UNWG SG1 Briefing

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Outline

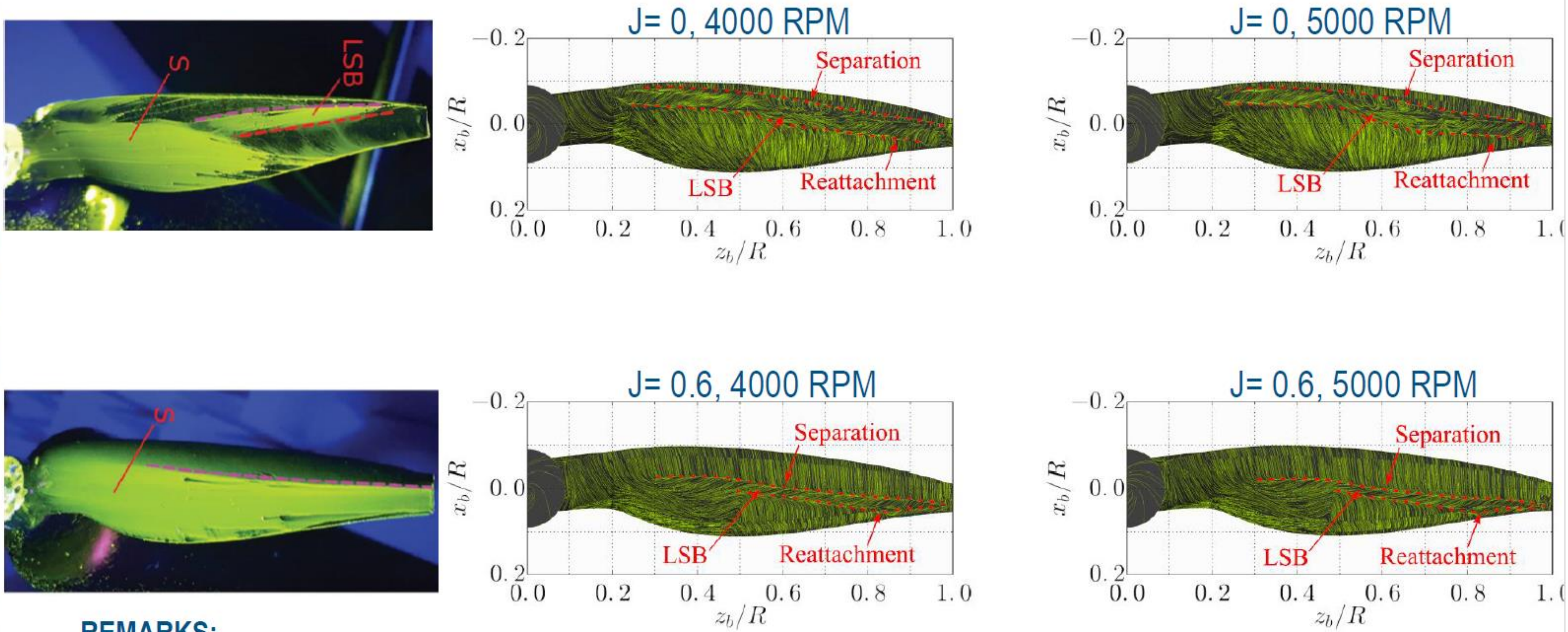
- Recap of meetings past and present
- Recap of guest presentations
- Database of datasets
- Breakout session topics

Meetings Recap

- March 2022: We canceled this meeting due to the VFS.
- June 2022: Guest speaker Damiano Casalino (Dassault Systems).
- July 2022: Guest speakers Philip McCarthy (NRC Canada), Christopher Thurman (NASA Langley).
- August 2022: Discussed existing topics and any potential problematic topics.
- September 2022: Discussed existing topics and any potential problematic topics.
- October 2022: We will not have this meeting because it be right before the ATWG/UNWG.

Guest Presentation (Damiano Casalino)

AERODYNAMICS



REMARKS:

- Experimental oil flow visualizations are only qualitative
- At J=0.6 it is not clear if the flow reattaches in the experiment!

20

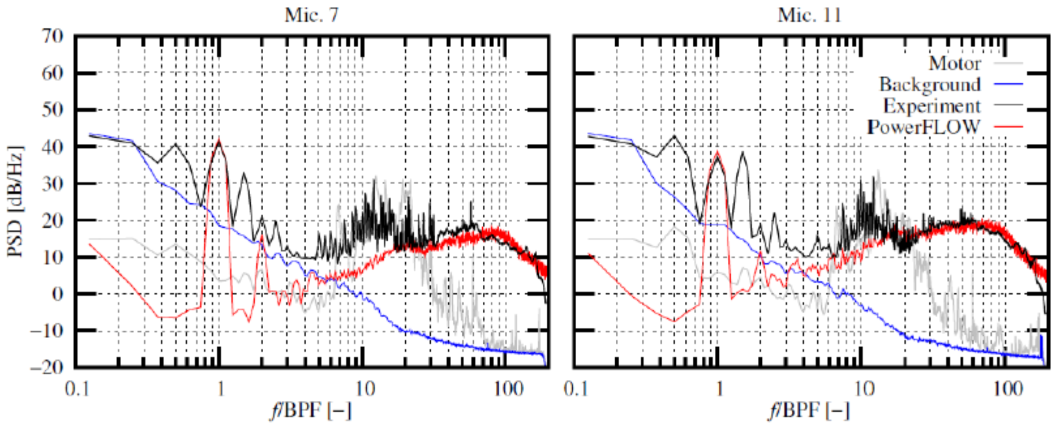
Laminar Separation Bubble (LSB)

