Rotorcraft Noise Abatement Procedure Development

ASCENT 38

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Motivation

- Rotorcraft noise increasingly becoming a larger issue with general public
  - HAI’s “Fly Neighborly Guide” is helpful for community noise
    - Since publication, new rotorcraft and operations have been developed
  - Need for more detailed data and information about noise produced from the operation of rotorcraft
  - Need for detailed and specific noise abatement procedures

- This project investigates noise abatement flight procedures of rotorcraft through modeling
  - Physics based modeling of noise leveraging previous research performed for NASA and DoD
  - Comprehensive modeling of the many sources of rotor noise
  - Complete vehicle modeling during example flight procedures
    - Flyover
    - Approach, departure
    - Turn maneuvers, etc.

Objectives

- **Utilize computational and analytical modeling to develop noise abatement procedures for various helicopters and various phases of flight.**
- **Determine if it is feasible to develop noise abatement procedures for categories of helicopters.**

Schedule and Status

Schedule (CY 2017):

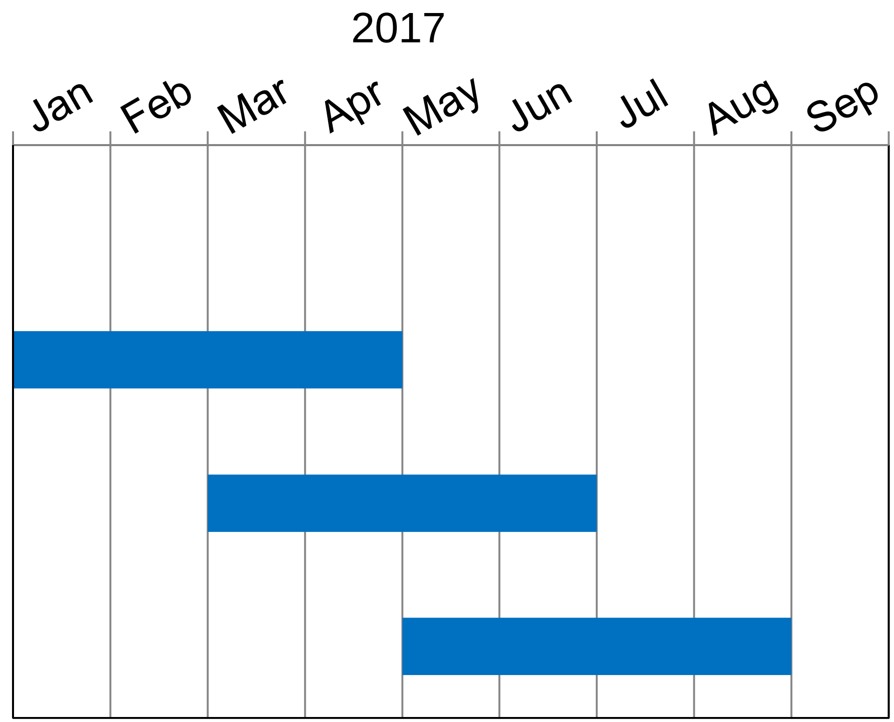
Objective : Develop abatement procedures and flight test plan

Complete model setup for 7 helicopters

Predict baseline and preliminary noise abatement procedures

Develop noise abatement procedures for different helicopter categories

Complete noise predictions; compare predicted noise abatement with that in the flight test; report effectiveness of procedures



Outcomes and Practical Applications

- Outcomes
  - Development of noise abatement procedures for various helicopters and phases of flight
    - 2 bladed/4 bladed; Heavy/light; New technology/older technology
    - approach, level, take off, turn, decelerating turn
  - Noise abatement procedures will be developed for the helicopters planned in the upcoming flight test
    - FAA/NASA planning flight test now
    - Procedure development will support the flight test
    - The flight test will validate the procedures and predictions
  - Different noise metrics and pressure time history will be used for comparison

- Practical applications
  - Demonstrate the value and ability of physics based tools for the development of flight procedures
    - For rotorcraft manufacturers
    - For Government (FAA)
  - Evaluate noise abatement procedures based on the operating parameters rather than design parameters
    - Noise abatement procedures will be used for different helicopters
    - Goal is that procedures will have wide range of application

Approach

1. **Selection of helicopters to be used for noise abatement procedures**
   - **Gross take-off weight**
   - **Number of main rotor blades**
   - **Regular vs quiet tail rotor**
   - **Technology level**

