MFPT 2024 Abstract

Conceptual Foundation for the Conversion of the Advanced Noise Control Fan to an Un-Ducted/Open-Rotor Configuration in Support of NASA Project Risk Reduction

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The NASA Advanced Aircraft Transport Technology Project has initiated a Technical Challenge (TC) to impact the of next generation ducted and open fans to address the propulsion/airframe of future subsonic transport aircraft – Efficient Quiet Integrated Propulsors (EQuIP). While the EQuIP Technical Challenge emphasizes mid-to-high Technology Readiness Levels (TRL) 4-6, it is recognized that TRL 3 development is needed to support and focus the mid-TRL efforts. Open rotor acoustic levels have been an impediment to acceptance – current acoustic design techniques and reduction strategies are not sufficient to overcome that barrier. To address this limitation, the Advanced Noise Control Fan (currently a ducted fan) is being converted to an un-ducted/open-rotor configuration. This paper documents the conceptual foundation of a test rig that will be available to propulsion community for such development. This test rig configuration will be utilized for concept screening/development and for un-ducted/open-rotor technology maturity – with a significant impact on workforce development. risk-reduction.

Open rotor fans are being proposed for future subsonic transport aircraft to improve the efficiency of the propulsion system, as a critical contribution to aviation sustainability. The Advanced Noise Control Fan is being converted to an open rotor/un-ducted configuration (UnD/OR–ANCF). The UnD/OR–ANCF is expected to provide an enabling test bed to impact the development of next generation open rotor fans designs in support of NASA's EQuIP Technical challenge. Concepts and toolkits were developed during the development of the UnD/OR–ANCF. These can be used for design of specific rotor/stator configurations enabling exploration of various open rotor fan design facets (e.g. aeroacoustics, aeromechanics, aerodynamics). In addition to the expected technical role, the UnD/OR–ANCF will impact workforce development by providing a comprehensive test bed for multi-disciplinary and multi-institutional educational opportunities. The initial operating capability is the fall of 2024.

The Advanced Noise Control Fan (formerly the Active Noise Control Fan (ANCF)) was utilized in the design, test, and evaluation for technical risk mitigation of most of the innovative fan noise reduction technologies developed by NASA for over 20 years[1,2]. From 1994 to 2016, it was located in the NASA Glenn Research Center's (GRC) Aero-Acoustic Propulsion Laboratory (see **Error! Reference source not found.**). The ANCF is a low-speed ducted-fan testbed for measuring and understanding fan-generated aeroacoustics, duct propagation, and radiation to the far field as well as evaluating noise reduction concepts. It is a highly configurable, 4-ft-diameter ducted fan composed of a center-body that is cantilevered from a U-shaped support structure. The nominal operating condition of the ANCF is 1,886 revolutions per minute, corrected (RPMc), resulting in a tip speed of ~400 ft/s, an inlet duct Mach number of ~0.15, and a fundamental blade passing frequency (BPF) of ~500 Hz. The fan speed can vary from 100 to 2,400 RPM with resulting changes in tip speed/duct M#/BPF.

The ANCF is considered a low-technology readiness level (TRL ~3) testbed and provides the only complete aero-acoustic data/geometry set publicly available. The ANCF was used in over 6 internal, 8 external programs (2 reimbursable), 2 NRAs, 3 SBIRs, and 2 Aero Acoustic Research Consortium projects. These were integrated in GRC's noise reduction program roadmaps and milestones. The international aeroacoustics research community employed the ANCF to facilitate advancement of multiple noise reduction and measurement technologies and for code validation. Over 100 papers written based on ANCF data (~4-6 per AIAA Aero-Acoustics Conference). Multiple domestic and international institutions requested the ANCF databases and utilized these for internal research and development programs. In 2016, the ANCF was transferred to the University of Notre Dame (UND) where it continues to positively impact ducted fan aeroacoustic research. The Notre Dame Turbomachinery Lab operates the ANCF at their White Field laboratory location, while NASA maintains ownership.

