Capabilities and Preliminary Checkout of a New Propeller Test Stand

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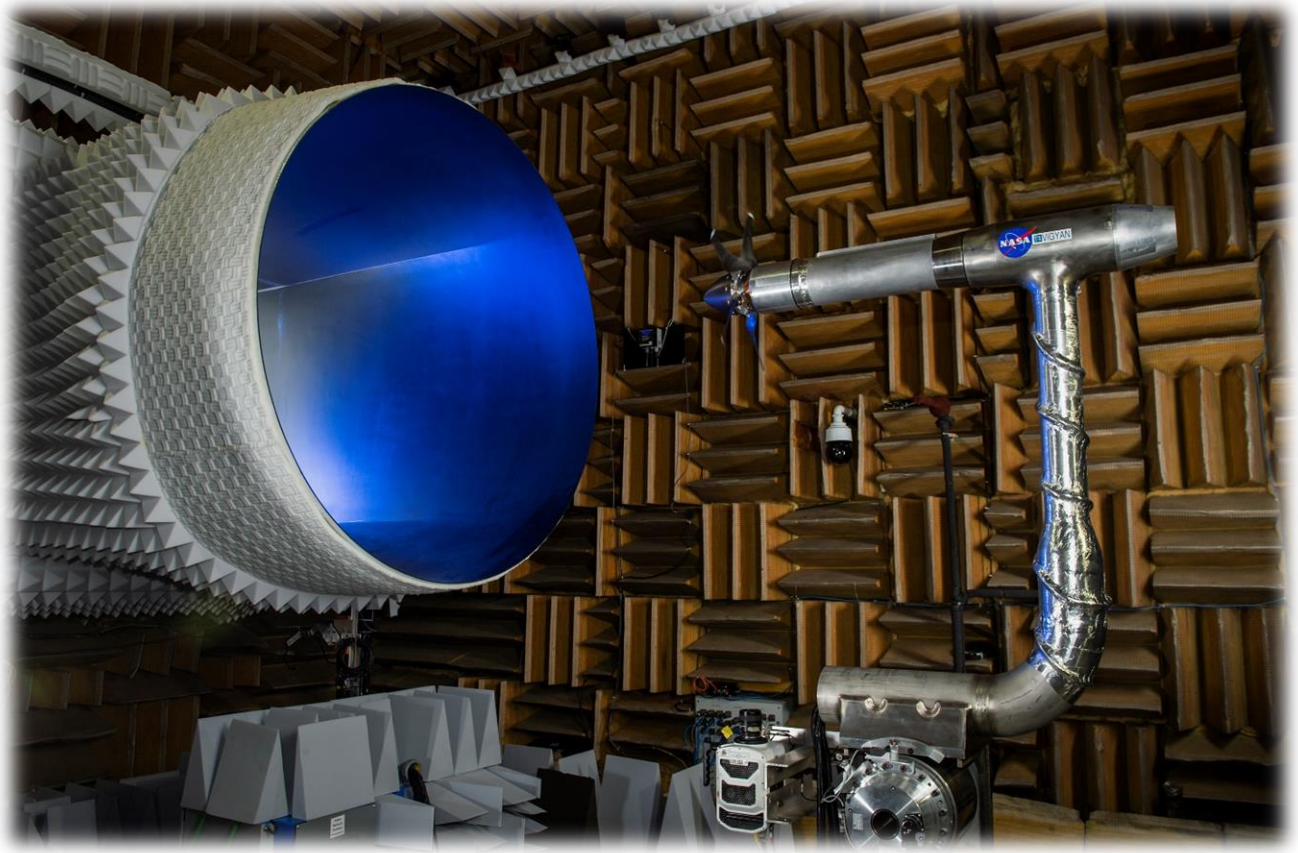
April 14th, 2021

Outline

- **Capabilities (Out of the Box)**
- **Tested Articles (So Far…)**
- **Sample Test Data**
- **Observed Limitations**
- **Recent Improvements**
- **Upcoming Work**



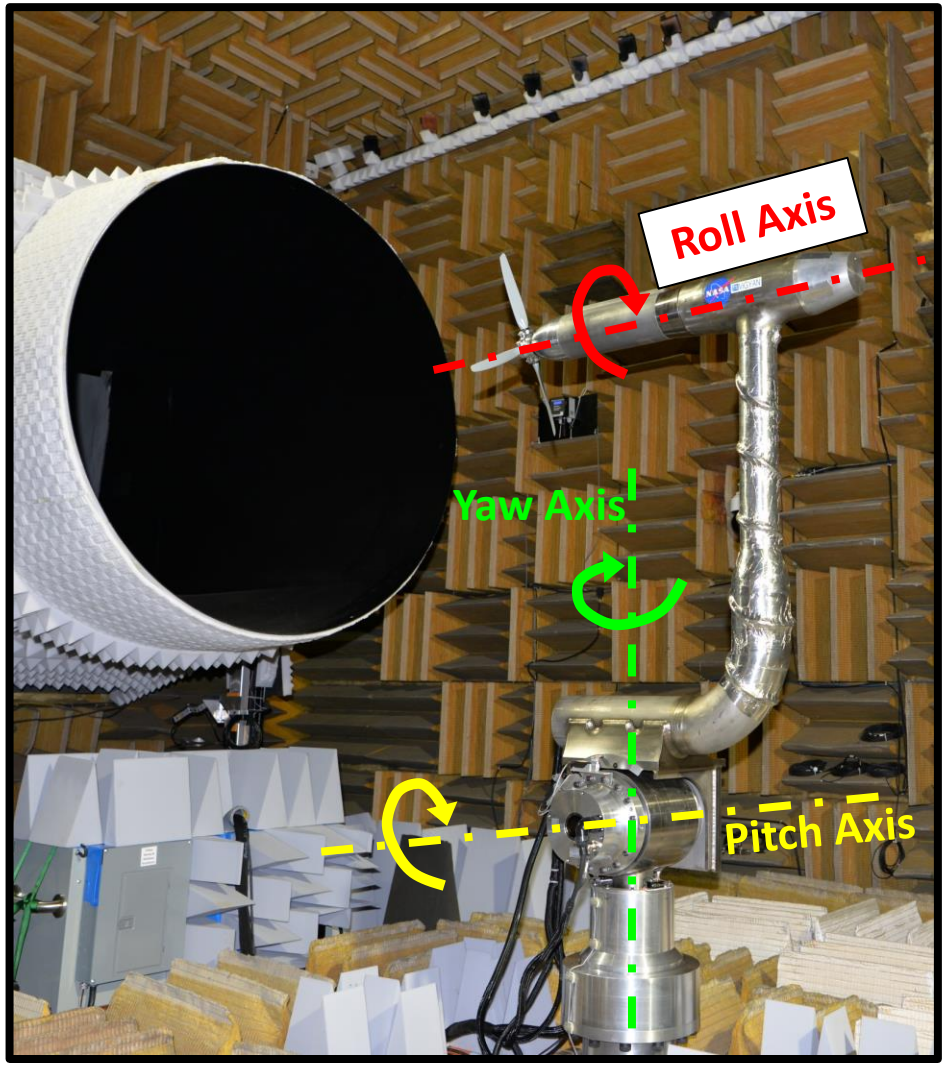
Key Capabilities

- Rotation rates
  - $250 \leq \Omega \leq 16{,}000$ RPM
  - Resolution: ± 1 RPM
  - Controlled by Variable Frequency Drive (VFD)

- Power capability
  - 52 kW at 15,000 RPM
  - Short term overdriving possible

- Roll, pitch, yaw
  - Roll: ± 180 deg.
  - Pitch: ± 25 deg. (for non-zero yaw conditions)
  - Yaw: ± 90 deg.
  - All to an accuracy ± 0.1 deg.