2. **Analyze noise abatement procedures for each of the selected helicopters**
   - **Model helicopters for noise prediction**
   - **Identify or develop noise abatement procedures**

3. Evaluate whether unique noise abatement procedures should be developed for each category
   - Determine whether abatement procedures work for different helicopter categories
   - Consider if a category is really representative of individual helicopters in the category

4. Model noise abatement procedures to demonstrate their advantages
   - Detailed analysis of abatement procedures

5. Analyze noise abatement procedures in support of the flight test
   - Assist the flight test by providing noise abatement procedures and different maneuvers

Status and Accomplishments

- **Administration**
  - Nothing at this time
- **Technical Status**
  - Validation of noise prediction system:
    - Maximum noise level peak for Bell 430 approach case is not observed at same value as the flight test
      - Peak levels observed at 6 degrees instead of 9 degrees
      - Increasing flat plate area (drag) results in same trend as the flight test
      - Further work is underway to resolve the issue
  - New helicopter models setup nearly complete
    - Collected data for new helicopters
    - Helicopter geometric parameters are approximated in HeloSim
    - Need to finalize CHARM input files
      - Need to add extra details for blade planform, etc.
      - Approximations will be required (not all data available)
      - One goal is to see the limitations of these approximations

Recent Accomplishments and Contributions

Flight Test Comparison with the simulation

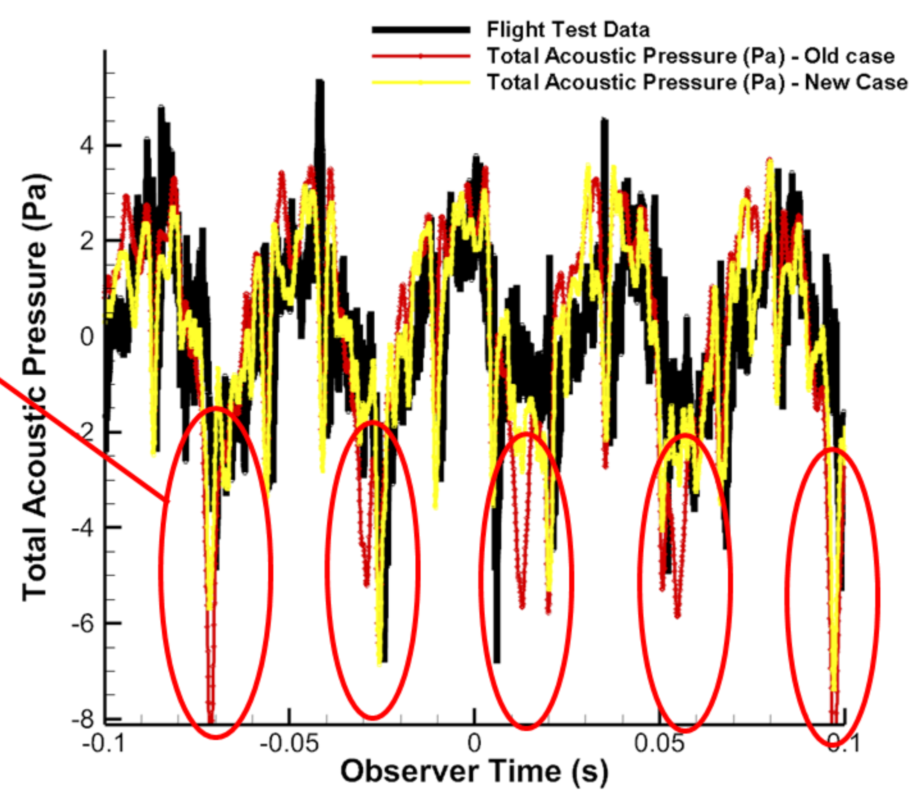
Flight Configuration – Bell 430 Run 126

- Flight Trajectory
  - Level flight
  - Velocity : 94.7 knots
  - GW : 8000 lbs
  - Height : 190 feet
- Numerical Results compared with overhead microphone (MC11 - reference)
  - Predicted **SEL = 97.26 dB**
  - Flight Test **SEL = 97.47 dB** (PSU-WOPWOP processing)
  - Predicted **EPNL= 99.11 dB**
  - Flight Test **EPNL= 99.99 dB** (PSU-WOPWOP processing)