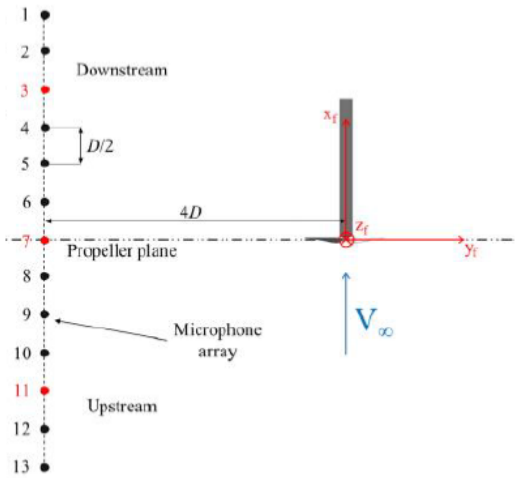
D. Casalino, “Update on PowerFLOW calculations of Rotor Noise in Transitional Boundary Layer Regime,” presented at the Urban Air Mobility Noise Working Group Subgroup 1, June 7, 2022

Guest Presentation (Damiano Casalino)

AEROACOUSTICS

J= 0.6, 4000 RPM





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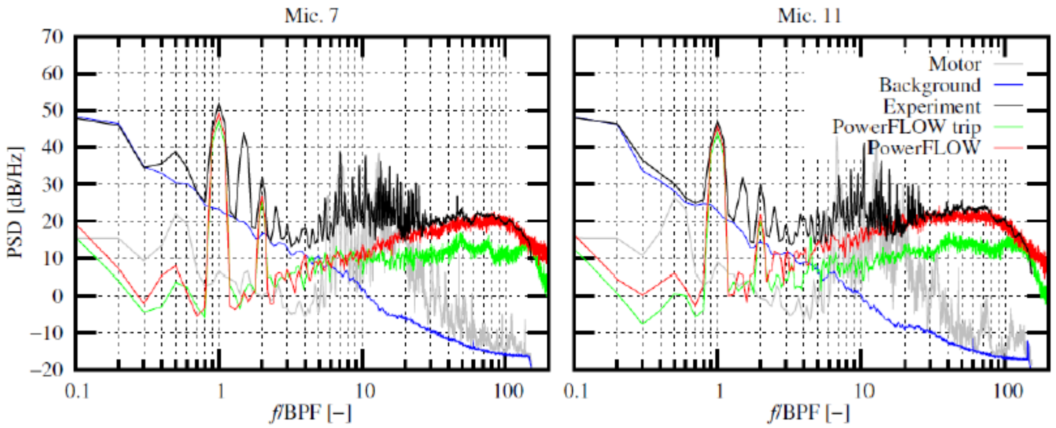