- Onboard measurements
  - Thrust and torque (and potentially off-axis loads)
  - Triaxial accelerometer
  - Qty. 4 temperature probes (fwd + aft motor, fwd + aft bearing)

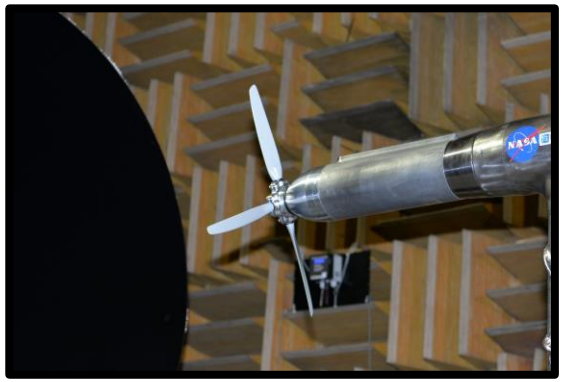


Tested Articles

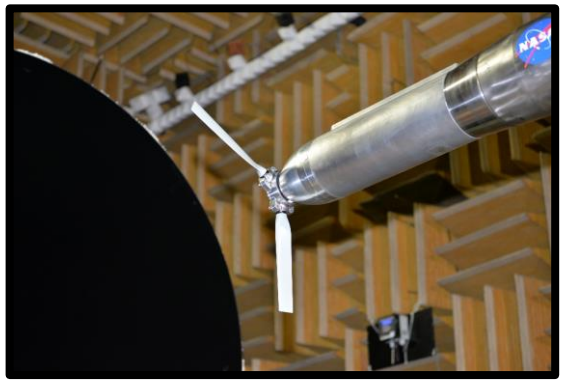
- Have tested 3 propellers thus far
  - 4-bladed L26H propeller
  - 3-bladed helically twisted propeller
  - 5-bladed foldable high-lift propeller (X-57 Maxwell)

- Encountered load limitations (torque) on all 3 propellers
  - Only smaller calibration range available during testing
  - Now have two load cells, each with low, mid, and high calibration ranges

L26H propeller (4-bladed)

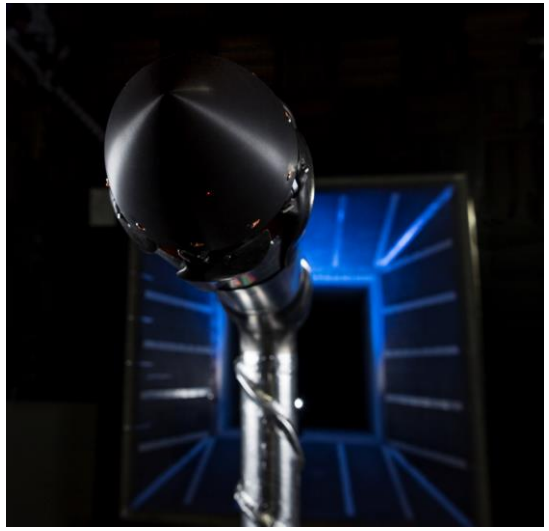


C24ND propeller (3-bladed)

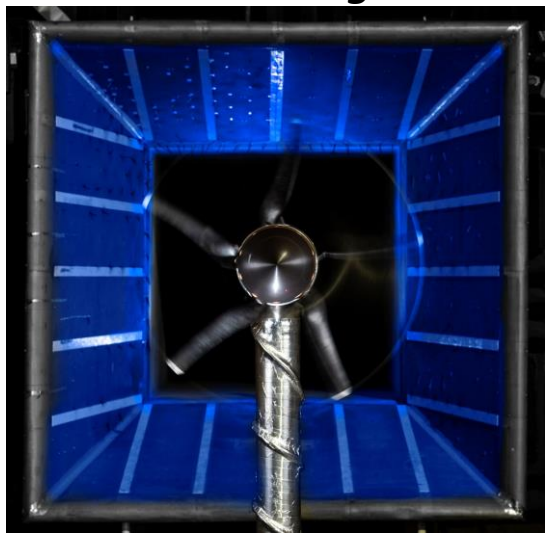


X-57 High-Lift Propeller (5-bladed)

Stowed



Rotating



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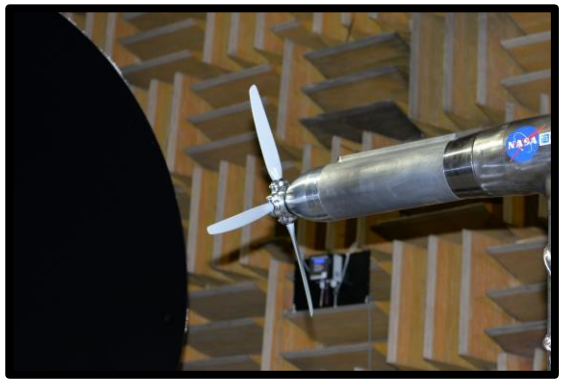
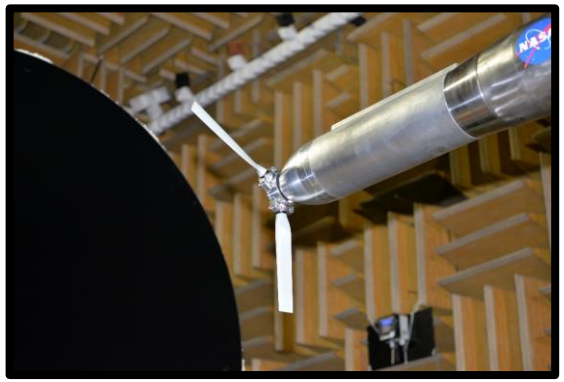


C24ND propeller (3-bladed)



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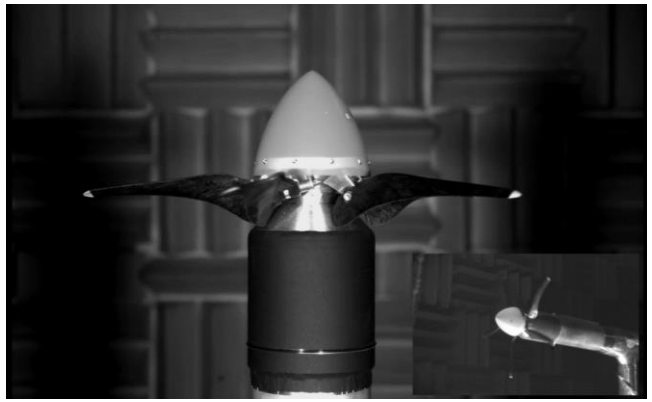
Deployment