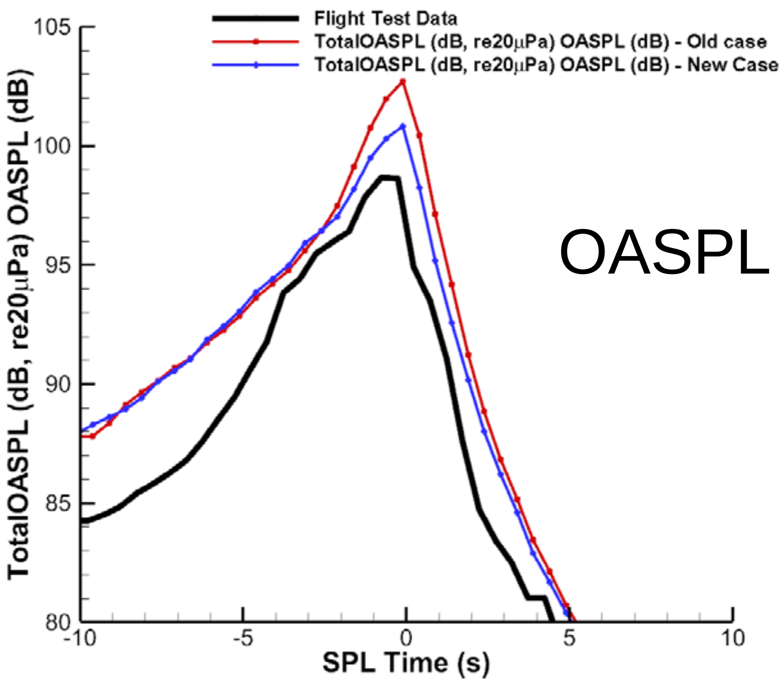
Acoustic Pressure (Bell 430 Run 126) – Ground Reflection included

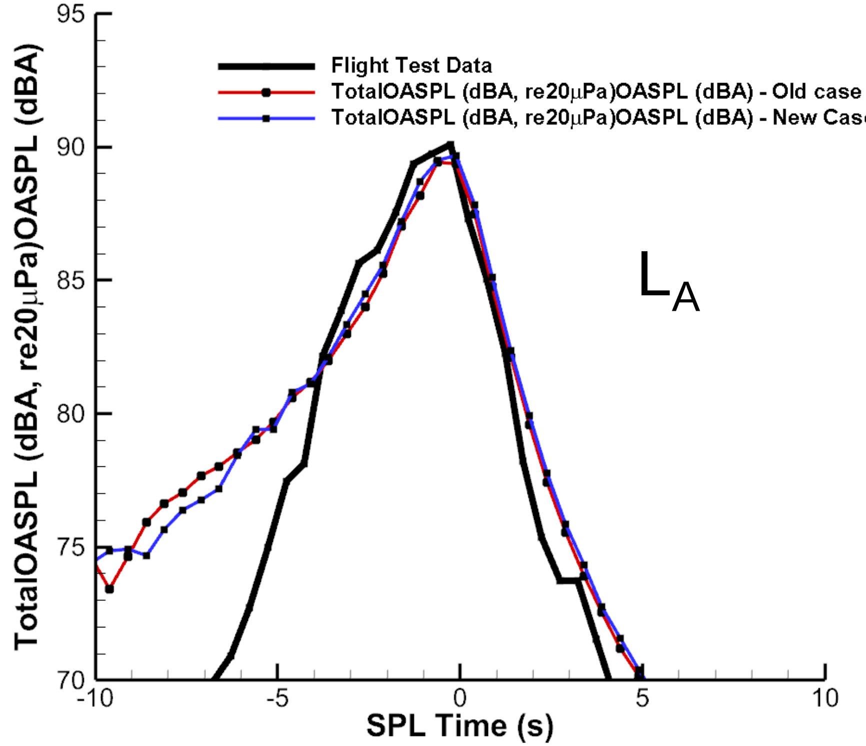
- Comparison of the simulation with the flight test data :
  - Flight Test data shifted to match the peaks
  - Helicopter is directly overhead (190 ft) when time = 0 sec

- Discussion:
  - Old case
    - predicted negative peaks too large
    - vortex core size: 0.10 chord
  - New case
    - larger vortex core size used
    - Vortex core size: 0.15 chord
    - lower negative pressure peaks
  - Predicted acoustic pressure matches flight test well



OASPL – dB and L_A – dBA (Bell 430 Run 126)





- Simulation over estimates the OASPL but L_A noise levels are predicted quite well.
- New case does a better job than the old case.

