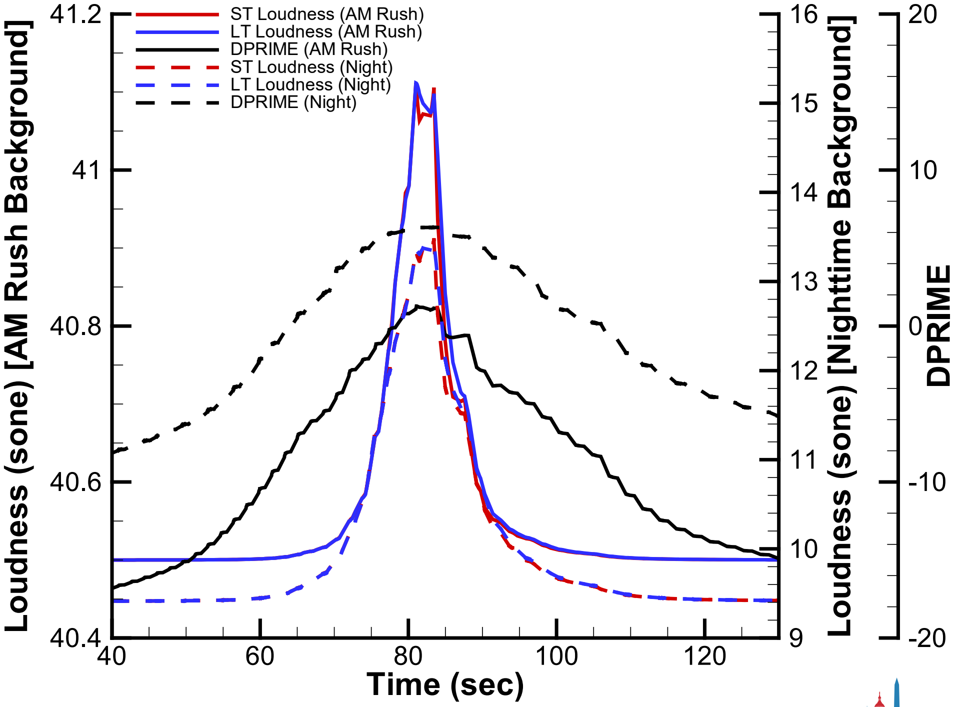

AEDT and AAM Similar undertrack

Larger differences laterally

- AAM results using 3D Spheres
- AEDT lines
- AAM color-fill

# AAM Loudness Metrics

- Utilizes 1/12 OB spheres
- Time Varying Loudness in the presence of background noise spectra
  - Short and long term loudness (sone)
  - dPrime
- Dallas morning rush & quiet night spectra
- POI 500 ft sideline near cruse-approach transition
- d’ results suggest barely audible at night but not during daytime



# AAM Acoustic Animation: 20 Hz OTOB

- Footprint: directivity and operating state transitions
- Swirling: propagation time effect
- Ripples near end: ground effects (4ft receiver height)

Landing Segment
App-3DView-20Hz-Band13OTOB-40to70dB.avi

Show from about 10 sec to 29 sec (end)

# Concluding Remarks

- Comparative analyses between AEDT and AAM suggest 3D spectral directivity can be an important feature to capture especially at lateral locations.
- Time varying loudness metrics can be evaluated at POIs or grids over spatially varying backgrounds
- Acoustic visualization tools can be used to assess the impacts of 3D directivity and operational procedure design.

Potential Plans for the Future

- Evaluation of helicopter modeling in AEDT
- Incorporate broadband and other noise sources in the spheres
- Demonstration of visualization and auralization from a common analysis
- Automated sphere selection and interpolation procedures for advanced air vehicles in AAM

# Acknowledgements


- This work was partially funded by the NASA Aeronautics Research Mission Directorate, Revolutionary Vertical Lift Technology Project
- Doug Boyd, NASA Langley for AARON tool development