LSB noise hump predicted

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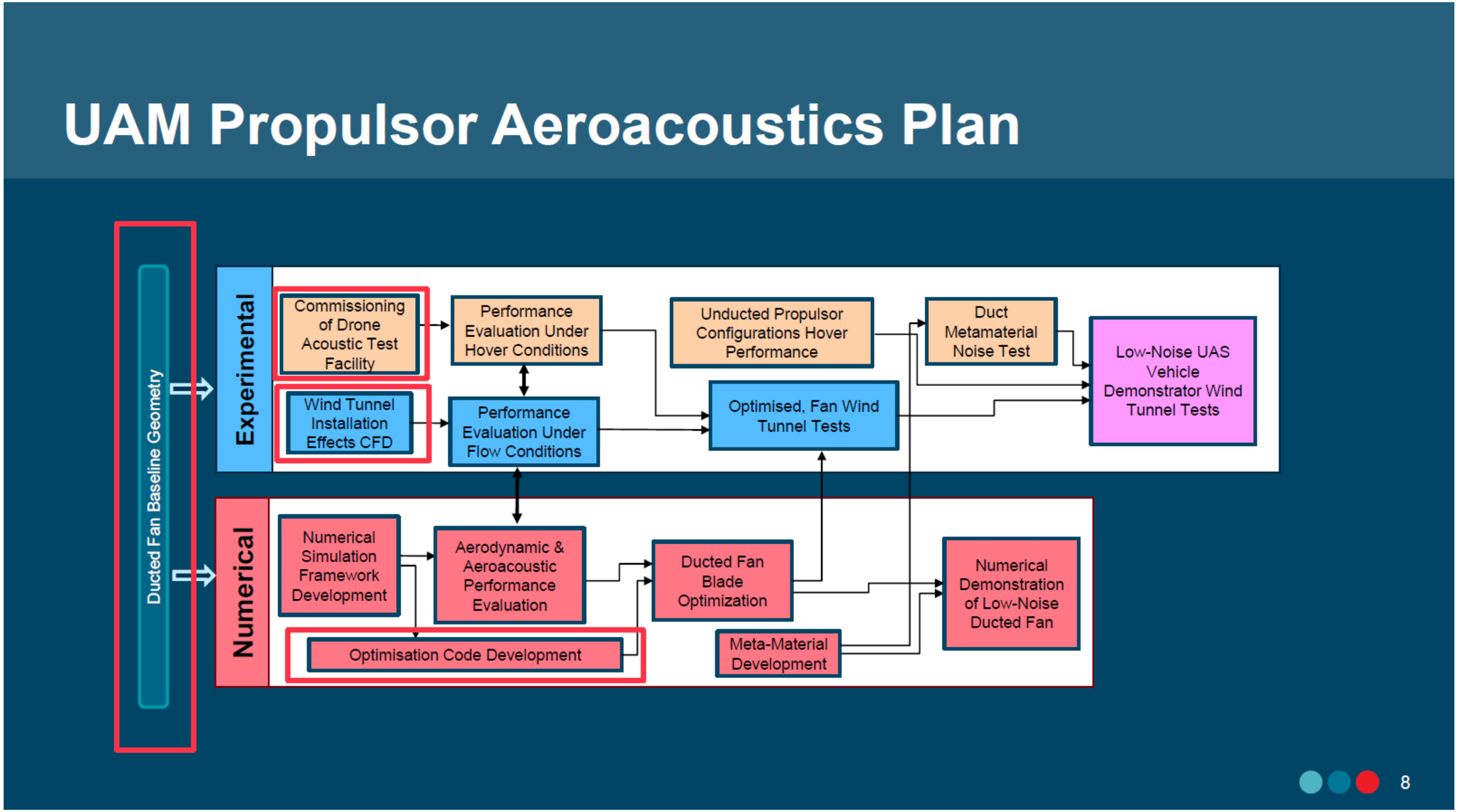
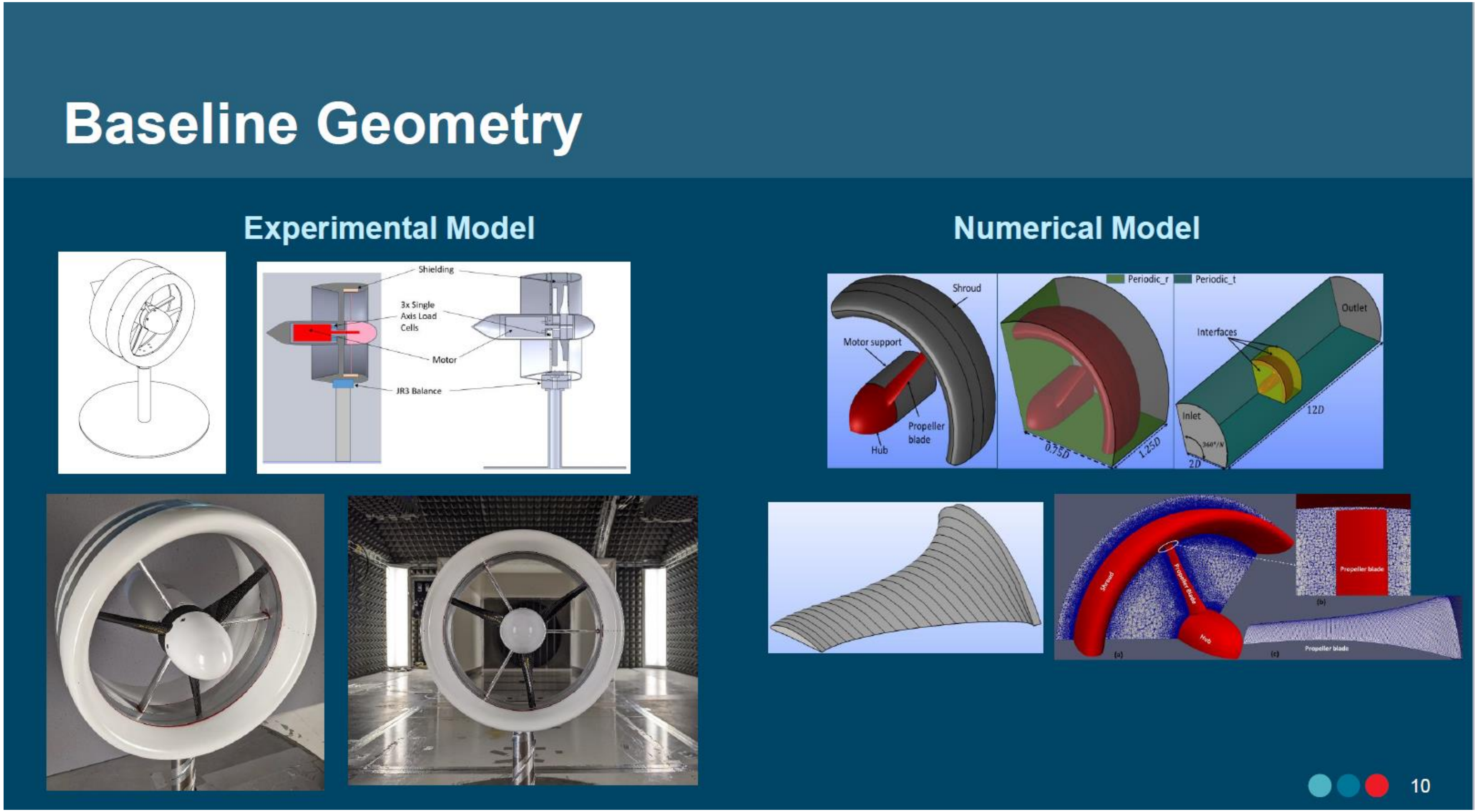
Guest Presentation (Philip McCarthy)



P. McCarthy, "UAM Propulsor Aeroacoustic studies at the NRC Canada," presented at the Urban Air Mobility Noise Working Group Subgroup 1, July 14, 2022

Guest Presentation (Philip McCarthy)