Old Case : Vortex core size 0.10c
New Case : Vortex core size 0.15c
(c is chord of the blade)

New Helicopters for Flight Test and Validation

- S76C

Selected due to different blade technology
(S76D: advanced rotor technology)

- S76D

- S92

Selected due to weight of the helicopter
(heaviest)

- AS350

Selected due to different tail rotor technology
(Fenestron on EC130)

- EC130

- Bell 407

Selected due to different number of MR blades

- Bell 206L

Recent Accomplishments and Contributions

- **Noise prediction for new vehicles**
  - New helicopter models setup nearly complete
    - Collected data for new helicopters
    - Helicopter geometric parameters are approximated in HeloSim
  - Need to add extra details for blade planform, etc.
    - Approximations will be required (not all data available)
    - We plan to assess which parameters most critical for accurate noise predictions

Recent Accomplishments and Contributions

- **Noise abatement using descent angle and acceleration**
  - **Comparison made between the 3 flight path angles**

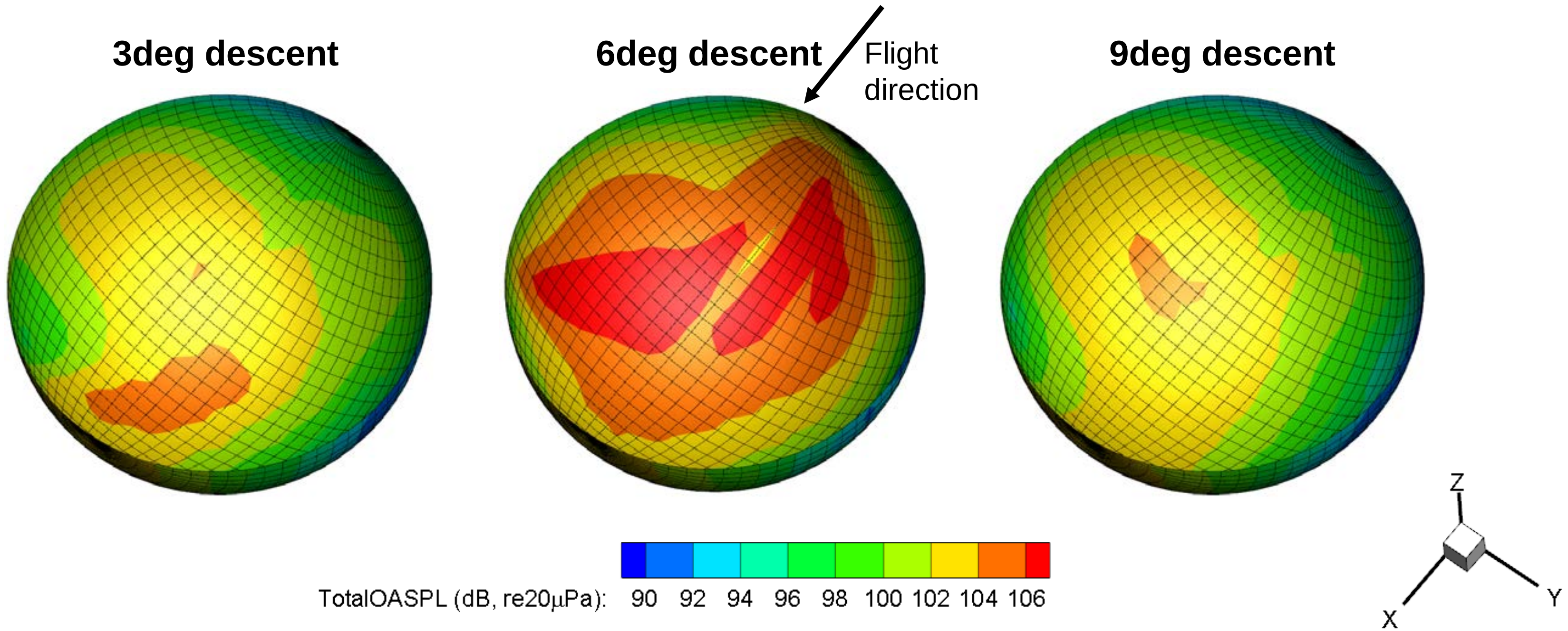
- **Goal:** Demonstrate noise abatement through flight path angle changes:
  - Actual changes to flight path angle
  - Effective changes to flight path angle – through acceleration or deceleration
- OASPL (dB) and L_A (dBA)
- BVI likely depending on specific flight state

