X-57 “Maxwell” High-Lift Propeller Testing and Model Development

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The X-57 “Maxwell”, NASA’s next manned X-plane, incorporates relatively small diameter, folding, electrically-driven propellers along the wing leading-edge that provide lift augmentation at low speeds.

14 CFR § 23.2110(b)

X-57 Mod IV flights will be the backbone of a means of compliance for low-speed handling for advanced air vehicles in response to recent changes to FAA airworthiness rules.
Novel propeller designs for advanced air mobility (AAM) vehicles can have traits that make accurate performance prediction challenging using traditional methods.

- Directly supports NASA ARMD ST3 & ST4:
  - Testing, model maturation, and standards development ensure U.S. leadership in AAM and the sustainability of National airspace and aviation.

X-57 and Revolutionary Vertical Lift Technologies (RVLT) Project collaborated to test two full-scale high-lift propellers (HLPs) in the Low Speed Aeroacoustic Wind Tunnel (LSAWT) at NASA Langley Research Center.

- Gathered performance and acoustic data to support model validation and improvements.
- Captured high-speed video to evaluate propeller stability, dynamics, and blade position.
- Performed shakedown test of RVLT’s new Propeller Test Stand (PTS).

LSAWT test helped to qualify propeller design and quantify performance and noise data, a critical piece of getting these unique propellers in the air.
X-57 Maxwell High-Lift Propeller Test Setup

- Mic Array
- HLP Assy
- PTS
- Facility Camera
- Acoustic Wedges
- Inlet Nozzle
- High-Speed Camera
- Corner High-Speed Camera (not shown)
The HLP demonstrated smooth and stable behavior throughout the test.
Multiple frames from high-speed capture are overlaid to create a digital “multiple exposure” image. Aligning these frames enables the examination of blade deflection and orientation at set conditions.

~ 3/8 inch difference at tip between 0 and 90 keas

Extreme centripetal loads and aerodynamic forces could cause these blades to want to stretch and detwist.
X-57 Maxwell High-Lift Propeller Test Results

➢ The LH propeller tracked with XROTOR model predictions remarkably well.
➢ Right-hand (RH) prop shows reduced performance compared to the left-hand (LH) prop.
➢ RH blades ~5% lower weight than LH blades. RH blades may partially unload at higher RPM.

![Graph showing propeller performance](image)

RH propeller exhibits ~16% reduction in torque for the same RPM.
X-57 Maxwell High-Lift Propeller Test Results

➢ Thrust measurements varied considerably due to PTS load cell issues.
  • Load-cell cross-loading and heat soaking caused drift in data.
  • Lower CT values show increased error in part due to larger relative error to thrust.

➢ Fortunately, thrust data is more reliable at lower J where HLP is expected to operate.

BEM model does not include spinner and nacelle blockage which accounts for some of the difference here.
Test Results (contd.)

- Left-handed propeller found to exhibit higher fundamental tonal acoustic levels.
- Corroborated by higher torque levels and predictions revealing HLP to be dominated by aerodynamic loading noise.

![Diagram showing acoustic levels vs. frequency and observer angle](image)

**4800 RPM, 75 KEAS High-Power Takeoff**

**SPL (dB re. 20 \( \mu \)Pa, \( \Delta f = 10 \text{ Hz} \))**

- **RH**
- **LH**
- **Background (75 KEAS)**

**BPF SPL (dB re. 20 \( \mu \)Pa)**

- **RH**
- **LH**
X-57 High-Lift Propeller Test Impacts & Future Work

➢ Provided significant benefit to X-57 Maxwell and AAM vehicle studies.
  • Verified operation of a full-scale prototype of the flight propeller (~15 hours runtime).
  • HLP blade-element momentum (XROTOR) model predicted propeller performance well.
  • Obtained experimental data to improve modeled performance and dynamics.
  • No instability or excessive vibration observed under all operating conditions.
  • Generated practices for static balancing of a 5-bladed, folding, spring-loaded propeller.

➢ Knowledge transfer to public, other Agencies, and industry partners.
  • X-57 Technical Publications Page
    ▪ https://www.nasa.gov/aeroresearch/X-57/technical/index.html
  • Advances airworthiness standards and provides novel acoustic reference platform for comparison of AAM technologies.

➢ Future Work
  • X-57 folding HLP dynamics test to establish damping at the blade hinge.
  • Follow-up HLP performance test with similarly weighted blades from the same batch.
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Questions?