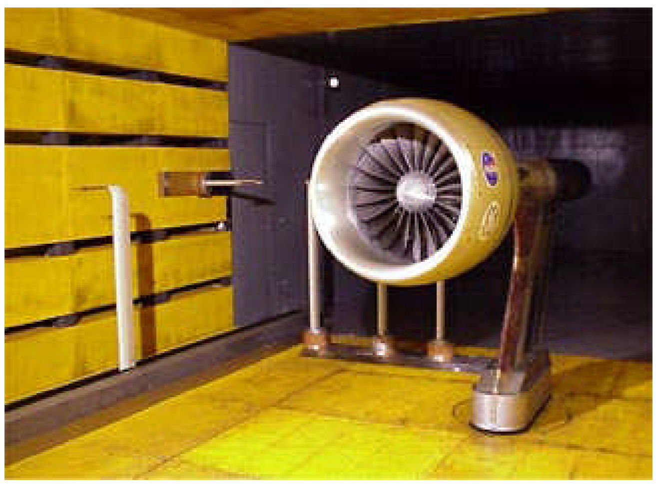
Turbofan Noise Studied in Unique Model Research Program in NASA Glenn's 9- by 15-Foot Low-Speed Wind Tunnel

A comprehensive aeroacoustic research program called the Source Diagnostic Test was recently concluded in NASA Glenn Research Center's 9- by 15-Foot Low Speed Wind Tunnel. The testing involved representatives from Glenn, NASA Langley Research Center, GE Aircraft Engines, and the Boeing Company. The technical objectives of this research were to identify the different source mechanisms of noise in a modern, high-bypass turbofan aircraft engine through scale-model testing and to make detailed acoustic and aerodynamic measurements to more fully understand the physics of how turbofan noise is generated.



Source Diagnostic Test turbofan engine simulator installed in Glenn's 9- by 15-Foot Low-Speed Wind Tunnel.

The Source Diagnostic Test research program was conducted using a one-sixth-scale model of the bypass section representative of current technology turbofan engines, which included the fan, stators, and nacelle. The fan consisted of 22 wide-chord fan blades and was driven by Glenn's Ultra High Bypass Propulsion Simulatora 5000-shp air-driven turbine designed for testing turbofan aircraft engine models in a wind tunnel environment. The stator vane assembly, located behind the fan and used to provide support for the nacelle as well as to straighten the swirling flow from the fan, included several hardware configurations to investigate the effect of vane number and vane blade geometry on acoustics and aerodynamic performance. In order to isolate and characterize the fan noise from the stator noise, an innovative test technique was successfully developed at Glenn, which isolated the fan in the nacelle. Called the Rotor Alone Nacelle (RAN), this system used an external strut arrangement to support the nacelle externally and thereby allow the stator vanes to be removed. During testing, a laser ranging system was used to measure the distance from the nacelle to the model centerbody. A sophisticated two-axis translating table and control system then used these centerbody measurements to automatically move the nacelle and external strut assembly to keep the fan centered in the nacelle. In addition to keeping the nacelle centered over the fan, realistic fan tip clearances representative of a turbofan engine were also achieved.

Rotor Alone Nacelle configuration with externally supported nacelle during Source Diagnostic Test.

The extensive, year-long testing program allowed a comprehensive data base of aerodynamic and acoustic performance parameters to be obtained using unique and innovative measurement techniques. Fan and stator vane performance was measured using fixed pressure and temperature rakes, and a translating multiprobe pressure rake was used to measure stator wakes. Fan thrust and power and the stator vane thrust were measured using rotating and static force balances. Steady and unsteady surface pressures on the stator vanes were measured using removable, instrumented vanes. Details of the velocity and turbulence components in the fan flow field were obtained using Laser Doppler Velocimetry (LDV) and, for the first time at NASA, two-point turbulence measurements using multicomponent, multiprobe hotwire anemometry.

A special LDV window mounted over the fan tip allowed details of the flow to be obtained. Farfield acoustics were measured using a translating microphone assembly to provide sideline measurements. Acoustic duct modes within the nacelle were measured simultaneously by 180 dynamic pressure sensors, located at three axial areas in the nacelle, and a rotating microphone assembly in front of the fan and behind the stator vanes.

The extensive acoustic and aerodynamic data base created as a result of this research will be used by NASA and the U.S. aerospace industry as a guide for future acoustic research in turbofan engine noise-reduction technologies. More computationally efficient and more accurate fan-noise-prediction computer codes will be developed and validated using these data.

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