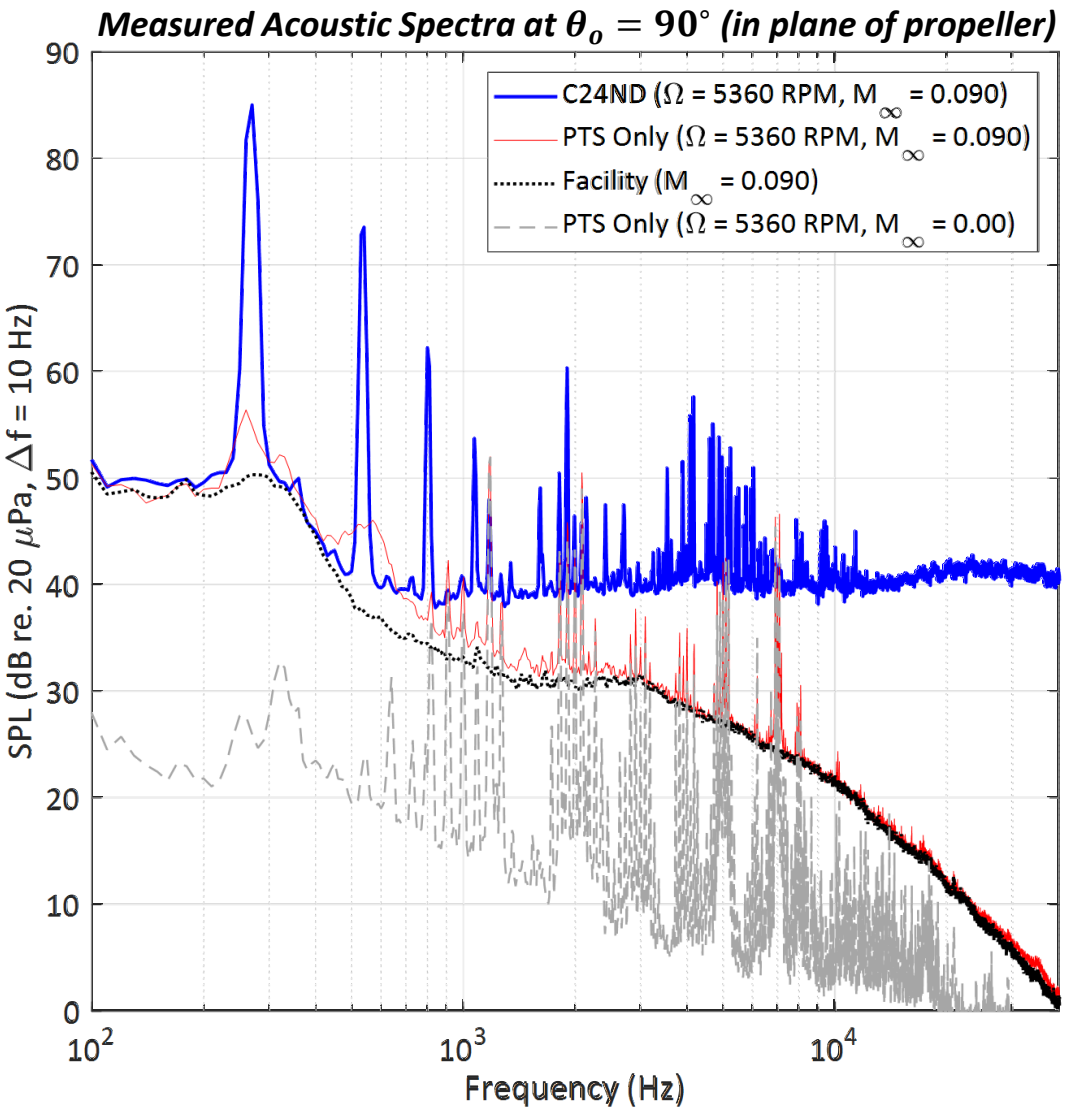
High Frame-Rate Videos



Sample Test Data

Facility, PTS, Propeller Noise

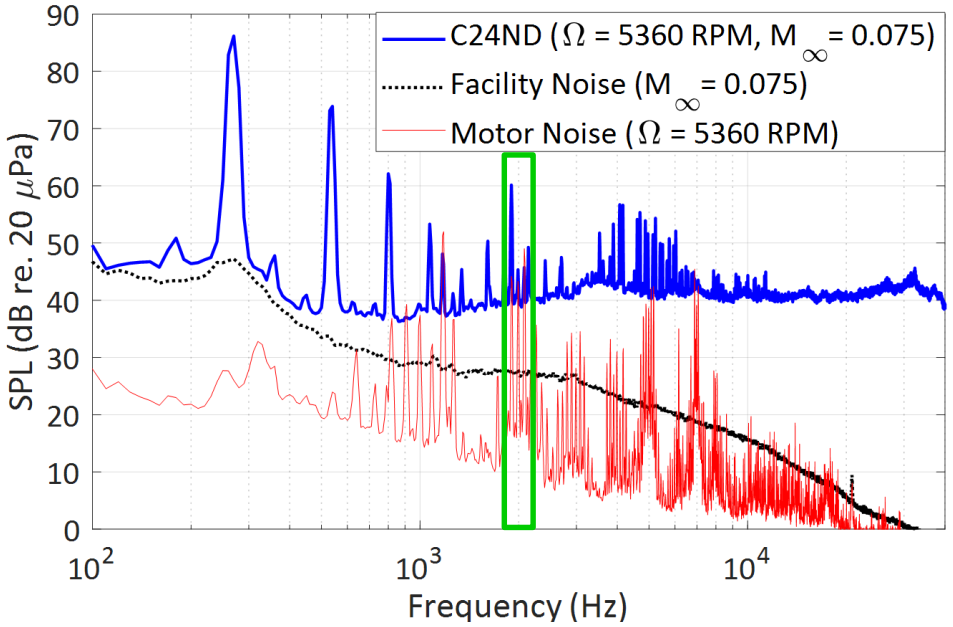
- Goal of distinguishing between different noise sources in facility
- PTS motor observed to emit tonal acoustic energy across spectrum at low amplitudes
- Motor noise observed to be affected little by freestream flow
  - Slight additional low frequency noise observed
  - Believed to be due to flow over spinning empty hub
- Majority of motor tones seen to be affected by cases of loading by propeller

