Hushing the roar

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# of air traffic growth

Unless something is done to reduce aircraft noise significantly, the growth of air traffic in the U.S. will be hindered by a lack of new airports and limited runway capacity. Of all aviation-related environmental issues, noise is the number-one concern of the communities surrounding airports, both existing and proposed. This is making the construction of new facilities and the expanded use of existing runways an increasingly political issue. New technologies are just one approach to solving the problem.

Higher, faster, and farther have long been the goals of aircraft designers; less obvious has been the quest for quiet. However, engine and aircraft makers have been pursuing quieter technologies for years. Today, along with fuel efficiency and safety, noise reduction is one of the key elements of aircraft and engine design. Making airplanes quieter is not just good for the environment. It is critical to the entire system of air travel as well—a fact that airlines, manufacturers, and regulators recognized early on.

"Noise is still number one," says Carl Burleson, director of the office of environment and energy at the Federal Aviation Administration. It is the "front-page issue" for most communities, although concern about air quality—emissions, particulate matter, and the like—is rising rapidly, he says.

Weather remains the major reason for air traffic snarls and stranded passengers. But the biggest obstacles to building new airports and expanding runway capacity are environmental concerns—with noise at the forefront.

Runway capacity, according to a number of studies, is a primary issue facing the air traffic system, which the federal government predicts will have to handle a threefold increase in passenger growth by 2025. Expanding that capacity will require either building new runways or allowing more aircraft to operate on those already in use.

Today, it typically takes 10 years to build a new runway in the U.S., says Burleson, noting that environmental issues will restrain the growth of our air traffic system before technological issues do.

"We really have a set of emerging environmental issues that could potentially put constraints on the ability of the industry to grow, and could fundamentally change access to mobility for the American public," he says. "That's why environment is such a critical issue."

Noise is primarily a political problem, says Kevin Shepherd, a NASA expert on how aircraft noise affects communities. "Congress hears about it, airports hear about it; it's used a lot to block airport expansion," he says.

Loss of sleep and difficulty hearing conversations are some common complaints resulting from aircraft noise. But the problem can get so bad in certain places around some airports that the FAA winds up paying damages. When noise levels under flight paths go above mandated limits, homeowners are entitled to sound insulation and even buyouts, all at government expense.

With the U.S. population growing and the number of aircraft needed to satisfy the demand for travel growing along with it, the federal government is searching for ways to increase the capacity of the national airspace system. Obviously, airplane noise complicates that.

"It's not just an impediment to expansion of airports; it can be an impediment to expansion of the traffic," says Tod Lewis, another NASA aircraft noise expert.

Anyone who remembers the racket unleashed by the early straightpipe turbojet engines knows that modern jet aircraft have actually gotten quieter, thanks in large part to the advent of high-bypass turbofans, which today power all jet transports.

To combat the sound of the jet blast from the rear of the engine, the QTD2 team developed serrated edges, or chevrons, for the back of the nacelle and the engine exhaust nozzle.

A turbofan pushes a lot of air at slower speeds, yielding more thrust and greater fuel efficiency than a turbojet, which moves much less air at higher speed—and screams like a rocket.

"That was one of the best things that ever happened for aircraft noise, and it was not actually designed for [noise reduction]," says Charlotte Whitfield, an aeroacoustics specialist at NASA. "It's about the only time that performance benefit and noise benefit have gone hand in hand."

But it is not enough, so aircraft and engine makers as well as people in academia and government are constantly working on ways to make airplanes even quieter. Their efforts cover a range of initiatives focusing on engines, airframes, and procedures. NASA is heavily involved. Its Quiet Aircraft Technology program, which provides research and funding, aims to reduce perceived aircraft noise by 50% within 10 years and by 75% within 25 years, relative to 1997 levels.

Quiet Technology Demonstrator 2

In the fall, Boeing wrapped up Quiet Technology Demonstrator II (QTD2), a program that included General Electric, Goodrich, NASA, and a brand-new 777 loaned by All Nippon Airways. In the tests, conducted in Glasgow, Mont., the widebody jet flew repeatedly over a sophisticated microphone array at only 100 ft. The demonstration focused on modifications to three areas: engine inlets, engine nozzles, and landing gear. The results were so good that Boeing plans to incorporate some of these noise improvements on production 787 and 747-8 airliners.

