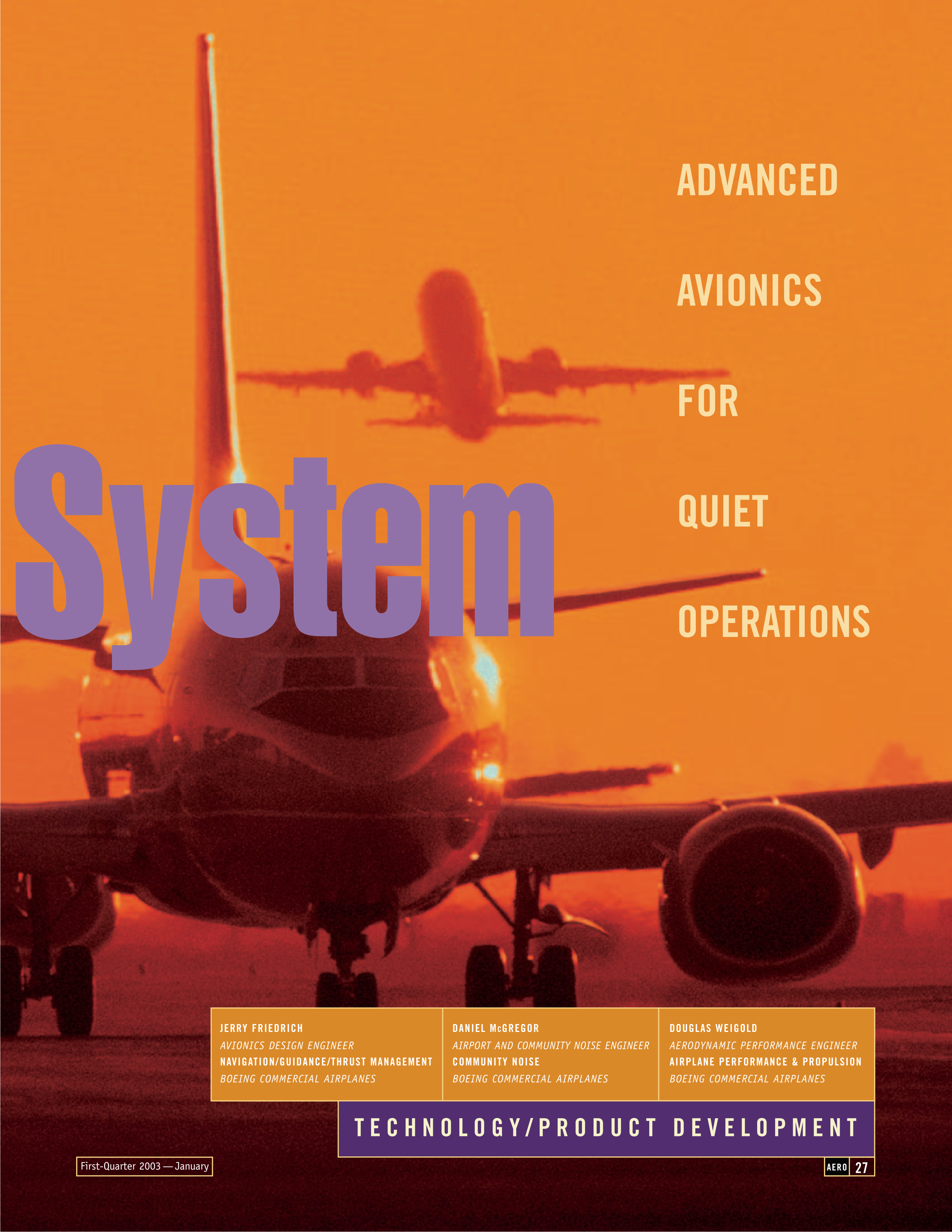
Quiet Climb

Boeing has developed the Quiet Climb System, an automated avionics feature for quiet procedures that involve thrust cutback after takeoff. By reducing and restoring thrust automatically, the system lessens crew workload and results in a consistently quiet footprint, which helps airlines comply with restrictions and may allow for an increase in takeoff payload.



System

ADVANCED AVIONICS FOR QUIET OPERATIONS

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TECHNOLOGY/PRODUCT DEVELOPMENT

With higher density populations surrounding airports throughout the world, the sound of airplanes has become an issue of increasing importance in recent years. Noise-abatement requirements and procedures imposed by local airport authorities have affected airline operations in many ways, resulting in restricted hours of operation, required weight offloads, fines, and surcharges.

Airplane and engine manufacturers have been successful in producing quieter airplanes, but more stringent noise-abatement requirements and the high cost of engine modification have prompted the industry to consider additional ways to decrease airplane sound in communities.

One alternative is a maneuver in which the flight crew takes off with full takeoff power, climbs rapidly, and then cuts the thrust manually to a predetermined value at a specified cutback altitude. The airplane continues to climb, albeit at a much slower rate, until it is high enough that sound in the community is not an issue. The crew then adds more power to continue flight.

One potential problem with this maneuver is that the pilot must cut back and restore engine thrust manually at the correct altitudes. The Boeing Quiet Climb System (QCS), which is selected during the takeoff procedure, automatically reduces and restores engine thrust at the specified altitudes, thereby reducing pilot workload.

In an effort to standardize noise-abatement procedures, the Federal Aviation Administration (FAA) has issued advisory guidelines that define departure profiles, including the minimum thrust required and the cutback altitude. This article discusses

1. FAA advisory guidelines.
2. The Boeing QCS.
3. Basics of sound measurements.
4. Effect of the Boeing QCS on sound in communities.

1 FAA ADVISORY GUIDELINES

In 1993, the FAA issued advisory circular AC91-53A, "Noise Abatement Departure Profiles," which standardizes procedures by defining acceptable criteria for speed and minimums for thrust cutback settings and altitudes for various airplane takeoff configurations.