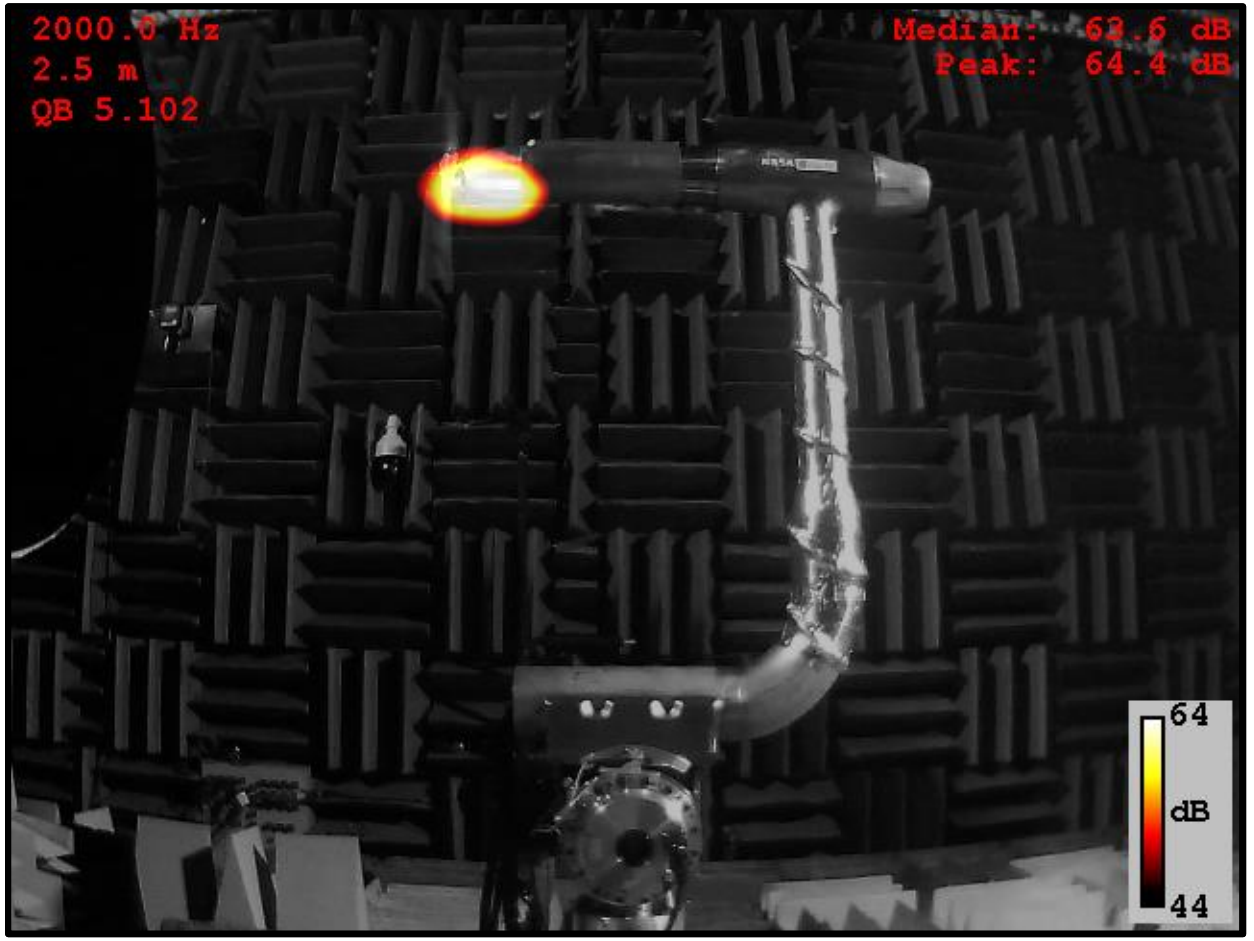


Sample Test Data

Facility, PTS, Propeller Noise (contd.)

- Commercial ACAM 120 to visualize noise sources at select frequency ranges (beamforming)
- Some tonal noise around 2 kHz from bearing/nacelle interface
- Slight acoustic energy off PTS strut at high frequencies





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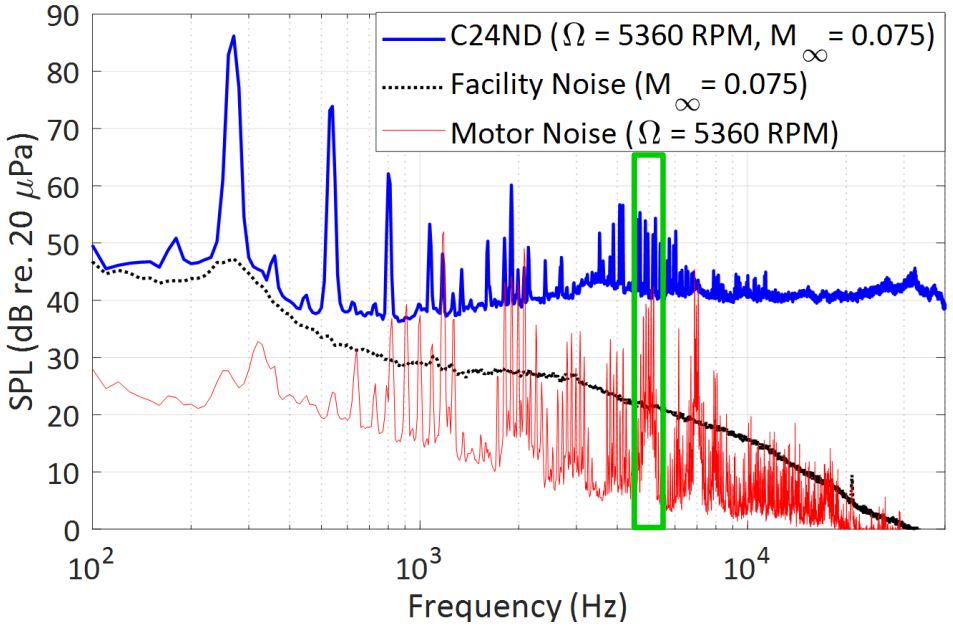

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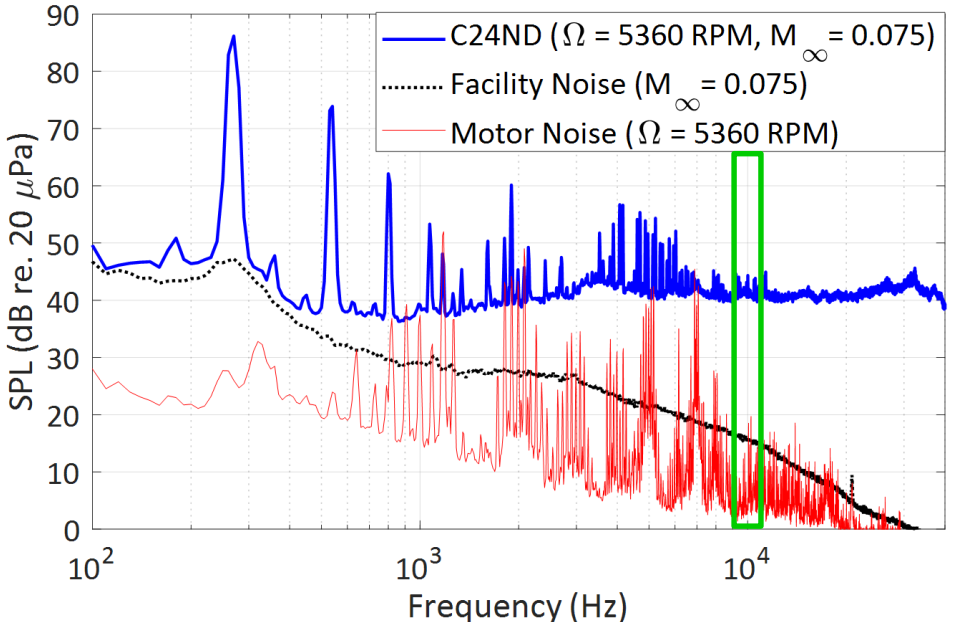

