Rotorcraft Noise Abatement Procedure Development

ASCENT 38

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ASCENT
AVIATION SUSTAINABILITY CENTER

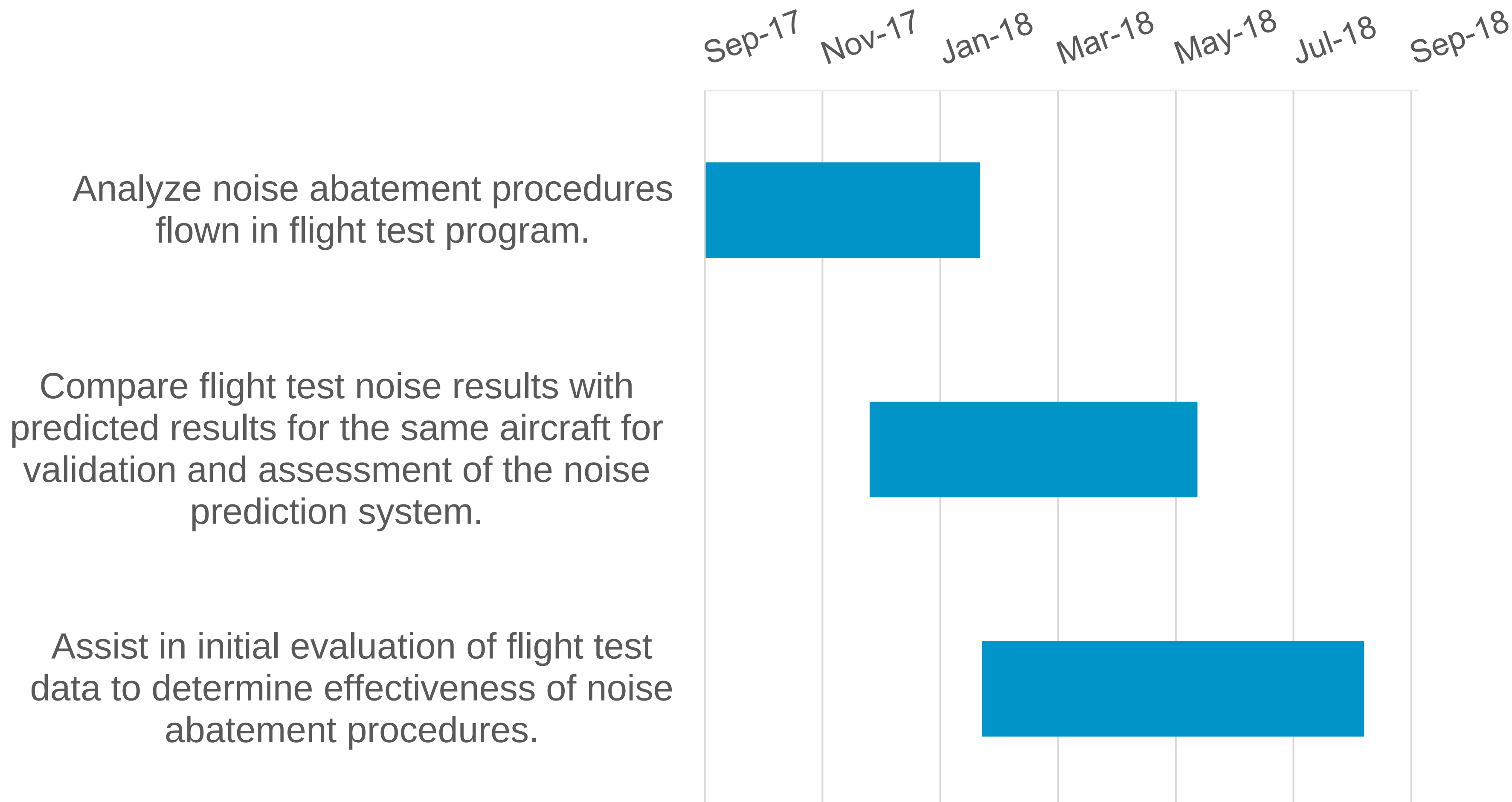
Motivation

- 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



Outcomes and Practical Applications

- Outcomes
  - Analyze noise abatement procedure flown in the FAA/NASA flight test in August/September 2017.
    - 6 different aircraft
    - Different technology levels, manufacturers, etc.
  - Comparison of predicted noise results with flight test data
    - Determine weaknesses in noise prediction system
    - Validate the noise abatement procedures and the predictions
    - Develop strategies for more effective noise abatement procedure development
  - Assessment of effectiveness of noise abatement procedures used in the flight tests