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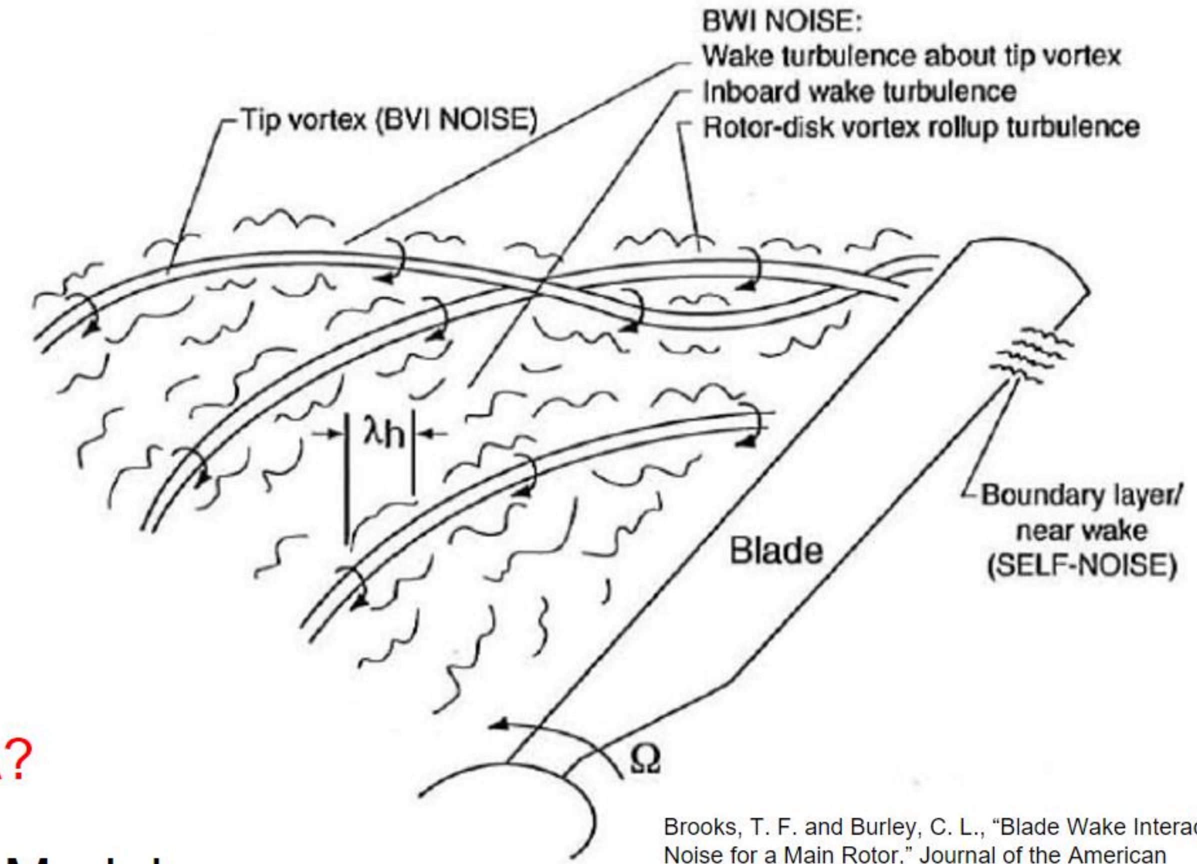
Guest Presentation (Chris Thurman)

Rotorcraft Noise Sources:

- Deterministic (tonal)
  - Thickness noise
  - Loading noise
- Stochastic (broadband)
  - Blade self-noise – BPM Model
  - Blade-wake interaction (BWI) noise – N/A?
  - Turbulence ingestion noise (TIN) – Amiet Model



Brooks, T. F. and Burley, C. L., "Blade Wake Interaction Noise for a Main Rotor," Journal of the American Helicopter Society, Vol. 49 (1), 2004, pp.11 - 27.

C. Thurman, "Surrogate Modeling and Characterization of Blade-wake Interaction Noise for Hovering sUAS Rotors using Artificial Neural Network," presented at the Urban Air Mobility Noise Working Group Subgroup 1, July 14, 2022

Guest Presentation (Chris Thurman)

PROBLEM Blade-Wake Interaction (BWI) can be a significant contributor to Urban Air Mobility (UAM) noise. No accurate prediction modeling capability exists for BWI noise, which occurs at mid-frequency range where BPM self-noise model under-predicts.

OBJECTIVE

- Develop BWI noise prediction model to characterize BWI noise model hovering rotors over a range hover operating conditions.