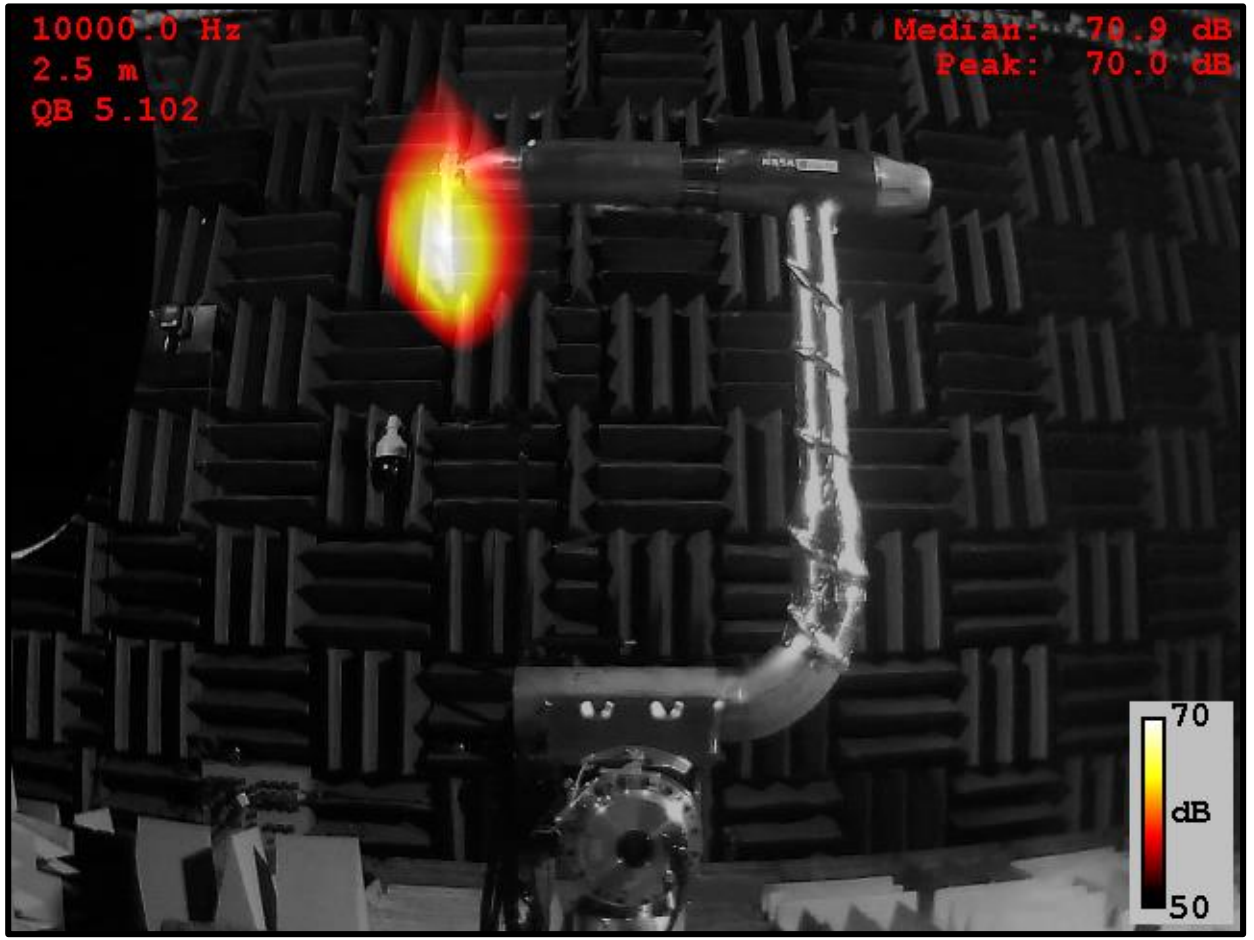

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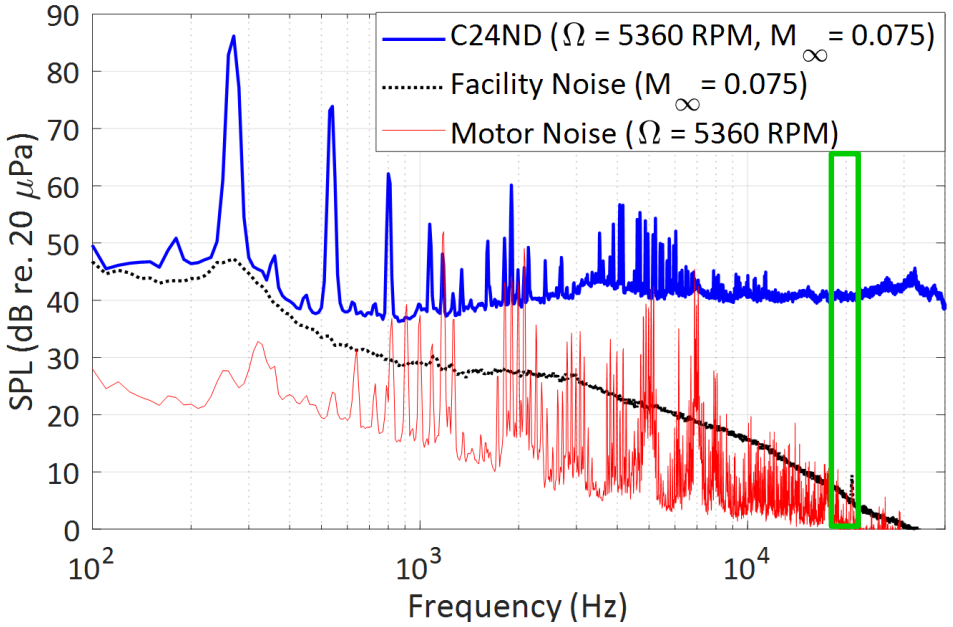

