NASA Facts

National Aeronautics and
Space Administration

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Making Future Commercial Aircraft Quieter

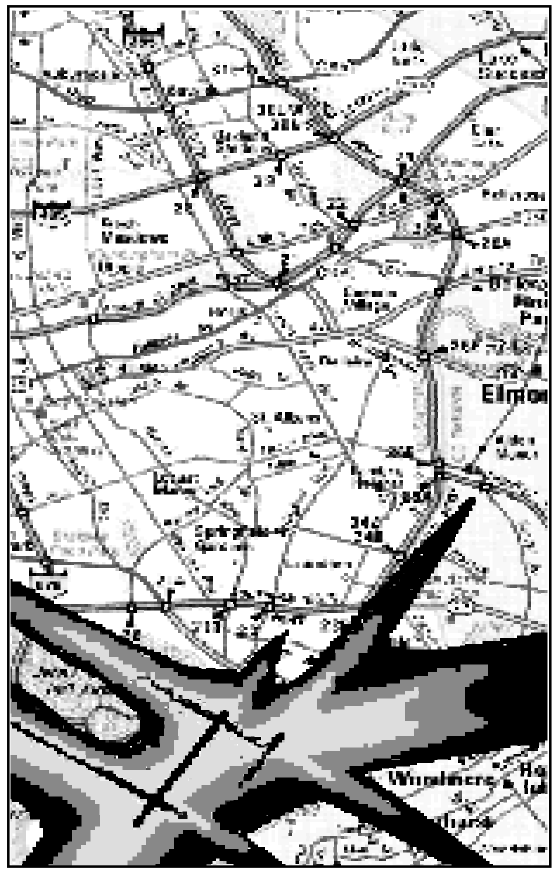
Glenn Effort will Reduce Engine Noise

The U.S. aviation industry is a significant contributor to the nation's economy, boasting annual sales in excess of $36 billion and providing nearly 1 million jobs. With the recent boom in air travel brought on by the global marketplace, the industry stands to gain an even greater share of the nation's and the world's economy. Continued competitiveness is important to the industry and to the U.S. economy. Quieter airplanes have a competitive advantage.

Just as significant, aircraft noise continues to be a nuisance. Increases in air traffic and growth in populations that surround airports are resulting in a noise impact on a larger percentage of the community and a stronger desire to reduce the noise around airports. The figure to the right illustrates the noise annoyance "footprint" surrounding an airport and how that might be reduced so that airplane noise affects fewer people. Commercial technology necessary to significantly reduce the footprint is not yet available and may be 20 years away.

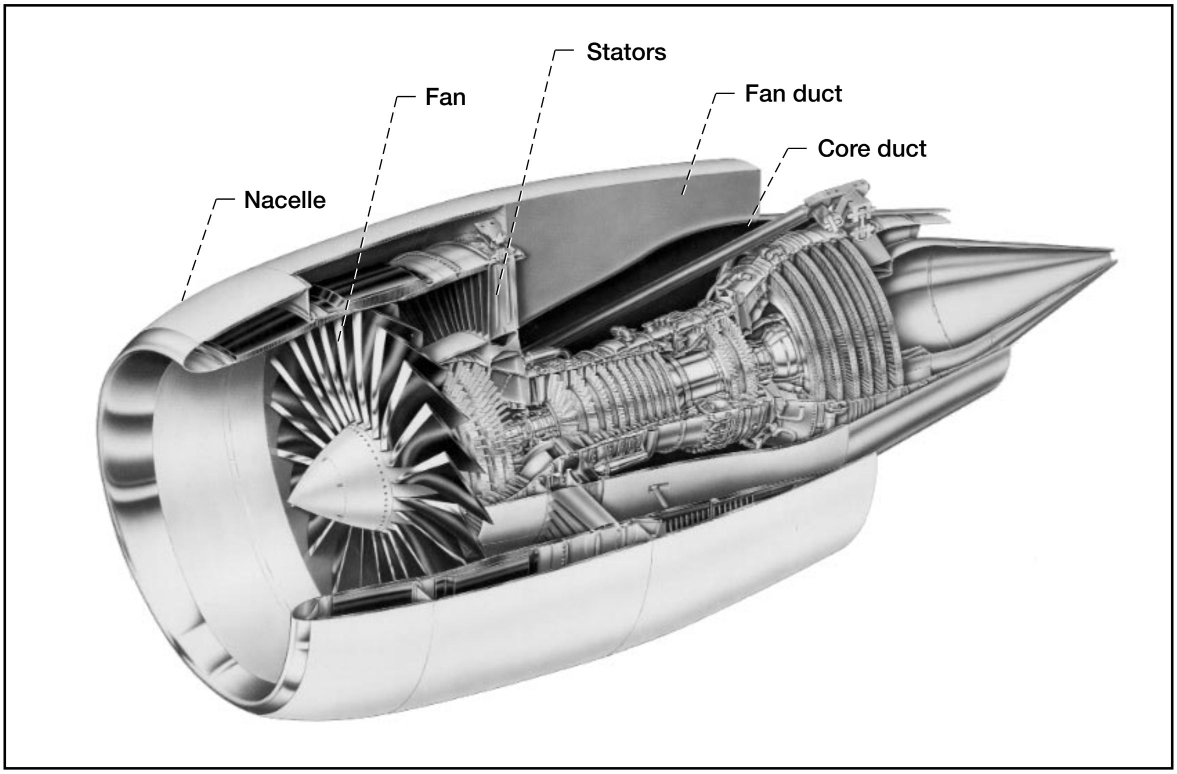
In response to this, NASA is working to develop the required technologies by the year 2000. These technologies are being developed under the Advanced Subsonic Technology (AST) program, which was initiated in 1992 as a partnership between NASA, the U.S. aviation industry, and the Federal Aviation Administration. The goal of the AST program is to develop high-payoff technologies that enable a safe, highly productive global air transportation system. This system will include a new generation of aircraft and engines that are both environmentally compatible and economical.