Outcomes and Practical Applications

- 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**
  - **FAA and NASA completed an acoustic flight test during the fall of 2017**
  - **Penn State supported the flight test by providing VOLPE with acoustic predictions for each of the helicopters in the flight test**
    - **Predictions on a hemisphere below the helicopter**
    - **VOLPE used these predictions to help plan noise abatement procedures interactively during the flight test**
    - **Predictions were also performed on the ground plane**
  - **Preliminary comparisons of the SEL contours for all helicopters have been carried out for a 80 kt, 6 deg descent flight condition**
  - Work is ongoing to develop a new strategy for "noise abatement curves" that provide pilots the information they can use to reduce noise through proper operating procedures

Planned Helicopters for Flight Test and Validation

- S76C

- S76D

- S92

- AS350

- EC130

- Bell 407

- Bell 206L

Actual Helicopters Flown in Flight Test and Validation

- R44

Selected due to different engine power and size

- R66

- 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

- Initial comparison between PSU-WOPWOP prediction and flight test data:

  Helicopter flight condition : 80kts and 6deg steady descent

  – Comparison between the flight test data and prediction
    - Aircraft: R44, R66, B407, B206L, AS350 and EC130
    - Pressure time history measured by the microphone array is processed using PSU-WOPWOP to predict the SEL levels on the ground plane

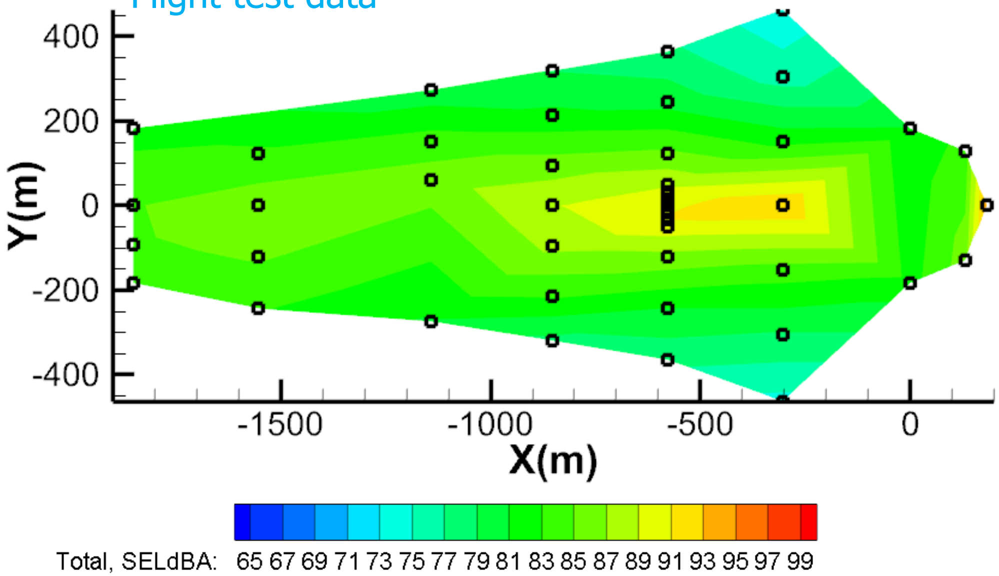
  – Microphones that did not capture the pressure signal (in the flight test) are excluded in the contour plots

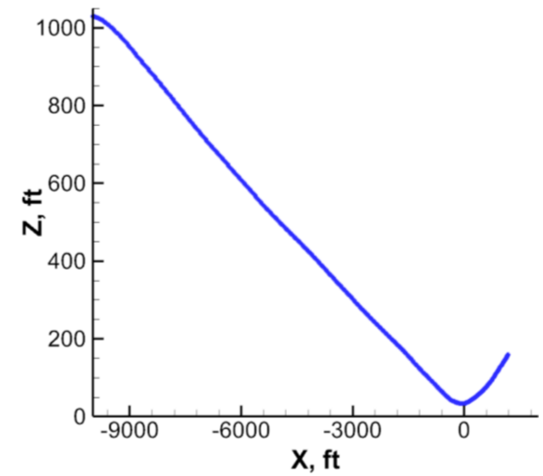
  – same microphone locations/ observer positions are used to plot the ground contour using prediction in the bottom figure

