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# *Active Rotor Research Challenges*

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*TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.*


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## Research Challenges for Acoustic Reduction Using Active Rotor

**Research on the active flap SMART rotor to date suggests that a modest amount of in-plane noise reduction can be achieved at a single location via this cancellation technique.**

**Research Issues to Improve in-plane noise reduction for operational use:**

- **Directionality Issues**
- **Feasibility across entire flight envelope**
- **Optimal hardware configuration/actuation**
- **Data Quality and Knowledge-base**
- **Acoustic Design Tools**

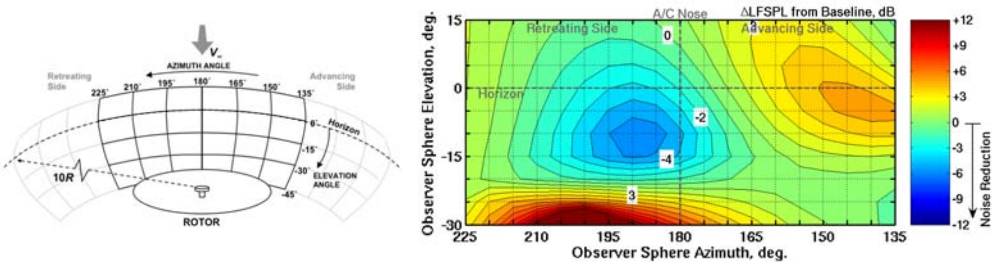


**Figure 6. Change in noise levels predicted by CAMRAD-II and PSU-WOPWOP using a single active flap for in-plane noise cancellation at 124 kts, 1-G flight condition: a) 10R mercator contour surface, b) region anticipated to be of greatest interest to operators (+/- 20 deg side-to–side & up-and-down).**

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A) Directionality Issues. The concept of reducing free-field noise via introducing an additional "anti-noise" source is known to be problematic. A device that is tuned to reduce noise at one location is likely to increase noise elsewhere – generating pockets of high and low noise levels in space where the "anti-noise" can either, add or cancel the original noise level. Figure 6 illustrates this critical directionality issue via predicted noise level changes in a spatial region forward of the rotor using a single active flap configuration similar to the SMART rotor. While the noise directly forward in the plane of the rotor is reduced, it shows that higher noise levels could be incurred in other directions. Clearly, the feasibility of implementing such a device for free-field noise cancellation requires a compromise between the spatial/directionality requirements from an operational standpoint, and the actual design, implementation of the device. The challenge lies in identifying new hardware configuration and actuation strategy to maximize reduction in a given area forward of the rotor. A practical solution likely requires multiple active devices, distributed across the rotor blade span, with enough amplitude authority to operate at lower frequencies for effective spatial cancellation. Feedback from the aviation users on the potential benefit to buy time or prevent detection is sought, particularly with regard to this directionality issue.

B) Feasibility across entire flight envelope. With measurement only obtained at a moderate airspeed of 124 kts on the SMART rotor, it is unclear if state-of-art active "on-blade" devices are robust enough to deliver sufficient cancellation authority at higher airspeeds. The negative thickness noise peak is known to increase drastically with airspeed and would demand larger amplitudes and/or greater number of devices to generate the "anti-noise" required.

C) Optimal hardware configuration/actuation. The challenge to achieve significant (> 10 dB) reduction in rotor in-plane noise requires a re-evaluation of the optimal active control configuration. Foremost is the need to introduce a device that only affects the in-plane (chordwise) forces and not the out-of-plane forces, primarily associated with lift, to avoid an increase in noise elsewhere around the rotor. As mentioned previously, use of multiple devices distributed along the blade span will also be highly desirable for directionality concerns. In addition, it should be beneficial to configure these devices to create a pulse identical but opposite of the "thickness" noise which will require greater high frequency actuation than was demonstrated in the SMART test. This should provide more complete cancellation and minimizes the residual higher frequencies that are shown in Figure 4.

D) Data Quality and Knowledge-base. At the research level, it is imperative that better acoustic quality be obtained to enable quantitative understanding and assessment of the robustness and feasibility of this technology. Helicopter acoustic wind tunnel testing is often plagued by noise contamination from the surrounding environment (e.g. ambient noise, reflections from structures etc.) and limitations of the facility size that constrained far-field microphone installation. The NFAC's 40- by 80-foot anechoic test section offers the cleanest and best solution especially for 12-foot diameter or smaller model-scaled rotors. This is inherently due to frequency restrictions imposed by the anechoic treatment as discussed before. A smaller rotor also allows for more favorable microphone distance scaling that will significantly improve the fidelity and assessment of far-field rotor noise measurement. In addition, use of a smaller rotor in a large anechoic facility will enable a greater number of microphones providing better spatial (directionality) evaluations.