Boeing's interest in pursuing quiet technology is driven by a desire to provide passengers with a peaceful ride—comfort is one of the many selling points of the new 787—and help its airline customers deal with noise restrictions.

"We can see that requirements are getting tighter and tighter around airports as far as community noise goes, so we're being proactive in reducing the noise of our aircraft so they'll meet the future requirements," says Larry Craig, chief engineer for noise and emissions at Boeing Commercial Aircraft. "The cabin noise [reductions are driven] more by ourselves from a passenger comfort standpoint."

During the demonstration, the inlet of one of the General Electric 90 engines on the 777 was modified, increasing the area that could be treated acoustically to soak up noise.

That arrangement wiped out the buzz that permeates the cabin as the aircraft climbs. Buzzsaw noise is a byproduct of the large number of tones at the rotational frequency of the engine as the tips of the fan approach transonic speeds, creating instabilities and shock waves. It does not happen during takeoff or cruise flight, but can be annoying during the climb, says Craig.

The new inlet design will be stock on the 787 and the 747-8, but the technology can be transferred to any engine. Craig says Boeing is considering the inlets for all future development programs.

Another change to the engine had to do with adding chevron nozzles to the exhaust. This reduces noise both in the cabin and outside the airplane. The chevrons reduced peak jet noise at low frequencies and aft angles from the standpoint of community noise and yielded a 5-6-dB reduction in the rear of the cabin.

"That's quite significant," says Craig. "We had passive weight treatment in the sidewall of the 787 to combat that noise source, and we've taken it out, and it's a savings of several hundred pounds."

Craig says noise levels in the aft cabin of a typical airliner hover at around 75-80 dB, a figure Boeing wants to lower on the 787. For comparison, a normal conversation is 60 dB, while the traffic you would hear standing on the curbside of a busy street is 80 dB. The scale is logarithmic, so a few points' difference has a large effect on how we perceive noise.

In basic terms, the chevrons work by accelerating the mixing process in the jet flow, says NASA's Whitfield. By speeding up the mixing process, you slow down the average velocity of the jet exhaust, which reduces noise.

Other concepts Boeing is looking into include chevrons that actually change shape during different parts of flight, Craig points out. Since the chevrons are sticking into the exhaust flow, they add some drag and incur a fuel-burn penalty. By using so-called shape-memory alloys that shrink and expand with changes in temperature, it is possible to make a chevron that retracts itself out of the jet flow in cruise flight when sound mitigation is not as important as when the aircraft is close to the ground. The shape-change alloy chevrons are still in the beginning phase and not yet slated to go on any aircraft, says Craig, but the technology is interesting because it is automatic and involves no moving parts.

Boeing also looked at the noise caused by the landing gear when the aircraft is approaching an airport at low power settings. When a four-engine 747 is on approach, the noise produced by the wings and landing gear is about equal to that made by the engines.

"But with the new 787 engines, we're going well below the 747 current model engine noise," Craig says. "So we definitely have to be looking at airframe noise in the landing gear."

In wind tunnel tests conducted in cooperation with NASA and Goodrich, researchers made an interesting discovery: The noise heard on the ground from the landing gear is caused more by smaller details such as hydraulic lines and wires than by the wheels and struts.

The tests, which involved a toboggan-like cover attached to the 777's main landing gear, were successful in reducing noise further.

Craig says Boeing is in discussions with engine companies and other potential partners to conduct a demonstration that would be beyond QTD2 and be applicable to a 737 replacement or other aircraft down the line.

Noise is just as important for General Electric, a key player in the QTD2 study.

"It's certainly driving our engines today," says Steve Petersen, manager of the acoustics and installation aero teams at GE. "It's right up there with fuel burn, emissions. It's a key requirement now in sizing engines."

GE has been applying noise-damping treatments to its CF-56 and CF-6 engines since the 1970s. The kind of chevrons tested on the 777 during QTD2 are already in service on CF34 series engines on Bombardier and Embraer regional jets, as well as the CFM-56-5B on the Airbus A321.

Petersen says the company is actively studying higher bypass ratios, and more advanced chevrons and noise-absorption coatings, among other things.

"It's being quieter without sacrificing fuel burn, which is really the key airplane metric," says Darin Ditommaso, manager of systems technologies at GE.