  – Only the steady descent part of the flight is simulated
    - Actual flight path is plotted, but not currently used in PSU-WOPWOP predictions

R44 – Preliminary Result

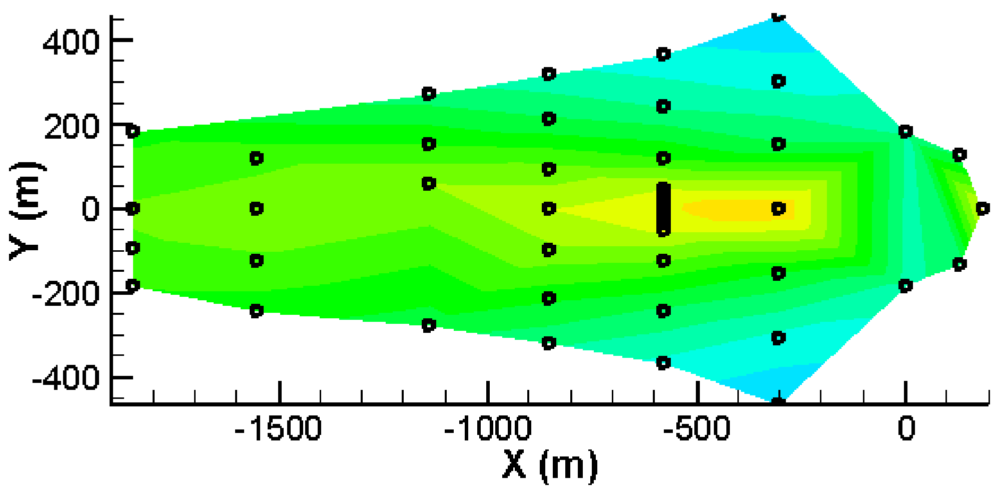
Flight test data





Measured flight path

PSU-WOPWOP prediction

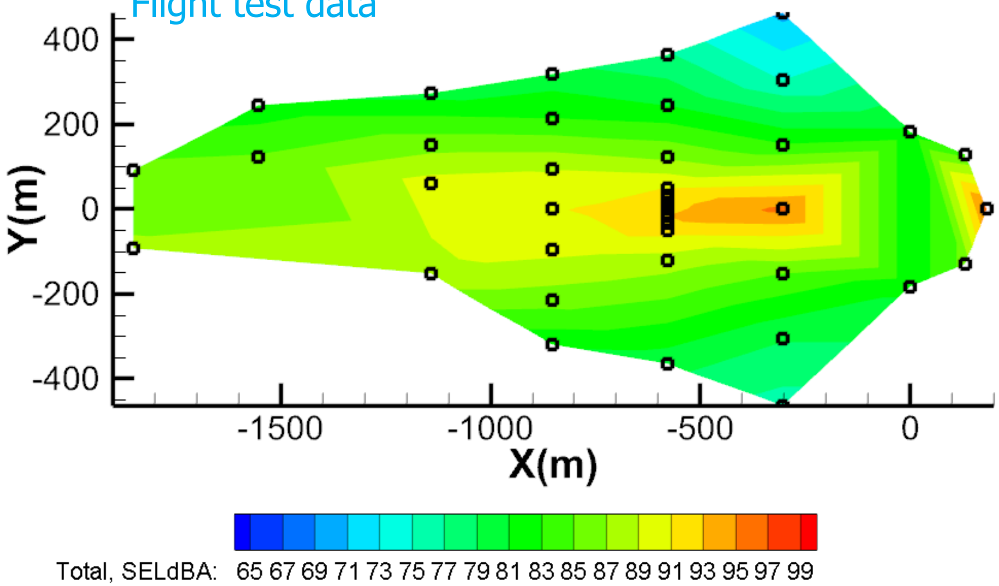


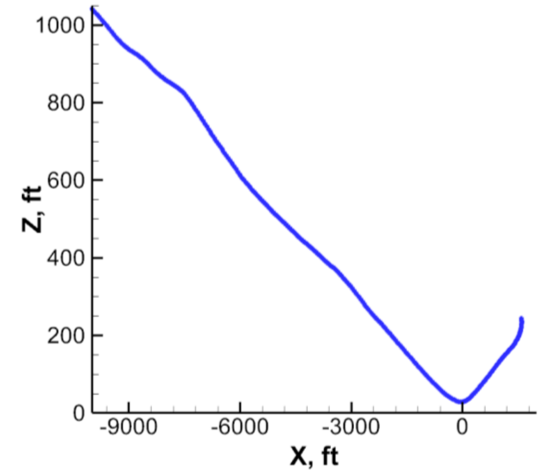
- PSU-WOPWOP is used to process acoustic pressure into SEL noise levels for both.
- Only valid microphones from the flight test are shown for both the data and prediction
- Low SEL levels in prediction are due to not achieving 10 dB down criteria.
- Predicted SEL levels and directivity agree well with flight test data.