Fan testing at NASA and OEMs will require a workforce that has experience and understands open rotor acoustic testing. A significant benefit of the UnD/OR–ANCF developmental test rig will be Science, Technology, Engineering, and Math (STEM) support for workforce development. The obvious benefit is the hard skills STEM students gain through the valuable experience designing their own concepts based on engineering/computer aided design, rapid prototype manufacturing, using the aero-design tool chain. They are then provided the opportunity to test and evaluate their design – providing the basis of a well-rounded, complete thesis with a high likely hood of generating follow-on development. Another noteworthy benefit, often overlooked, is STEM students interacting with experienced professionals in variety of disciplines and skills sets. Young professionals intermingle with highly experienced mechanics who impart critical practical knowledge. In addition, the opportunity to observe NASA project planning emphasizes the necessity in meeting relevant objectives and goals. As a result, STEM students gain valuable soft skills of equal import to the hard skills.

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[1] Sutliff, D.L., "Advanced Noise Control Fan: A 20-Year Retrospective of Contributions to Aeroacoustics Research", NASA/SP–2019-643.

[2] Figueroa-Ibrahim, K. Ross, M.H., Morris, S.C., Sutliff, D.L., and Walker, B.E., "Evaluation of Radiated Sound from the Advanced Noise Control Fan facility in an Outdoor Environment using Ground Microphones", AIAA 2019-3825.

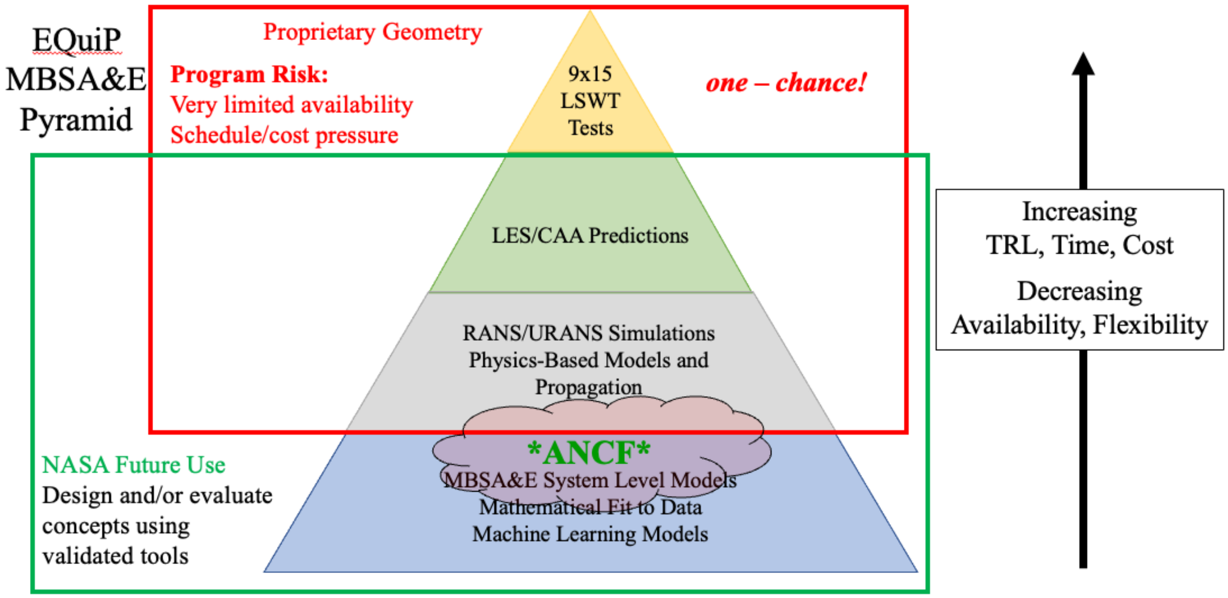

Figure 1. Model Based System Analysis and Engineering Pyramid.

Figure 2. Advanced Noise Control Fan in Short Duct Configuration and Inflow Control Device.