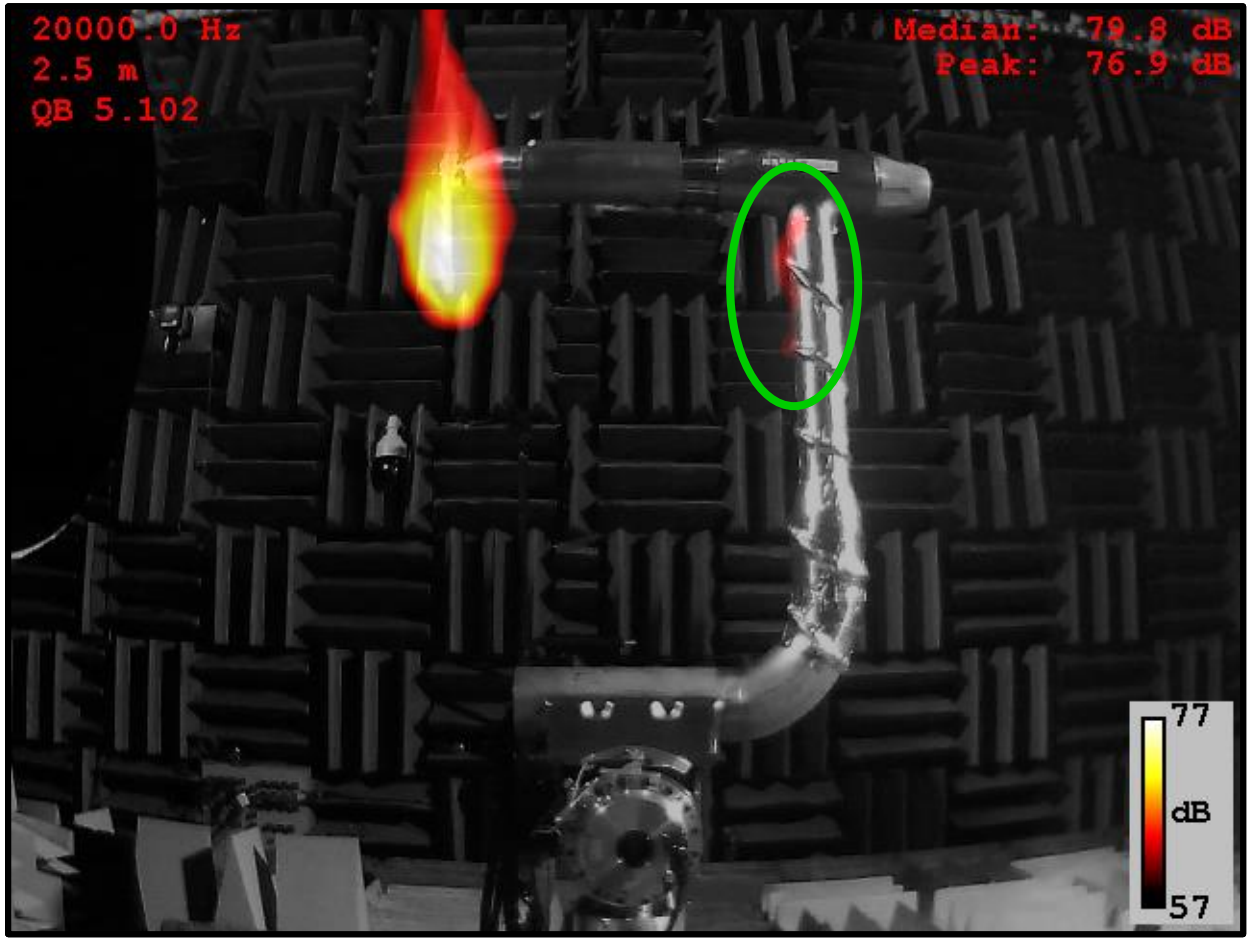

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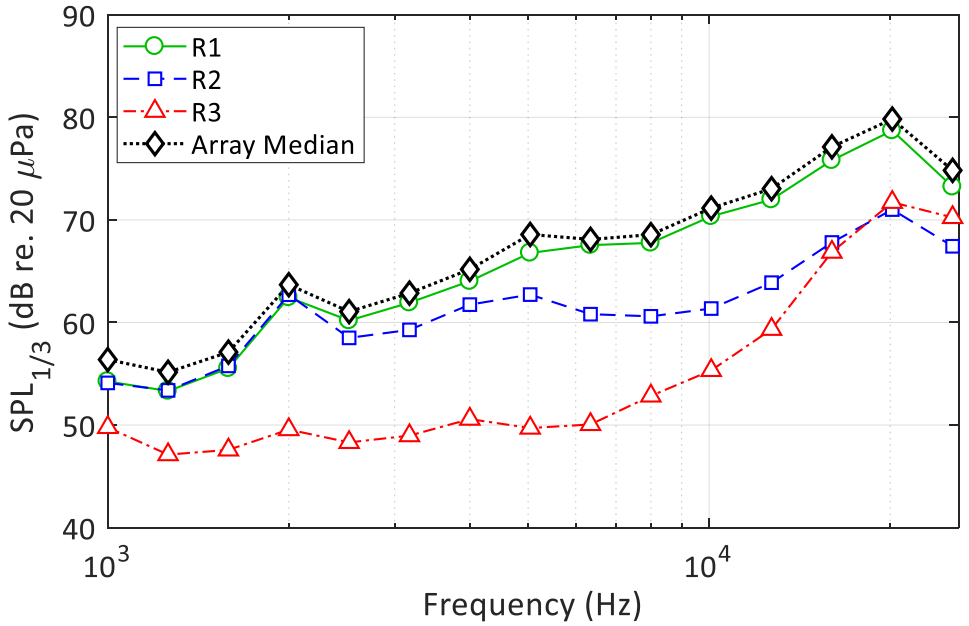
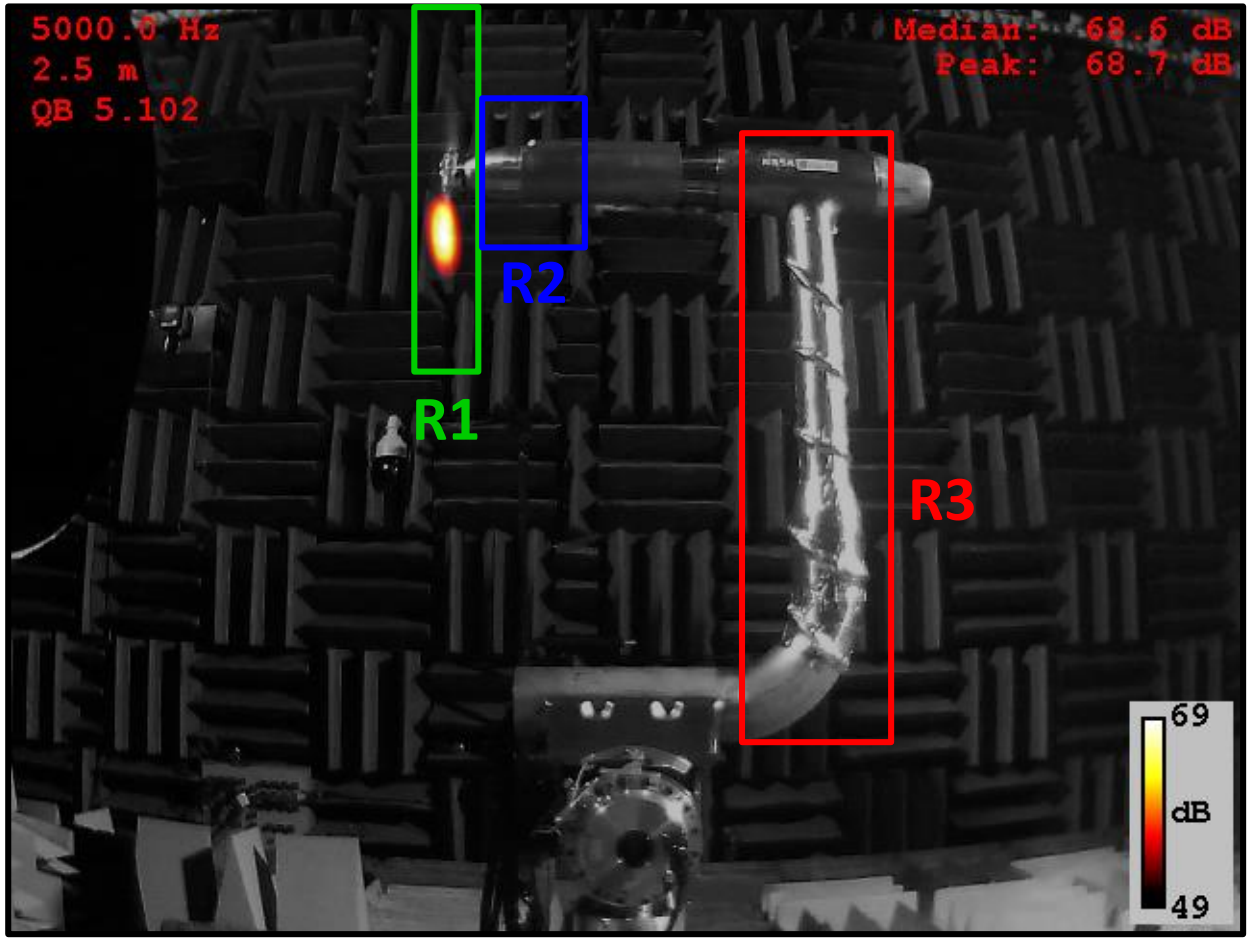