R44 – Run 227156 – 80kts – 6deg

R66 – Preliminary Result

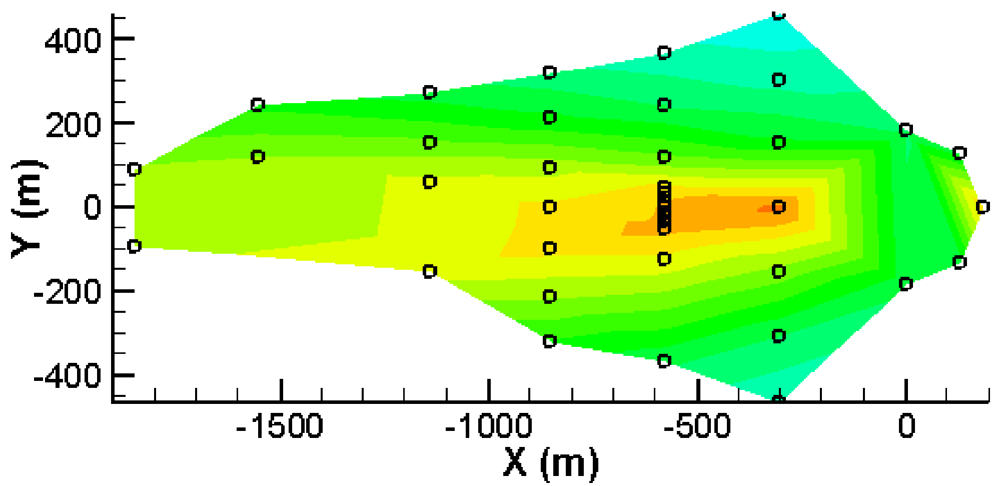
Flight test data





Measured flight path

PSU-WOPWOP prediction

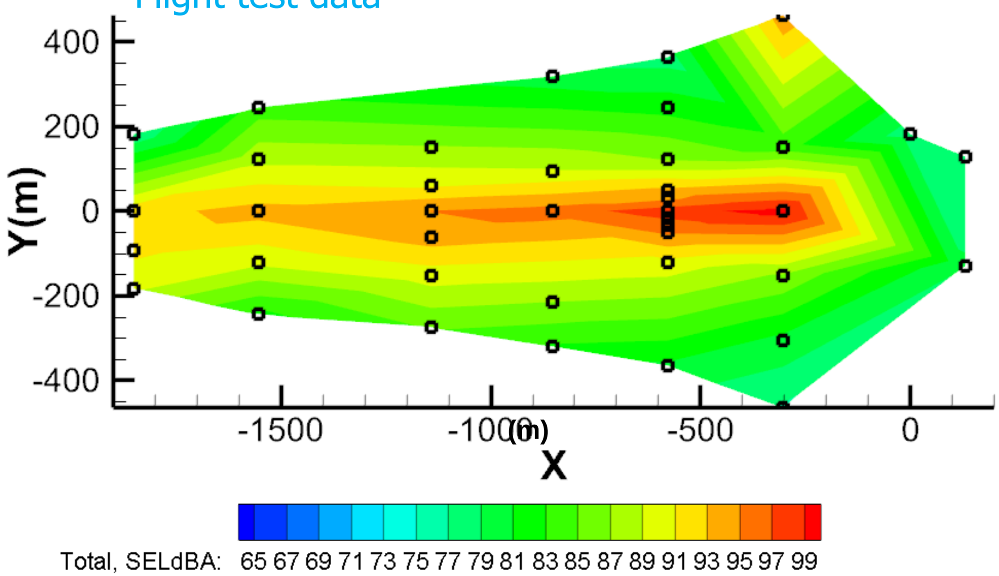


- R66 has turbine engine (R44 has piston), but PSU-WOPWOP does not model engine noise
- Main rotor blades are different chord and twist, but otherwise vehicles are very similar
- Small overprediction in this case, but still quite good agreement