APPROACH

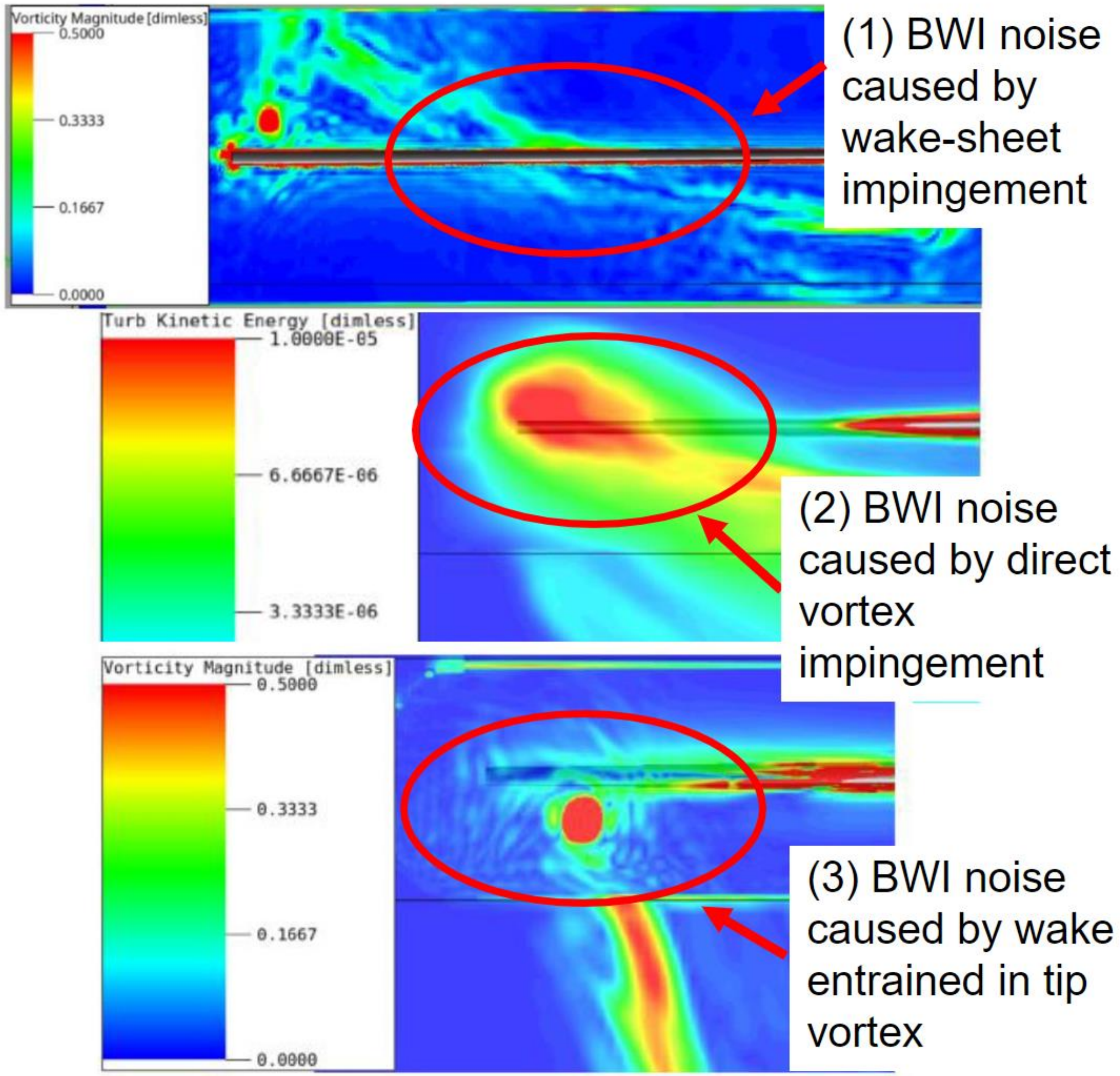
- Using Design of Experiments (DoE) with a design space over characteristic rotor geometric, perform lattice-Boltzmann simulations to extract BWI noise, and develop a discrete BWI noise metric using machine learning.

ACCOMPLISHMENTS

- Completed PhD
- Showed vortex miss distance has dependence on CT and not T.
- Showed 3 types of BWI noise caused by: (1) wake-sheet impingement during turbulent-wake state and mild vertical descent conditions (2) direct vortex impingement, (3) wake entrained in tip vortex. (See Figures).

SIGNIFICANCE

- Establish database and prediction modeling capability to create BWI noise model capable of prediction at any frequency/observer location.
- Showed for the first time the (1) significance of BWI noise for small hovering rotors and (2) three types of BWI noise.
- Determined the most influential parameters for BWI noise and fully characterized BWI noise for small hovering rotors, information that could be used to develop mitigation strategies.



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Database of Datasets

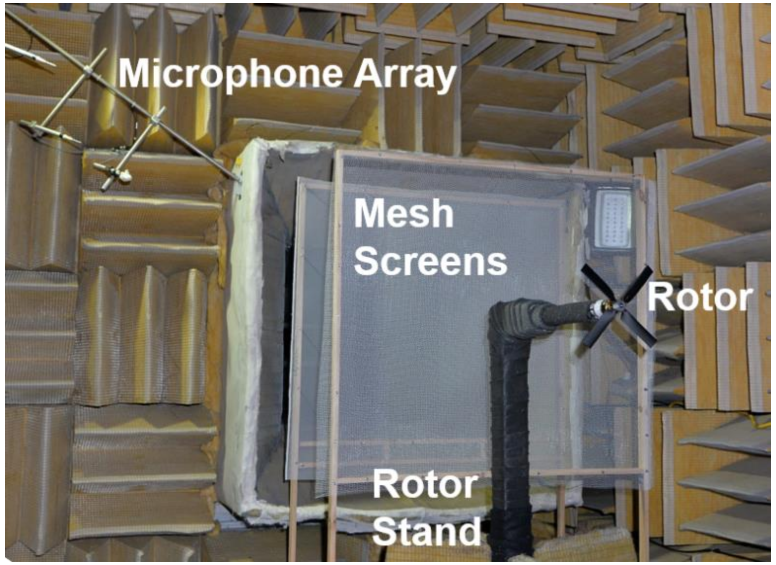
1. Ideally twisted rotor dataset (released 2021)
    - Hover, multiple RPMs and pitch angles in SHAC facility
    - Initial study and prediction of broadband noise from AAM rotors
2. Helically twisted proprotor design optimization (2022)
    - Hover and multiple forward flight velocities in LSAWT facility
    - Includes four different proprotor designs and performance and acoustic data
3. Installed proprotor design optimization (late 2023)
    - Including broadband noise, installation, and perception in optimization cycle
    - Will include another LSAWT entry and TM report out
4. Optimum hovering rotor (early 2023)
    - Three different blade materials to highlight LBL-VS noise
    - SHAC entry with acoustic data

➢ Other datasets are welcome!