For the future, GE says the GP7200 being built for the A380 already meets the noise requirements at Heathrow that will not go into effect for years.

In fact, says Petersen, the engines being built for the 747-8 and A380 will be both more powerful and quieter than current, comparable-sized engines. This provides a tangible benefit to operators using airports like Heathrow, where a point system is used to restrict the number of takeoffs allowed to carriers.

Continuous descent

New technology is only one approach to reducing noise levels; much could also be accomplished by adjusting arrival procedures. A concept known as the Continuous Descent Approach concentrates on an airliner's flight path from about 12,000 ft above the ground to the surface. The idea is to keep engine power at idle thrust and let gravity pull the plane downhill.

For all intents and purposes, it is a normal approach, says Lewis, NASA's principal investigator for low-noise guidance flight validation. The only thing passengers would notice would be less noise from the engines.

In a perfect world, an airplane on a long-distance trip would take off, climb immediately to its optimal cruising altitude, and stay up there as long as possible before beginning a constant, engines-idle descent that would end when the wheels touched the runway. In the real world, airplanes have to mesh into the air traffic control system, which usually interrupts climbs and descents with level-offs and turns that force airliners to spend more time at lower altitudes, where they burn more fuel and make noise that can be heard on the ground.

A Continuous Descent Approach eliminates level flight at low altitudes where pilots must step on the gas to keep the plane moving.

Toboggan fairings were developed to help reduce landing gear noise.

During the QTD2 tests, microphones were located on the exterior of the test aircraft and the runway.

"You'd have a higher average altitude throughout the approach, and thereby better noise attenuation," Lewis says.

To obtain vertical guidance to a runway, an aircraft following this flight profile would intercept the electronic glide slope farther away from the airport than it normally would today, and a little higher above the ground. Once the glide slope was intercepted, the low-noise approach would become like any other.

NASA has developed avionics that enhance the vertical navigation equipment that already guides modern aircraft in climbs and descents. The new low-noise guidance system calculates a quieter trajectory for whatever lateral route is programmed into the aircraft's flight management system. The system provides the pilots with an indication of the aircraft's estimated energy. If controllers ask the pilots to deviate, either laterally or by assigning a level altitude that requires a power change, as often happens, the system recalculates the aircraft's estimated energy and vertical trajectory. The goal is for low-noise guidance avionics to be able to deal with speed, route, and altitude adjustments issued by individual controllers.

The system is simple to interpret and use. Lewis notes that pilots who have evaluated the new avionics in a simulator say it is a "no brainer." This fall the avionics are scheduled to fly in a validation test, which will include microphone arrays on the ground to measure noise directly.

The catch to using low-noise guidance in the real world will come from air traffic control. So far, NASA has focused on pilots and crew procedures. The next step is a controller study, Lewis points out.

Busy airspace may not lend itself to continuous descent, especially in the environs of New York or Washington, D.C., where multiple departure and arrival corridors crisscross the sky. However, Lewis says, there are many places where it could provide benefits.

NASA is not the only player in continuous descent, which has attracted attention from Delta Airlines and the FAA, among others.

United Parcel Service has been experimenting with quiet approaches at its hub at Louisville, Kentucky, says Bob Walker, Advanced Flight Division manager. The company plans to implement continuous descent arrivals as a regular procedure at Louisville this year, and may do the same at other airports. The company expects large fuel savings, in addition to reductions in noise and emissions from the new procedures.

Aircraft noise is not a new issue, and it is not one that will go away anytime soon. NASA's predecessor, the National Advisory Committee for Aeronautics, worked on reducing aircraft noise before jet engines entered commercial air service in the late 1950s.

Give and take

The first serious investigation into community aircraft noise took place, not surprisingly, around London's Heathrow airport in 1963, says NASA's Shepherd.

Aircraft noise comes from a startling number of sources, not just the "airframe" or the "engines"—including the landing gear, the details on the gear, the flaps, the slats, the fan, the jet, the combustor, and so on.

You can work all those issues separately, as people are doing, and you can also ask what noise benefits would result from wholesale design changes—for example, by changing how engines are attached to wings. But aircraft design is a game of give and take, and changes that are good for noise must not detract from safety or performance. After all, the quietest airliner is one sitting on the ramp with its engines off.

"Noise reduction is not easy," Shepherd says. "If it were, we'd have done it."