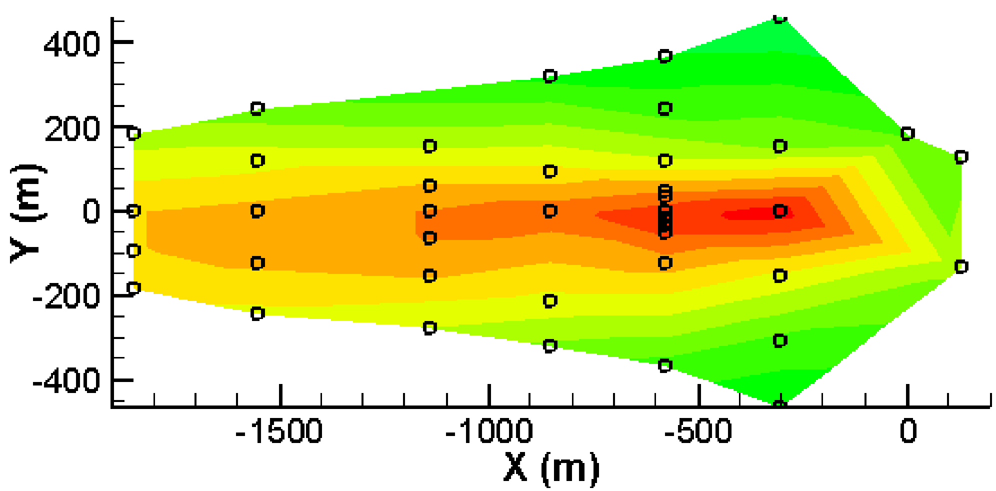
R66 – Run 234506 – 80kts – 6deg

Bell 206L – Preliminary Result

Flight test data



PSU-WOPWOP prediction

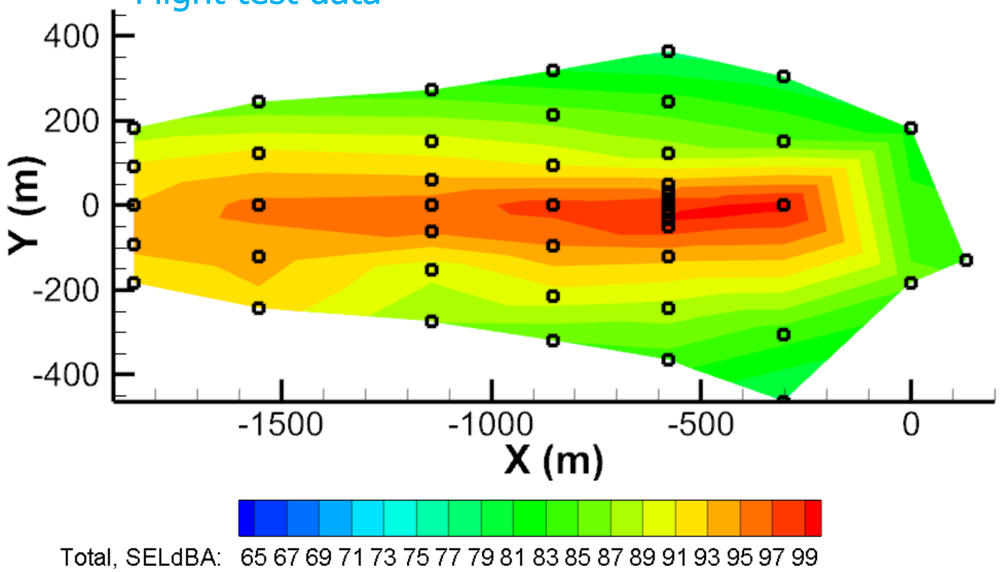


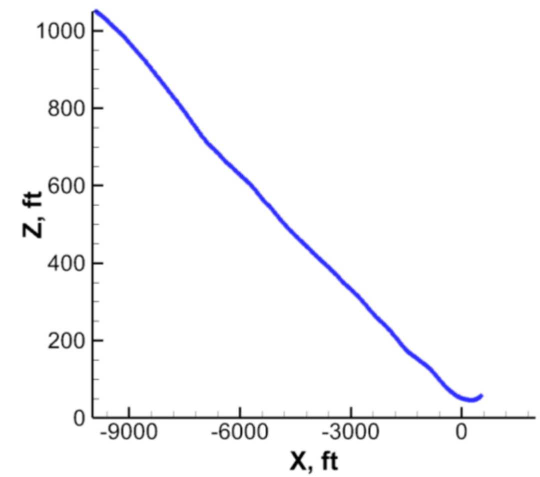
- Bell 206L is a heavier aircraft, SEL levels are higher, reflecting the heavier weight
- Bell 206L has a 2-bladed main rotor, like the R44 and R66
- No flight path data was available for the Bell 206L in the flight test
- Agreement between prediction and flight test data is good, with some overprediction.