Flight Configuration

- GW : 8170lbs
- Height : 100 ft
- Flight Trajectory:
  - 3, 6 and 9 deg. descent
- Acceleration: 0.0g, +0.05g, and -0.05 g
- Velocity:
  - steady descent @ 81kts
  - descent deceleration from 90 kts to 81 kts (12<t<22 s)
  - descent acceleration from 70 kts to 81 kts (12<t<22 s)

Recent Accomplishments and Contributions

- **Bell 430 descent case (no acceleration)**



- Maximum BVI occurs around 6 deg descent angle
- Changing flight path angle results in lower noise level

Recent Accomplishments and Contributions

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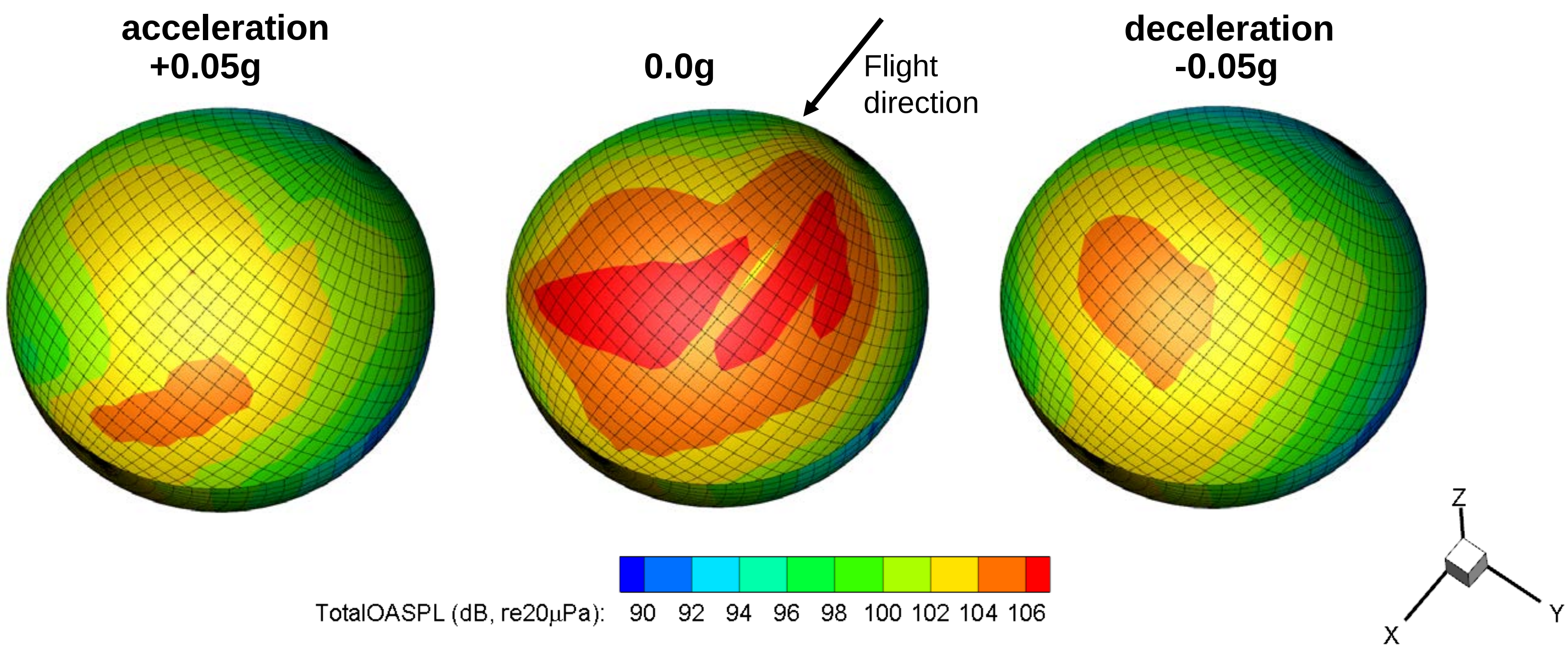
- **Bell 430 descent case (6 deg. descent)**