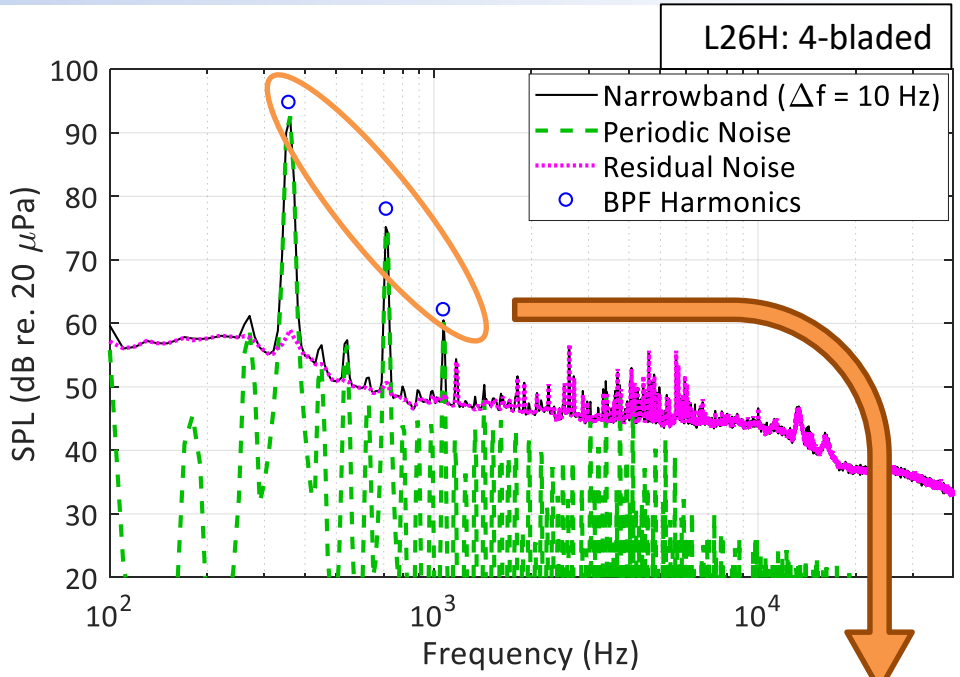


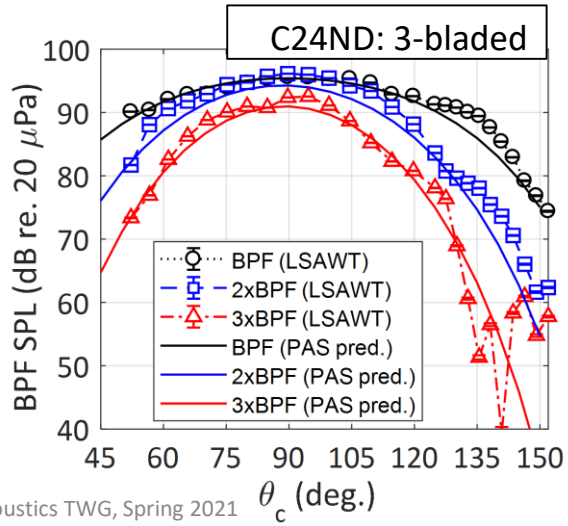
Majority of measured noise coming from propeller blades.

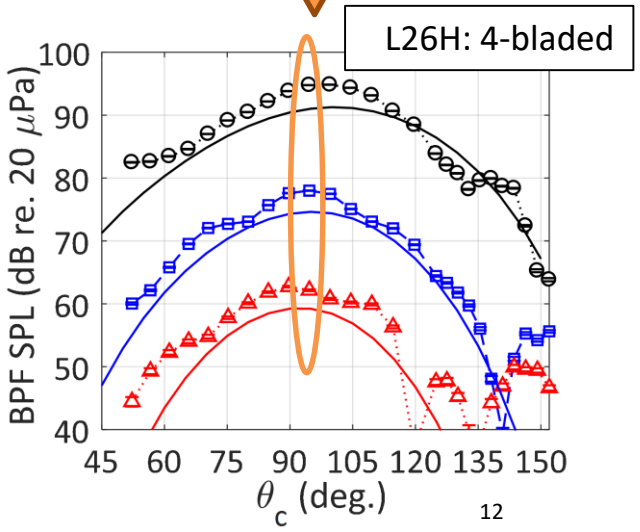
Sample Test Data

Propeller Tonal Noise and Predictions

- PTS exhibits excellent rotation rate stability
  - Observed to hold condition to ±1 RPM
  - Allows reliable periodic averaging
- Initial predictions performed for the 3- and 4-bladed propellers using ANOPP-PAS
  - Good agreement in noise trends at tonal frequencies of interest
  - Indications of facility reflections/scattering at aft observer locations



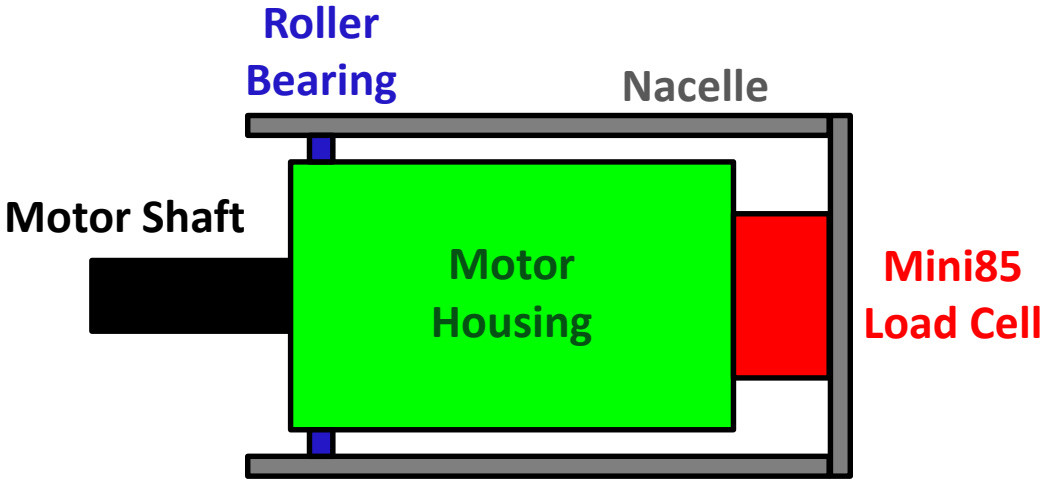




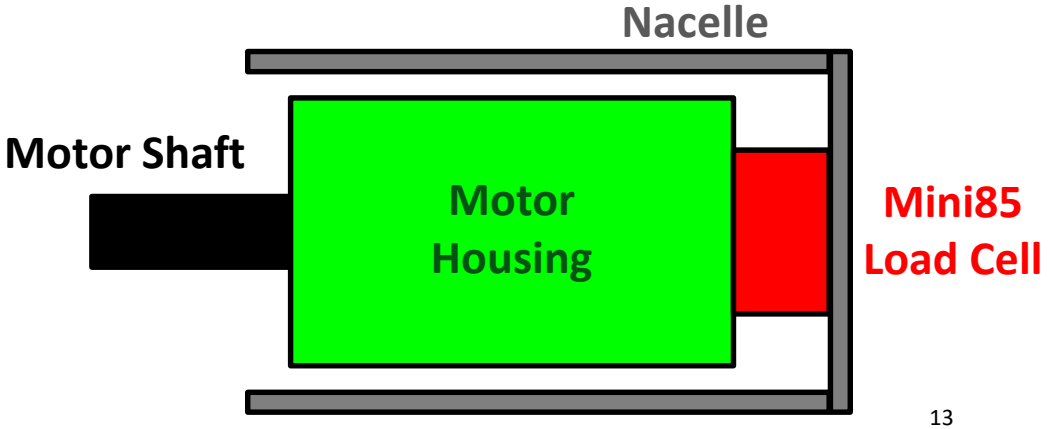
Observed Limitations

- Current load cell limits
  - Thrust: **±210, ±420, or ±840 lbf**
  - Torque: **±185, ±370, or ±740 in-lbf**
- Load cell drift issues
  - Thermal drifts observed on thrust measurement (Fz) during checkout entry
  - Mitigation methods currently being implemented
- Bearing configuration limitations
  - Baseline: Can only measure Fz and Mz components (thrust and torque)
  - Alternate: Removal of roller bearing to measure cross loads (Fx,y and Mx,y)
  - Conversion will reduce load resolution and accuracy, possibly increase load dynamics
  - High moment load due to unbraced motor cantilever
- Propeller hub mechanical limitations
  - Ground adjustable pitching of blades
  - Requires mechanical adjustment for each desired pitch condition

Baseline Load Cell Configuration



Alternate Load Cell Configuration



Recent Improvements

- **Coolant line insulation**
  - Plastic sleeves inserted in nacelle aft surface
  - Insulates load cell from temperature gradient

- **Sensor and power wire routing**
  - Routing holes opened up to allow maximum clearance
  - Reduces likelihood of wiring under tension
  - Insulation of instrumentation and coolant lines