B206L – Run 277109 – 80kts -6deg

Bell 407 – Preliminary Result

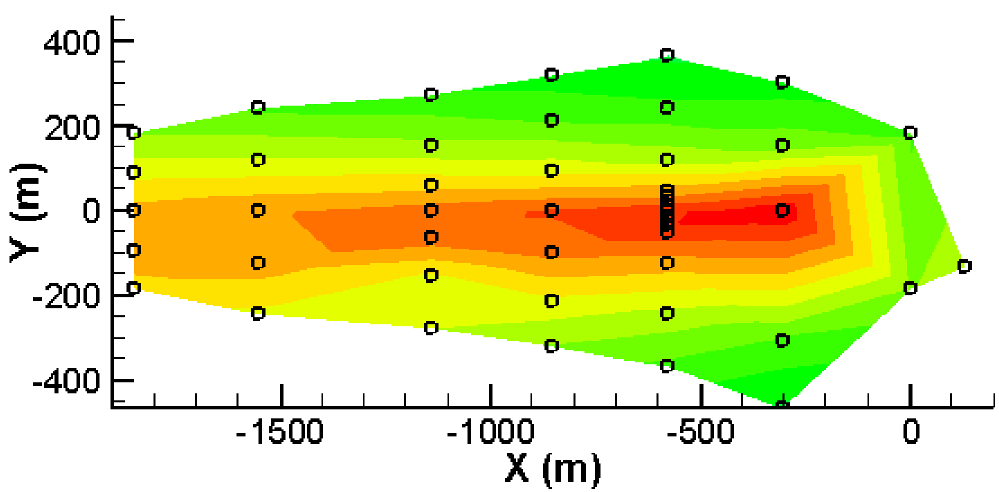
Flight test data





Measured flight path

PSU-WOPWOP prediction

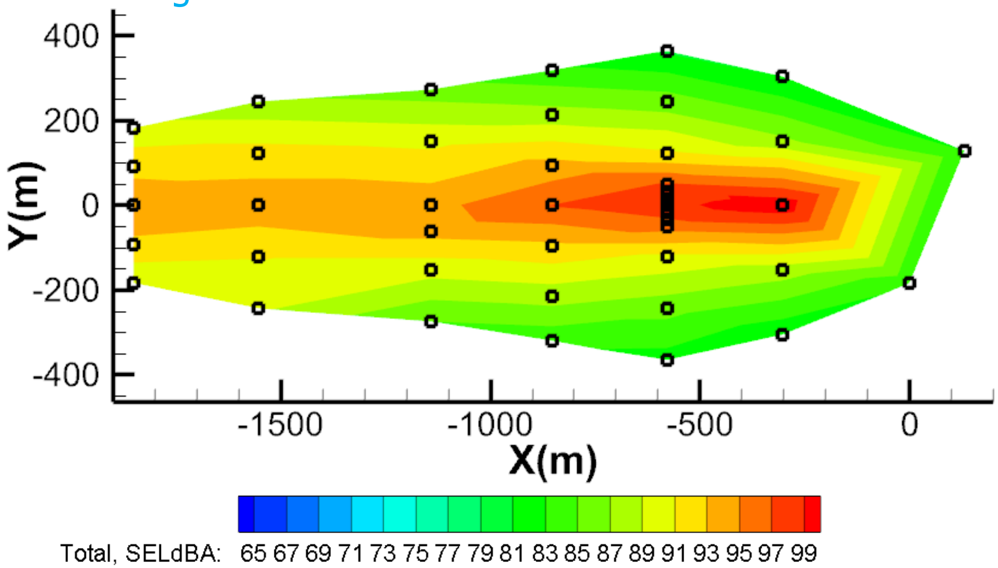


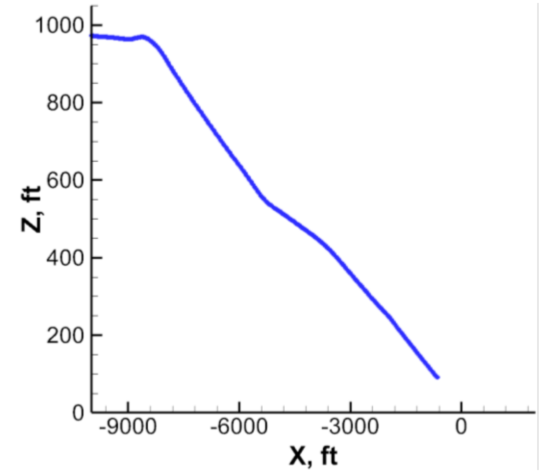
- Bell 407 designed as upgrade for 206L, 4-bladed main rotor and newer technology; somewhat heavier than 206L
- SEL levels are higher, reflecting the heavier weight
- Agreement between prediction and flight test data is good