E) Acoustic Design Tools. While advances in prediction methodologies have enabled comprehensive properties of the rotor airloads, aeroelastic deformations, and wake-induced effects to be predicted, the state-of-the-art tools have not demonstrated the ability to accurately and efficiently capture the effects of active "on-blade" controls on rotor blade in-plane forces. Primary difficulties are associated with predicting and validating chordwise forces. To reap the benefits of the noise cancellation approach, there is a need to assess acoustics computational tools to determine their adequacy in the design and evaluation of feasible active "on-blade" controls. Modeling of the SMART rotor using the state of the art tools is underway at AFDD using CFD/CSD coupling to obtain blade pressures. These blade pressures will be introduced into PSU-WOPWOP for comparison with microphone measurements during the SMART test.

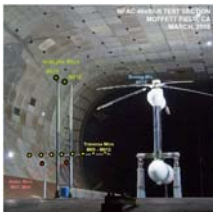
## SMART Test
## Accomplishments & Limitations

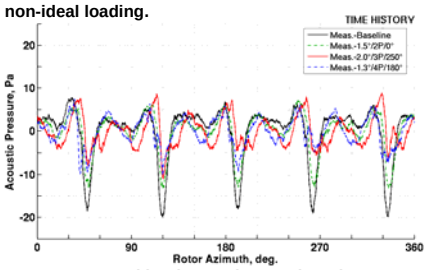
**Preliminary findings confirmed that active flaps are capable of locally reducing the far-field acoustic pressure.**

- **Comparison of the measured acoustic time history at M013 without active flaps (baseline) and with the active flaps turned on at different amplitude/harmonic/phase settings.**
  - **The negative peak pressure associated with thickness noise is significantly suppressed, by up to 50%.**
  - **The corresponding overall sound pressure level is shown to decrease by approximately 6 dB.**
  - **Detection distance evaluation with the tool ICHIN (I Can Hear It Now) demonstrated near 20% reduction in detection range (Figure 5) between the baseline and best low noise flap actuation scenario.**
  - **A performance penalty of approximately 2-3% was identified for all the cases with flaps deployed.**

**Results do not proclaim the full potential/deficiencies of this noise cancellation concept due to the following reasons:**

- **Uncertain acoustic data quality that reflects true far-field noise characteristics.**
- **Limited hardware implementation prohibits full noise cancellation potential to be explored. Flap authority constraints (less than two degrees) and fixed discrete harmonic inputs limited the ability to control flap deflection with the correct amplitude, timing and history to reproduce an optimal time-varying "anti-noise" pulse.**
- **Lack of microphone measurements to evaluate spatial extent on far-field acoustics radiation critical for aural detection assessment.**
- **Inability to isolate effects at non-in-plane locations due to non-ideal loading.**






**Measured in-plane noise at microphone M013**

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While results from the SMART rotor test appear to be very encouraging and have served to illustrate qualitatively that active controls can be implemented to achieve suppression of the negative thickness noise peaks. These results do not proclaim the full potential/deficiencies of this noise cancellation concept due to the following reasons:

A) Uncertain acoustic data quality that reflects true far-field noise characteristics. Unknown magnitude of wall reflections and standing wave contamination in low frequency acoustic content resulting from non-ideal low frequencies anechoic treatment performance in the 40- by 80-foot test section. The acoustic data also may not be representative of far-field noise due to placement of the microphones inside the wind tunnel in the anechoic treated section relatively near the rotor. It is imperative that the present data be viewed in terms of delta responses, rather than absolutes.

B) Limited hardware implementation prohibits full noise cancellation potential to be explored. Flap authority constraints (less than two degrees) and fixed discrete harmonic inputs limited the ability to control flap deflection with the correct amplitude, timing and history to reproduce an optimal time-varying "anti-noise" pulse. Use of the single/dual discrete harmonic controller led to incomplete cancellation and likely caused the additional noise fluctuations shown in Figure 4. In many instances, these additional noise fluctuations manifest and increase noise levels in the higher frequency range.

C) Lack of microphone measurements to evaluate spatial extent on far-field acoustics radiation critical for aural detection assessment. Use of only two microphones severely limited the ability to evaluate the acoustics state at other in-plane locations. Fundamental wave theory suggests that introducing "anti-noise" to the free-field is likely to cause localized constructive and destructive interferences. This directionality effect was not evaluated since there were only two in-plane microphones (M013 and M015) during the SMART rotor test.

D) Inability to isolate effects at non-in-plane locations due to non-ideal loading. Ideally, the noise cancellation approach calls for a device that solely changes blade in-plane forces for in-plane noise reduction. Measurement from the SMART rotor test, however, revealed that low frequency noise content was increased at out-of-plane microphone locations. This is due to an increase in out-of-plane lift noise that stems from changes in the blade lift introduced by deploying the active flap to create sufficient forces to torsionally twist the blade. Although this is generally not a concern for long range detectability of helicopters, it does degrade the ride quality by introducing an excessive amount of noise into the cabin.