1) Ideally Twisted Rotor Dataset (2021)

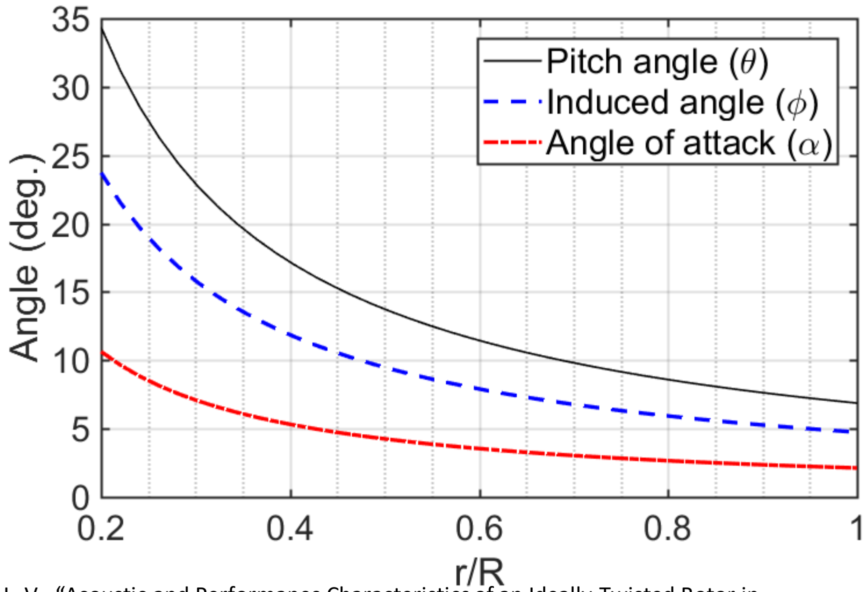
- Ideally, radially constant induced inflow to minimize induced power.
- From blade element momentum theory (BEMT) in hover:

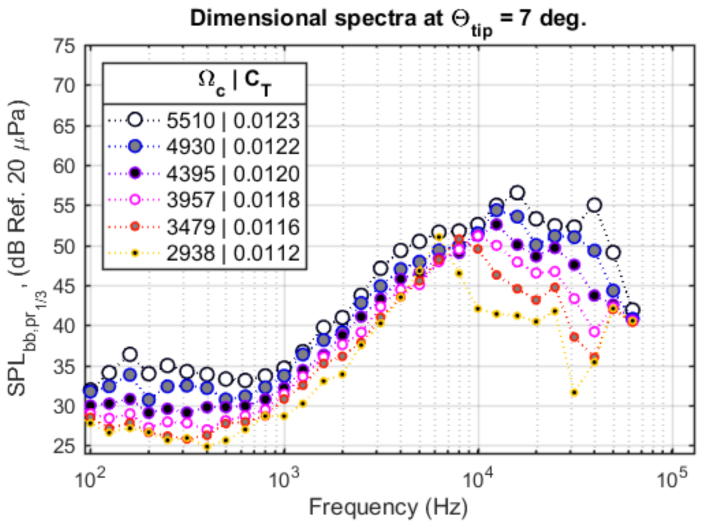
$$\lambda(r) = \frac{\sigma C_{l_\alpha}}{16}\left(\left(1 + \frac{32}{\sigma C_{l_\alpha}}\theta r\right)^{1/2} - 1\right) \qquad \theta = \frac{Constant}{r}$$



- Small Hover Anechoic Chamber (SHAC)
- Hover condition only
- Multiple surface materials (influence of roughness on broadband noise)

	Parameter	Value
Geometry	R (m)	0.1588
	c/R	0.20
	Θ_{tip} (°)	6.9
	N_b	4
	σ	0.255
Operating Condition	C_T	0.0137
	M_{tip}	0.27
	Ω_c (RPM)	5500