The NASA effort to make quieter aircraft is divided into three parts: engine, nacelle (the cowling that houses the engine), and airframe. As the Lead Center for Aeropropulsion and the Center of



The fade from black to light gray in this figure, illustrates how reducing the noise foot print around a major airport reduces the number of people annoyed by airplane noise.

Excellence in Turbomachinery, Glenn Research Center is the NASA center responsible for the Engine Noise Reduction Element of the AST program. The goal of this element of the program is to develop technology that would reduce engine noise by 6 decibels (dB) by the completion of the program in the year 2000. To put this in perspective, a 10-dB reduction is perceived as reducing the noise level by



Modern turbofan jet engine (courtesy of General Electric).

50 percent. This AST noise reduction program is making great strides towards accomplishing this goal.

Turbofan Engine Noise Generation

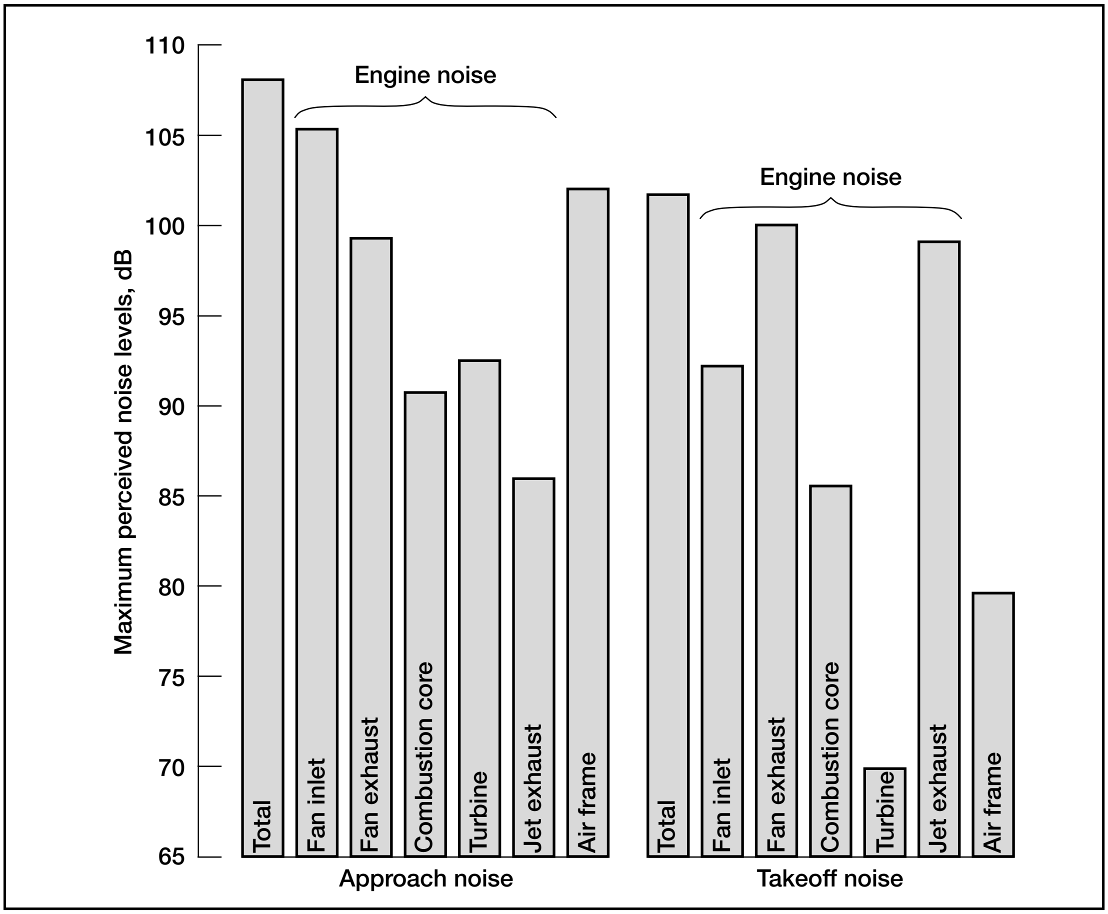
There are many sources of noise from current aircraft. Refer to the illustration above of the engine cut-away to visualize the workings of an engine. Turbofan engines work on the principle of sucking air into the front of the nacelle duct and pushing that same air out the back at a higher velocity. This change in momentum provides the thrust. The diameter of the engine is determined by the fan, which pulls air into the duct. This fan is a source of noise, similar to the noise caused by a propeller. The fan blades, by pushing through the air, cause noise by themselves. Once past the fan, the air is split down two different paths, the fan duct and the core duct.