B407 – Run 285242 – 80kts -6deg

AS350 – Preliminary Result

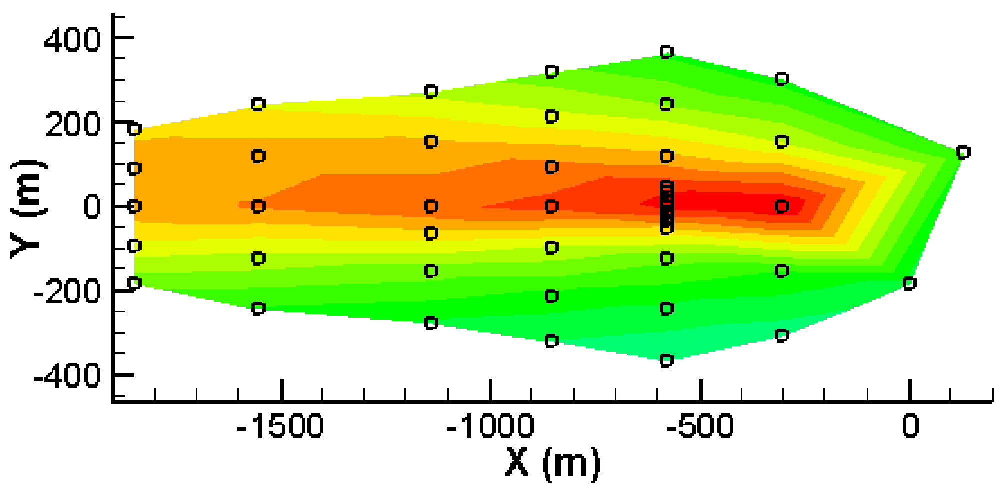
Flight test data





Measured flight path

PSU-WOPWOP prediction

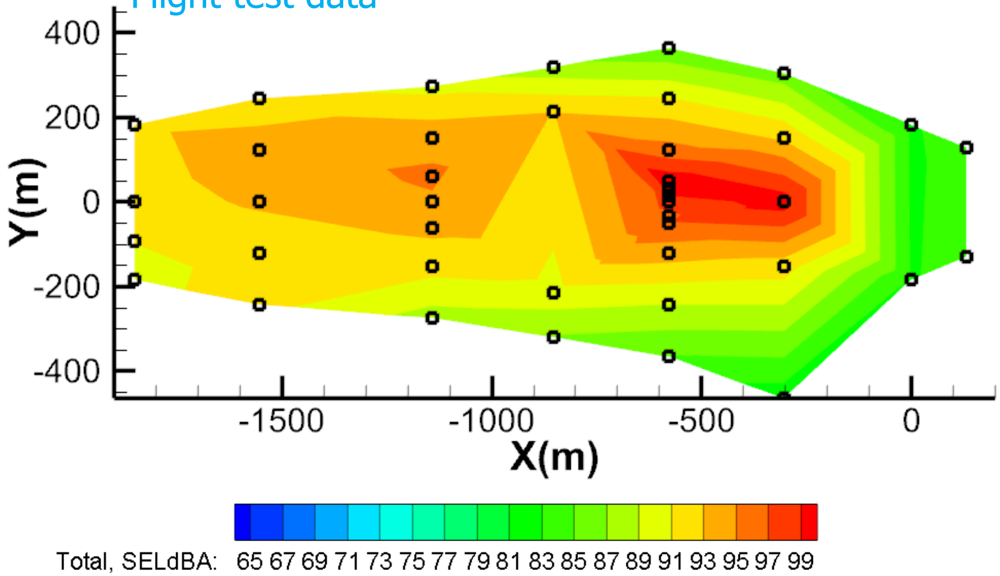


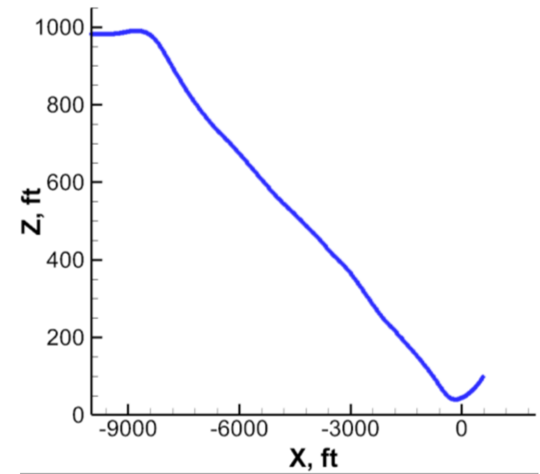
- AS350 is older technology, 3-bladed main rotor, that operates in the clockwise direction (from above) – opposite of previous aircraft
- Subtle features of directivity are reverse about y=0 plane
- Prediction overpredicts slightly, but overall agreement is good

AS350 – Run 289119 – 80kts -6deg

EC130 – Preliminary Result

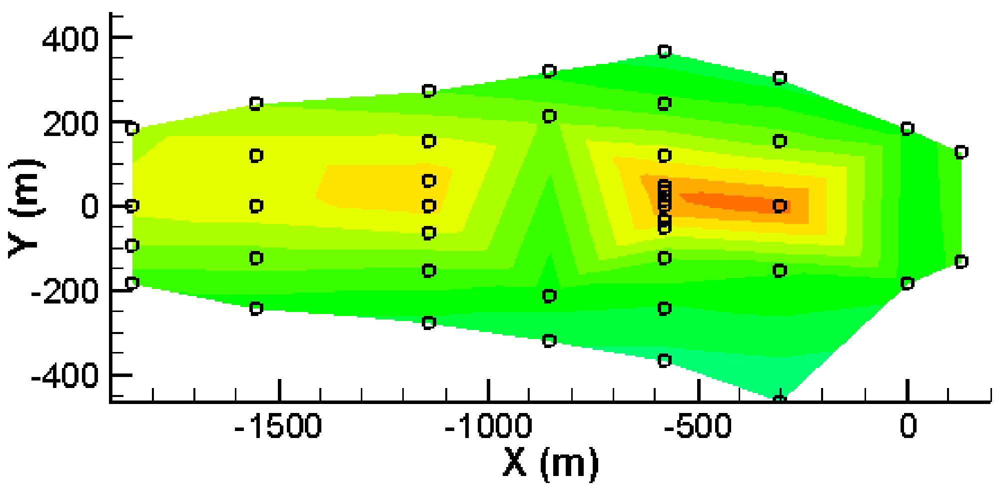
Flight test data





Measured flight path

PSU-WOPWOP prediction



- EC130 is an updated, newer technology AS350
- The EC130 has a Fenestron rather than a standard tail rotor
- The Fenestron was modeled in PSU-WOPWOP as a tail rotor with 11 unequally spaced blades
- The duct/shroud was not considered either acoustically or aerodynamically
- Low SEL levels in prediction likely due to not modelling Fenestron accurately (i.e., ignoring the shroud)

EC130 Run 296137 – 80kts - 6deg

Discussion

- Issues
  - Transient effects of the flight test are not currently included in the predictions
  - Aircraft roll see during flight not currently captured in the predictions (but it can be)
  - Broadband noise is not reflected off the ground in the predictions
  - Fenestron is modelled as an open rotor in the predictions at this time (no shroud or duct; no aerodynamic influence of the duct on the rotor included). This probably explains the underprediction for the EC130.

Recent Accomplishments and Contributions

- Compared flight test data and the simulation results for a single flight condition
- Also working on SEL equivalent metric to use for the development of noise abatement curves for different helicopters
  - This will include duration and different spatial locations into the noise metric
  - This metric will provide guidance to select the most quiet procedure

Summary

- Summary statement
  - Physics-based noise prediction system has been formed from previously existing tools
  - Good results from first comparison of noise prediction system with flight test data
- Next steps?
  - Focus on abatement procedure development and comparison between flight test data prediction system

Contributors

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  - Sikorsky Aircraft Corporation (SAC) – Eric Jacobs
- Interactions also with Juliet Page and Chris Cutler at Volpe