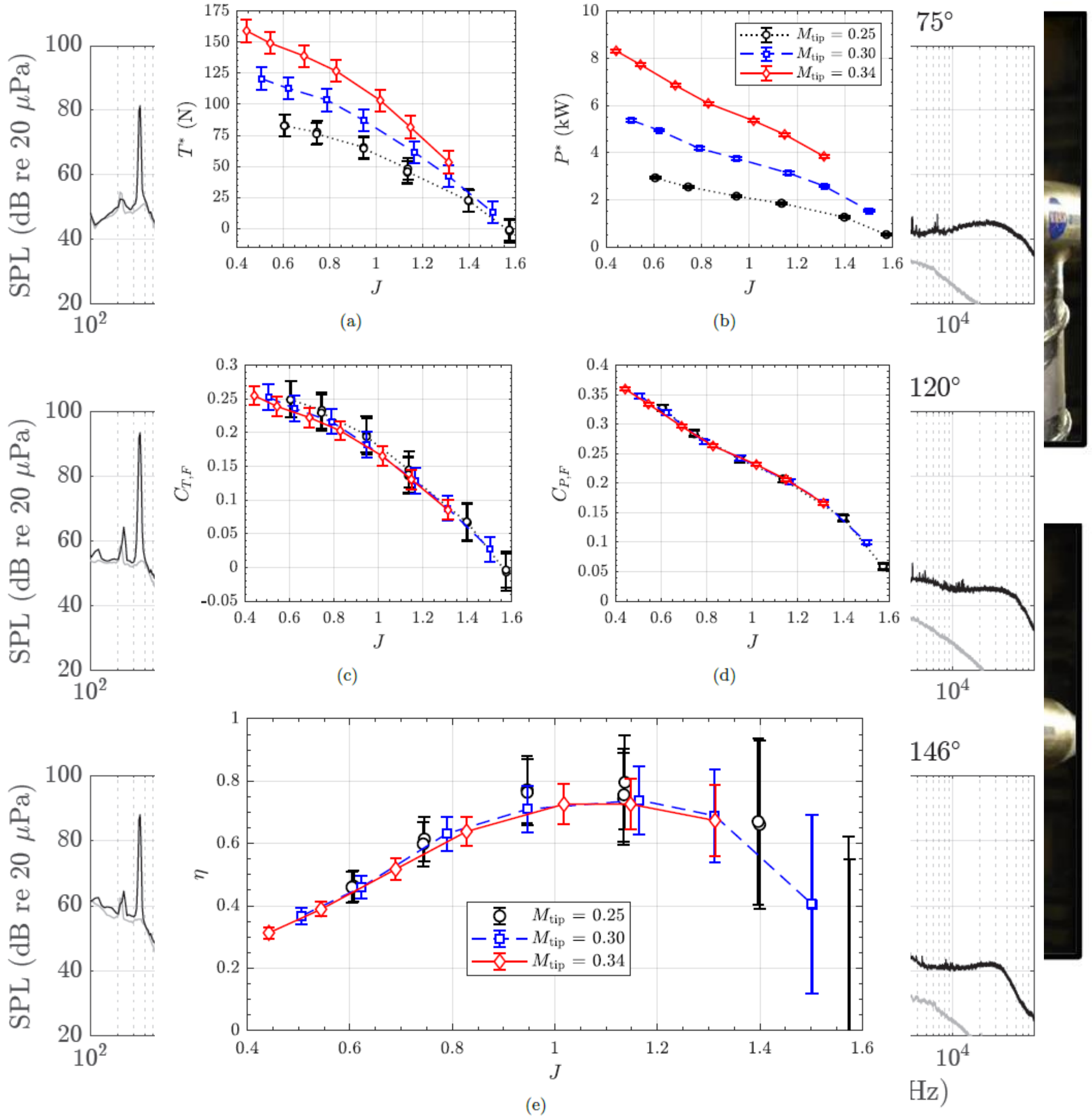




- Pettingill, N. A., Zawodny, N. S., Thurman, C. S., and Lopes, L. V., "Acoustic and Performance Characteristics of an Ideally Twisted Rotor in Hover," January 11–12 & 19–21 2021, AIAA Paper No. 2021-1928, presented at AIAA Scitech 2021 Forum. doi:10.2514/6.2021-1928.

2) Helically Twisted Rotor Design Optimization (2022)

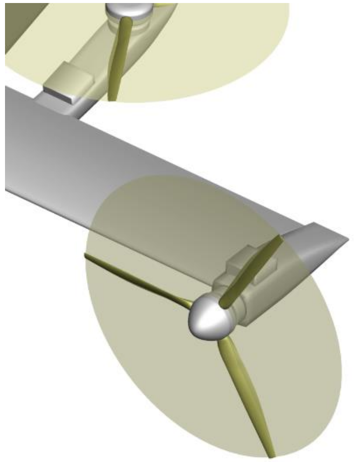
- Started with very noisy helically twisted rotor (a.k.a. C24ND)
- Low-fidelity and high-fidelity optimization efforts resulted in Opt-III and COPR-3 and COPR-5 designs
- Low Speed Aeroacoustic Wind Tunnel (LSAWT)
- A first TM is near publication documenting tunnel entry and measurement data
  - Performance data
  - Acoustic data
- A second TM early next year comparing predictions to measurements and will draw conclusions on acoustic trends



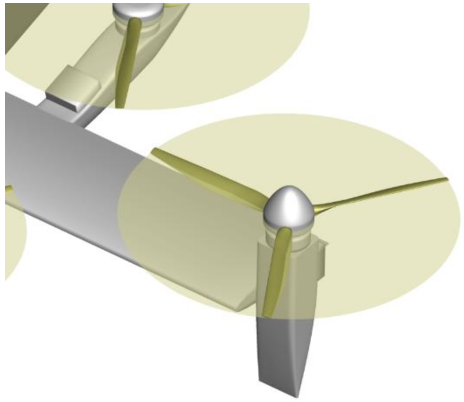
3) Installed COPR-3 Proprotor (Available Late 2023)

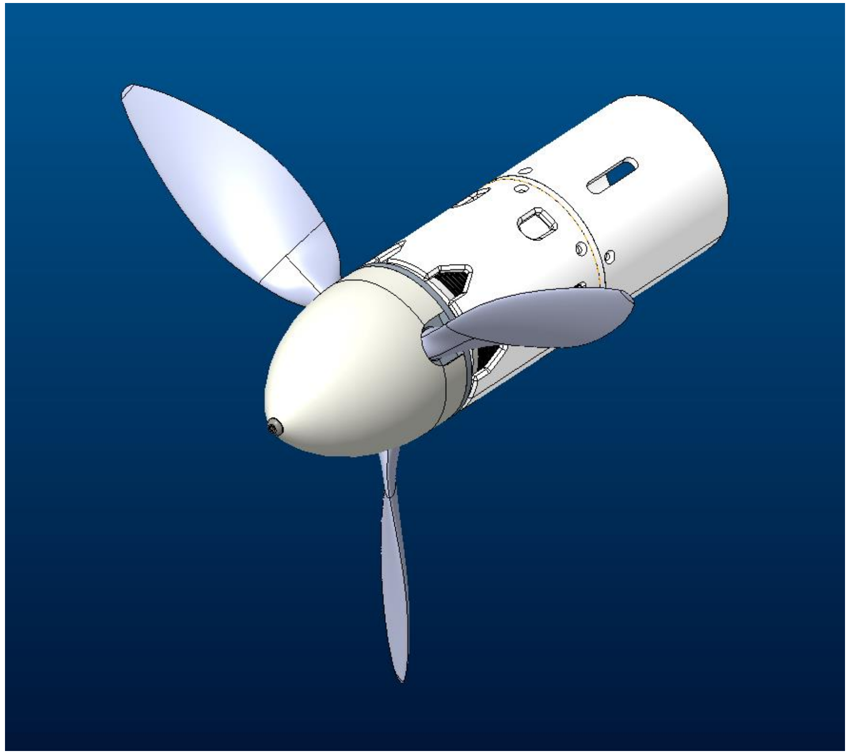
- Installed proprotor test data will be made available via UNWG SG1
- Will include geometry of baseline, wing, and multiple optimized geometries
  - Different aerodynamic, source noise, and perception constraints lead to different designs
- Wing/prop configurations based on RAVEN vehicle
  - Ratio of wing to proprotor radius ~ 1
  - Due to tunnel limitations, proprotor will have 1 ft diameter
    - COPR-3 has 2 ft diameter, allows for proprotor scaling study