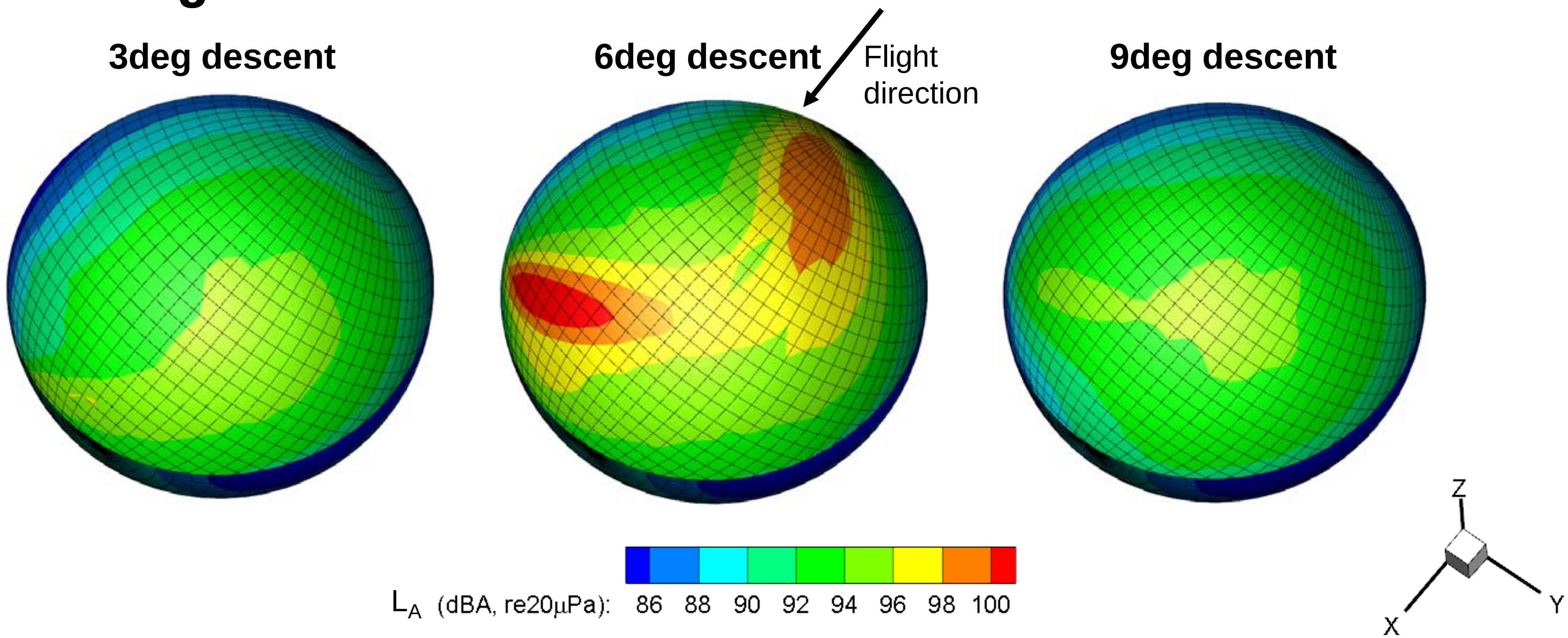
Effective fpa = fpa - g*sin(fpa) [fpa=flight path angle]
= 0.05 rad
= 3.062 deg

Effective fpa = fpa - g*sin(fpa)
= 0.156 rad
= 8.94 deg

- Acceleration and deceleration result in an effective flight path angle change – and approximately 2-4 dB noise reduction, with significantly smaller area of maximum noise