First consider the flow in the fan duct. Downstream of the fan, the flow is swirling because of the spinning fan. This swirl causes loss of momentum before the air exits the nozzle so it is straightened out with a set of vanes called stators. These stators are a large source of noise as the wakes of air from fan flow slap against the stators like waves on a beach. This regular slapping takes place at the rate of blades passing by and generates a tone at what is called the blade passage frequency, or BPF. Nonuniformities and nonlinearities result in many higher frequency tones being produced at 2 times BPF, 3 times BPF, and so on. These tones are often associated with the piercing sound generated by some engines. Fan/Stator interaction creates more than specific tones. The unsteadiness in the fan flow (often in the form of turbulence) interacts with the stators to create broadband noise. This is often heard as a rumbling sound.

In the core duct, the air taking this path is further compressed through a series of smaller fans called rotors. Each of these rotor stages is separated by a set of stators to straighten the flow. This is another source of rotor/stator interaction noise. The compressed air is then mixed with fuel and burned. This combustion is another source of noise. The hot, high-pressure combusted air is sent downstream into a turbine which drives the fan and the compressor rotors. Since the turbine tends to look and act like a set of stators, this is another source of noise.

Finally, the core duct and the fan duct flows are exhausted into the air outside the back of the aircraft. The interaction of these jet exhausts with the surrounding air generates broadband noise called jet noise.

The following graph is representative of the noise distribution components for typical aircraft. The importance of engine noise, in particular the fan and jet exhaust noises, is clearly depicted. These two



A breakdown of the noise components of a typical engine with 1992-level technology during takeoff and approach to landing indicates the large part played by engine noise. Note: because decibels are logarithmic values, the graph's total bar is the sum of the individual bars.

main areas are the primary focus of the research being done in the NASA Glenn AST engine noise reduction program.

Jet Exhaust Noise Reduction

Jet exhaust consists of the fan stream and the core/combustion stream. The core flow stream is typically at a higher speed than the fan stream. As the two flow streams mix with each other, noise is created in the surrounding air. Of particular difficulty, the jet exhaust noise is actually created after the exhaust leaves the engine. This means that jet noise cannot be reduced where it is created, but must be addressed before the exhaust leaves the engine.

The theory of noise generation is being studied and computer codes that can simulate the theory are being developed. The final goal of this effort is to have a computer model for jet noise that will predict the source of the noise and how it is sent into the surrounding air.