Forward Flight Proprotor



Hover Proprotor





4) Optimum Hovering Rotor (Available Early 2023)

- Minimum induced power requirement
- Minimum profile power requirement

$$\theta_{tw}(r) = \frac{1}{r}\left(\frac{4C_{T_{design}}}{5.73\sigma(r)} + \sqrt{\frac{C_{T_{design}}}{2}}\right) - \alpha_0$$

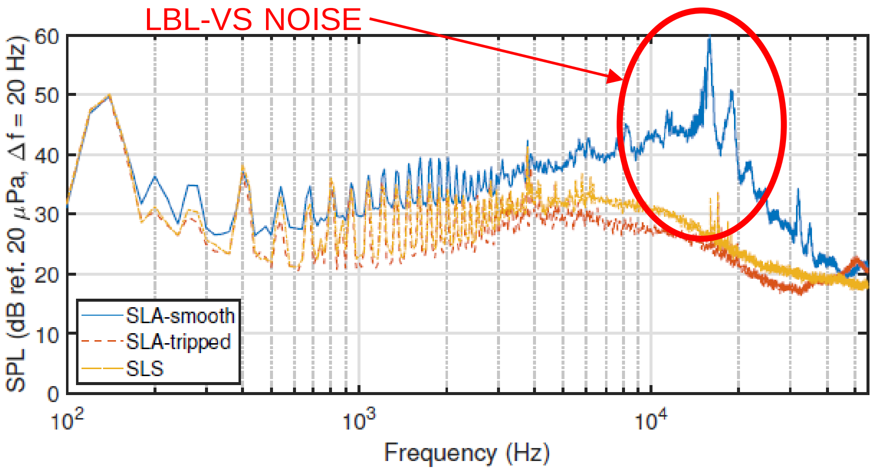
- Focusing on LBL-VS noise and how to mitigate
  - Dependent on surface materials

> ➢ SLA-smooth (Protolabs – Accura Xtreme)
> ➢ SLA-tripped (Protolabs – Accura Xtreme with boundary layer trip)
> ➢ SLS (Protolabs – PA12 Mineral-filled)

- Planned dataset release spring UNWG meeting

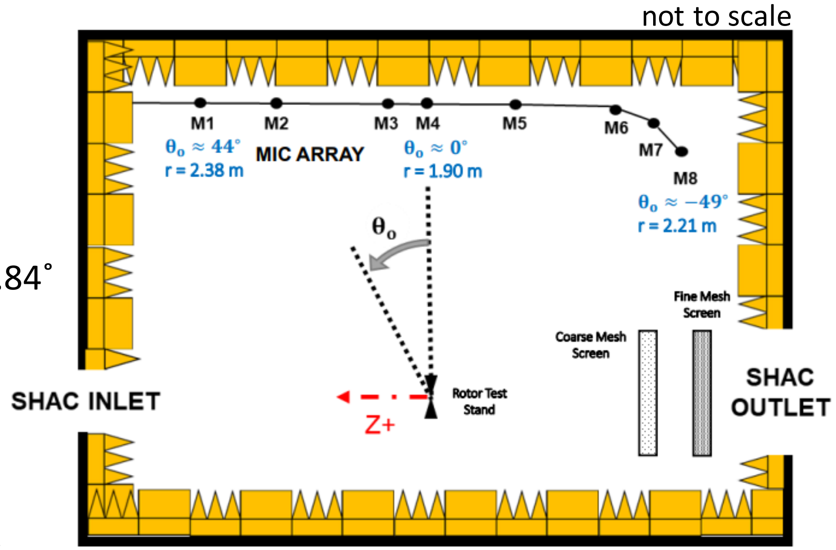
SLS

SLA-tripped



Design conditions

- R = 7.5 in
- Ω = 2500 - 5000 RPM
- T_{design} = 1.875 lb
- c_{tip}= 0.75 in
- TE bluntness = 0.03c(r)
- NACA 5408 airfoil: α_0 = -4.84˚
- Taper = 2.25 to 1



- Thurman, C. S., Zawodny, N. S., Pettingill, N. A., "The Effect of Boundary Layer Character on Stochastic Rotor Blade Vortex Shedding Noise," May 10–12 2021, presented at Vertical Flight Society's 78th Annual Forum & Technology Display. doi:10.4050/F-0078-2022-17428
- Pettingill, N. A., Zawodny, N.S., Thurman, C.S., "Aeroacoustic Testing of UAS-Scale Rotors for a Quadcopter in Hover and Forward Flight," June 14–17 2022, AIAA Paper No. 2022-3110, presented at AIAA Aeroacoustics Conference. doi:10.2514/6.2022-3110.

Breakout Session Topics

1. A dedicated technology maturation effort be performed on the most promising noise mitigation technologies and that opportunities be sought to evaluate their efficacy in flight.

2. Manufacturers work with appropriate organizations to develop low noise guidance for piloted operations and automated low-noise procedures for autonomous operations that are specific to their products.