Recent Accomplishments and Contributions

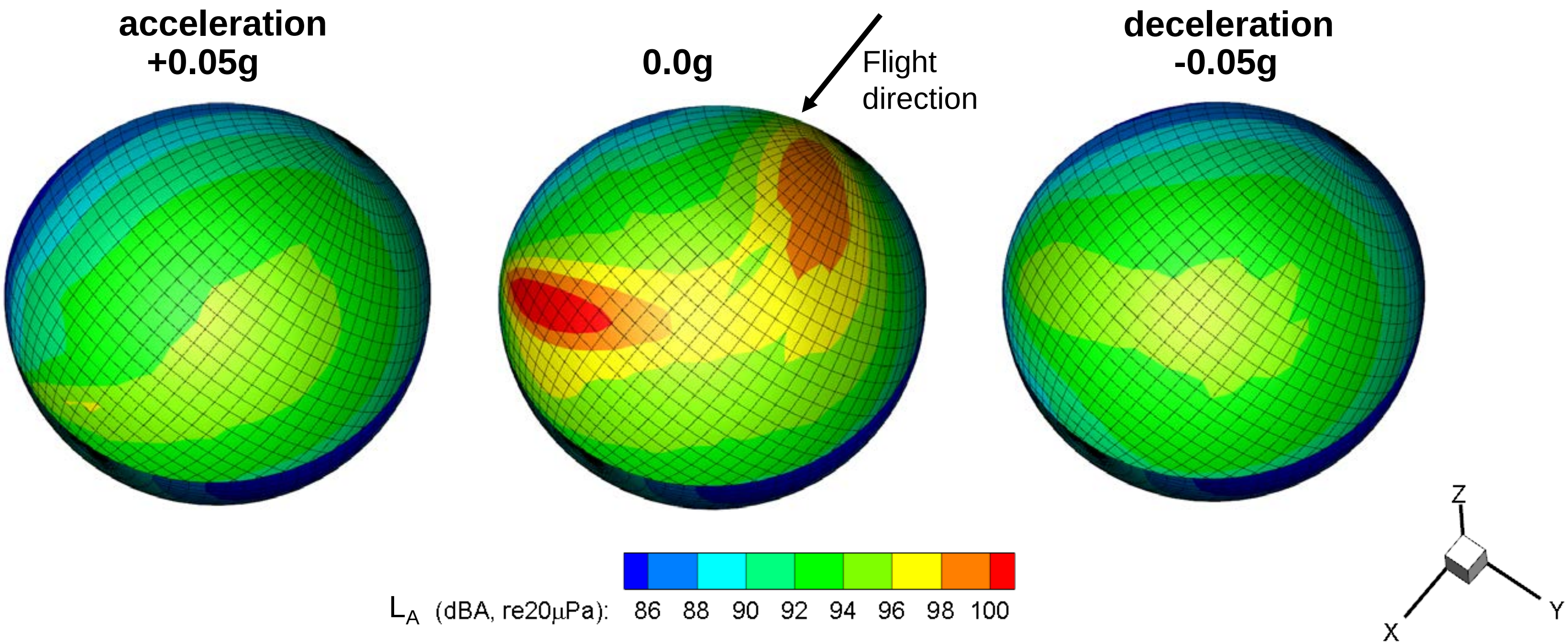
- **Bell 430 descent case (no acceleration)**
  A-weighted results



- Advancing and retreating side BVI evident in A-weighted plots
  - Forward hot spot has advancing side BVI directivity
  - Rearward hot spot has retreating side BVI directivity

Recent Accomplishments and Contributions

- **Bell 430 descent case (6 deg. descent) A-weighted results**



- Acceleration and deceleration result in an effective flight path angle change – and approximately 6-8dBA noise reduction
- Acceleration and deceleration results match different flight path angles very well

Recent Accomplishments and Contributions

- Maximum BVI occurs at a specific flight path angle
- Accelerating the aircraft effectively varies the flight path angle from the maximum noise value, which results in lower noise levels
- Though the flight test data shows maximum noise levels at 9 degree descent the abatement procedure is still valid
  - Changing the effective flight path angle results in less BVI noise
    - BVI noise change due to change in wake geometry position and where the interaction occurs
    - It doesn't matter whether actual flight path or if effective flight path angle is changed
  - Avoiding BVI noise on approach results in significant noise reduction

Summary

- Summary statement
  - Physics-based noise prediction system has been formed from previously existing tools
  - Analysis of the impact of simple operational changes on noise has been performed: descent angle, acceleration, etc.
  - Validation with Bell 430 flight test very helpful
- Next steps
  - Finish setup for other helicopters in flight test plan
  - Focus on abatement procedure development
  - Compute noise levels for time dependent cases
  - Evaluate noise abatement procedures (especially in preparation for flight test)

References

[1] Watts, M. E.; Greenwood, E.; Smith, C. D.; Snider, R.; and Conner, D. A.; "Maneuver Acoustic Flight Test of the Bell 430 Helicopter Data Report," NASA/TM–2014-218266, May 2014.

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