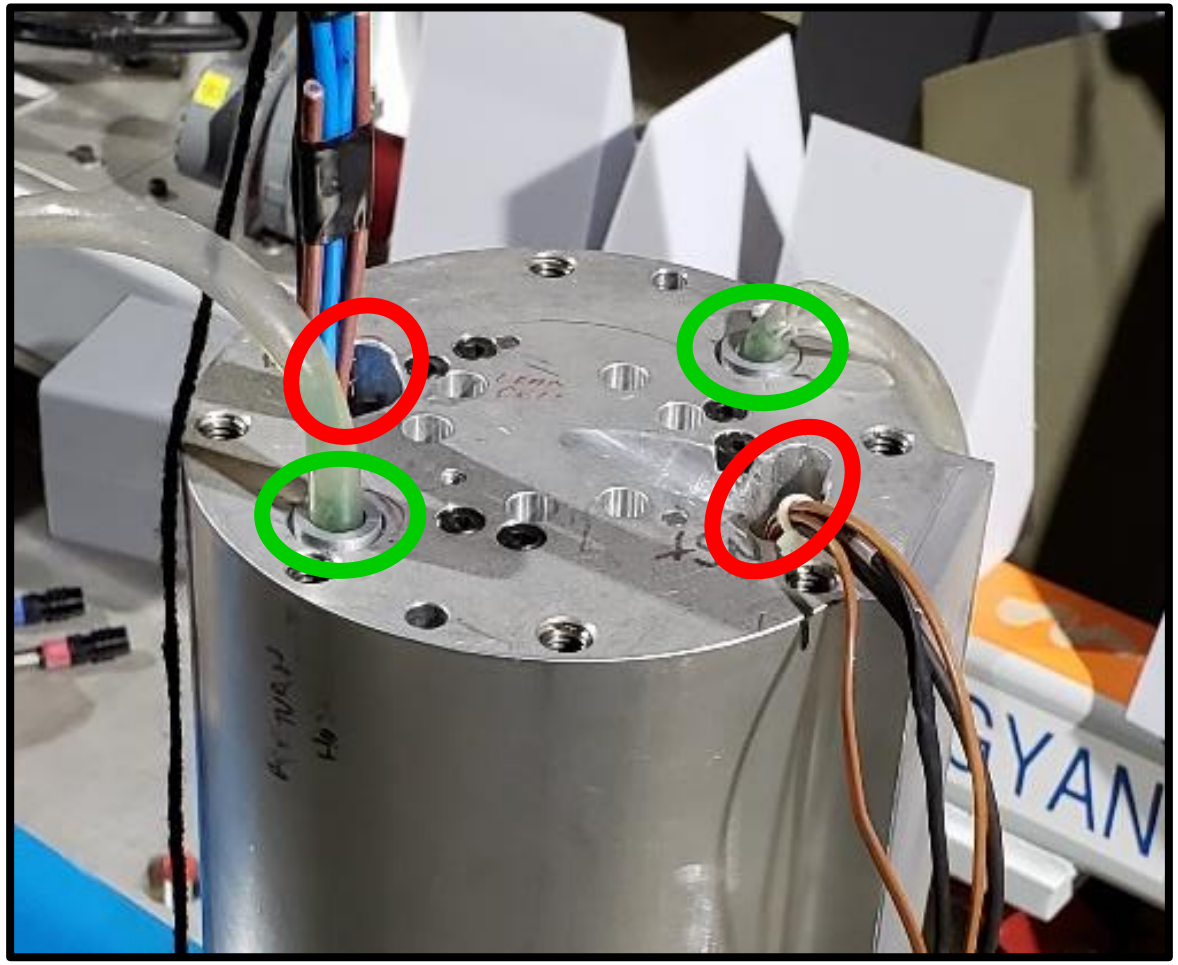


Image of nacelle aft surface (load cell located on inside surface)

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- **Sensor and power wire routing**
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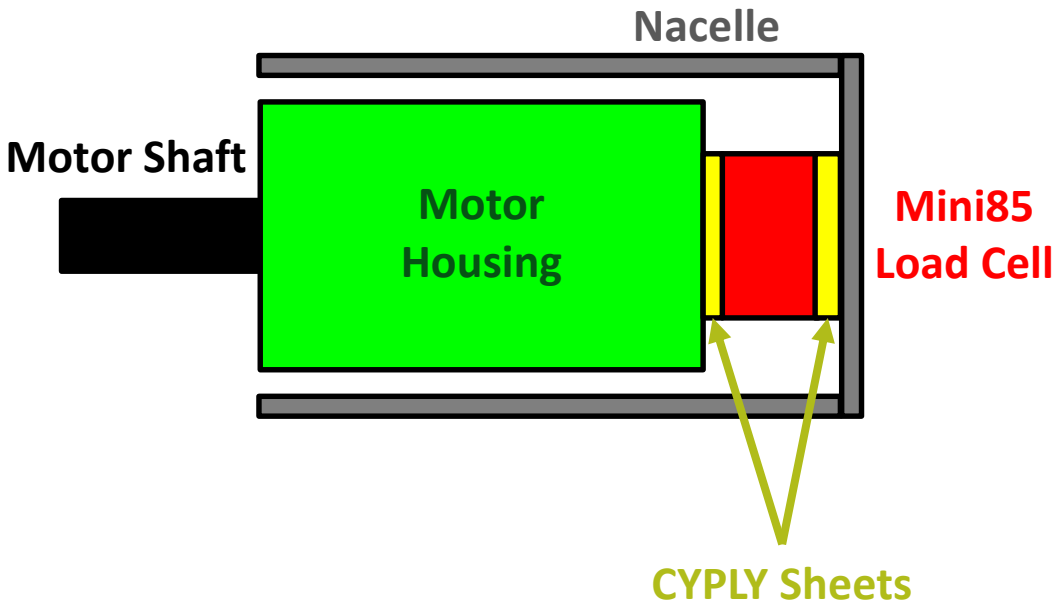
  - Insulation of instrumentation and coolant lines
- **Insulation of load cell contact surfaces**
  - Layers of CYPLY material inserted between measurement and mounting surfaces
- Testing of PTS **without front roller bearing present**
  - Found to greatly improve measurement accuracy and repeatability of thrust measurements
  - Currently assessing limitations (loading, rotation rate, etc.)

Current Load Cell Configuration



Upcoming Work

- Currently preparing for rotor stability test **(X-57)**
  - X-57 high-lift propeller will be the testbed
  - Test aimed at identifying blade damping parameters to inform models
- PTS being used in noise optimization validation effort **(TTT)**
  - Adjoint-based propeller design
  - 3-bladed propeller (C24ND) serving as baseline configuration
- Also planned for testing in the 14x22 wind tunnel **(RVLT)**
  - Part of the Vertical Lift Propeller Noise Test (VLPNT)
  - Aimed at simulating complex flow and noise conditions associated with vectored thrust UAM vehicles
  - Offers validation opportunities for NASA and affiliated codes (OVERFLOW2, CAMRAD II, CHARM, etc.)

Acknowledgments

- LSAWT personnel **(BIG TIME!)**
  - John Swartzbaugh
  - Stan Mason
  - Jeff Collins
  - Mick Hodgins
  - Bryan Lamb
- Members of Aeronautics Systems Analysis Branch (ASAB)
  - Brandon Litherland
  - Nick Borer
- ViGYAN Inc.
  - Sundareswara Balakrishna
  - Mike Makowiec
  - Richard White
- Funding
  - NASA RVLT project
  - Army
    - Ben Sim
    - James Stephenson
    - Oliver Wong

Thank You.

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