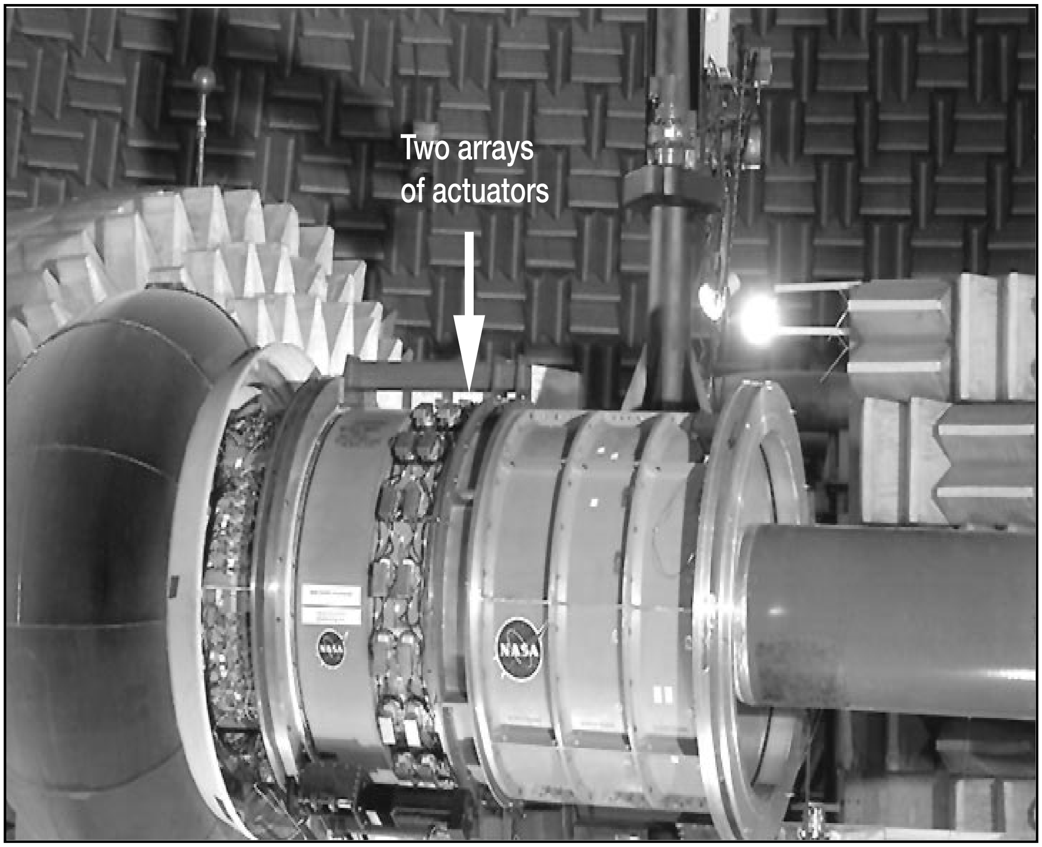
Theoretical understanding of jet noise is used to develop ideas for noise reduction concepts that are tested in model scale. Ideas that have already been tested or will be tested include mixer devices to combine the flows quickly, which reduce the noise generation area.

Recently, test data have shown that a 3-dB reduction in jet noise can be achieved. The final goal is to demonstrate a 6-dB reduction.

Fan Noise Reduction

In order to make progress on fan noise reduction, it is necessary to understand and be able to predict that noise. Therefore, as with jet exhaust noise, effort is being put into learning the theory of fan noise generation and developing computer codes that simulate that theory. The final goal of this effort is to have a computer code for fan noise prediction that can be verified.

A second approach uses the theoretical understanding of fan noise to develop a succession of ideas for testing, with each test providing both data upon which the computer codes are verified and results upon which the next test might be built. Fortunately, the fan thrust provides many options to explore and there are many components to vary. Besides basic geometry, there are



The Active Noise Control Fan at NASA Glenn showing two circumferential arrays of acoustic actuators.

blade-wake tailoring, boundary-layer (a thin layer of air along the duct wall that moves slower than the rest of the flow) effects, fan speed, number of blades and stators, and many more. Recently, model test data showed that a 3-dB reduction in fan noise can be achieved. As with jet exhaust noise, the final goal is to demonstrate a 6-dB reduction.

Active Noise Control

A new approach to noise reduction is the active noise control effort. The primary principle of active noise control is to sense the noise disturbances in the engine and cancel them before they leave the engine. In effect, negative noise is made to cancel out the engine's sound waves so that no noise is heard. This is a multidisciplinary effort involving duct acoustics, controls, and actuator/sensor design.

NASA Glenn has a unique facility for this testing. The Active Noise Control Fan is a 4-ft-diameter low-speed fan designed specifically for active noise control testing (shown in the figure on this page). To date, several concepts have shown successful cancellation of selected acoustic modes. Because noise is the sum of all possible acoustic modes, this effort is still in its infancy, but it has potentially high payoffs. Active noise control will contribute to the 6 dB noise reduction goal of the AST program.

Full Scale Validation

The final validation of the noise reduction technology will be performed on full scale turbofan engines. The most promising concepts from the model scale testing will be selected for real environment demonstration. The validated technology will then be available for use by all U.S. engine manufacturers to incorporate into a new generation of environmentally compatible and economical aircraft and engines.

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