Minimum thrust cutback.

The minimum thrust cutback represents the minimum level of thrust that would ensure a sufficient climb gradient if an engine were to fail. This thrust value is determined by the number of engines on the airplane. On a two-engine airplane, the minimum thrust cutback ensures an engine-inoperative climb gradient of 1.2 percent. If one engine fails after cutback, the thrust from the operating engine must maintain a climb gradient of at least 1.2 percent. On three-engine and four-engine airplanes, the minimum thrust cutbacks are engine-inoperative climb gradients of 1.5 percent and 1.7 percent, respectively.

Zero percent gradient cutback.

Under certain conditions, the advisory circular also allows a thrust cutback that maintains a zero percent engine-inoperative climb gradient. This type of cutback is permitted for airplanes with avionics systems that can detect engine failure and automatically increase the thrust on the remaining engine or engines to a value that maintains the minimum climb gradient. These minimum climb gradients are 1.2 percent on a two-engine airplane, 1.5 percent on a three-engine airplane, and 1.7 percent on a four-engine airplane.

Cutback altitude.

The advisory circular also specifies that the minimum altitude at which the thrust can be reduced, or cut back, is 800 ft above ground level (AGL).

2 THE BOEING QCS

Boeing developed the QCS, an advanced avionics feature, to directly assist flight crews in flying the quiet departure profiles defined in the advisory circular. The QCS controls thrust reduction and restoration automatically, thereby eliminating the need for manual control and ensuring consistency.

During the takeoff checklist procedure, the pilot selects the QCS and enters the altitudes at which thrust should be reduced (≥800 ft AGL) and restored. With the autothrottle system engaged, the QCS reduces engine thrust when the cutback altitude is reached to maintain the optimal climb angle and airspeed. When the airplane reaches the chosen thrust restoration altitude (typically 3,000 ft AGL), the QCS restores full climb thrust automatically. As such, QCS reduces pilot workload during a phase of flight that already is task intensive.

QCS incorporates multiple safety features and will continue to operate even with system failures. If a system failure does occur, there are several methods for exiting QCS. In the most common method, the pilot selects the takeoff/go-around switches on the throttle control stand. The pilot can take control of the throttles easily by disconnecting the autothrottle and controlling the thrust manually, as appropriate.

QCS availability.

The QCS is available on all 737-600/-700/-800/-900 airplanes and provides an automatic thrust cutback engine-inoperative climb gradient of 1.2 percent. The zero percent climb gradient QCS is scheduled to become available in first-quarter 2003 on the 737-600/-700/-800/-900. Boeing also is considering the QCS for the 747-400, which would have an automatic thrust cutback engine-inoperative climb gradient of 1.7 percent.

Other Boeing systems.

A system similar to the QCS is available on the MD-90 series. That system, however, requires that the pilot calculate the necessary thrust and then enter it manually for automatic thrust cutback during takeoff. The 757 also has an option similar to QCS that provides an engine-inoperative climb gradient of 1.2 percent. To be activated, the crew must select the system manually at the cutback altitude.

3 BASICS OF SOUND MEASUREMENTS

Airplane sound is measured along the flight path using monitors located near the ground. The level measured by each monitor is a function of the airplane, engine type, altitude, and thrust. An airplane event consists of a single flyover with incremental measurements recorded by the monitors (fig. 1). A time history, which is a composite of the individual measurements, shows changes in the sound level over time. The history provides information on the maximum (peak) level and the duration of the event.

Three common ways of representing sound.

One common way to represent airplane sound uses peak A-weighted decibels (typically referred to as peak dBA), which are decibels adjusted for how the human ear hears sound (fig. 1).

Another way to represent sound is time-integrated measurement (fig. 2). With this method, individual measurements of energy taken over time are summed.

A third way to represent airplane sound uses a contour, or footprint. A footprint shows the impact of sound on communities near the airport and provides information about how variables such as airplane configuration, flight procedures, and new airplane technology (e.g., QCS) affect the size and shape of the footprint (fig. 3).

FIGURE 1 FLYOVER SOUND IN A-WEIGHTED DECIBELS

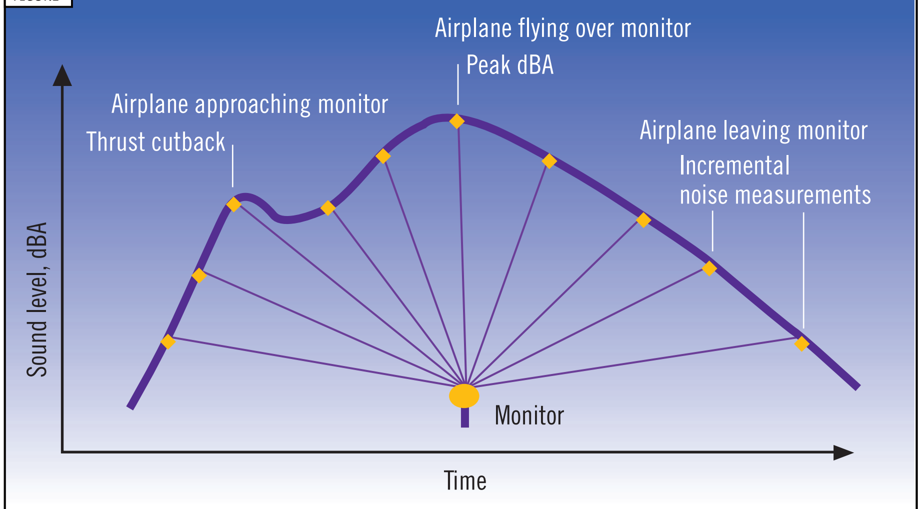
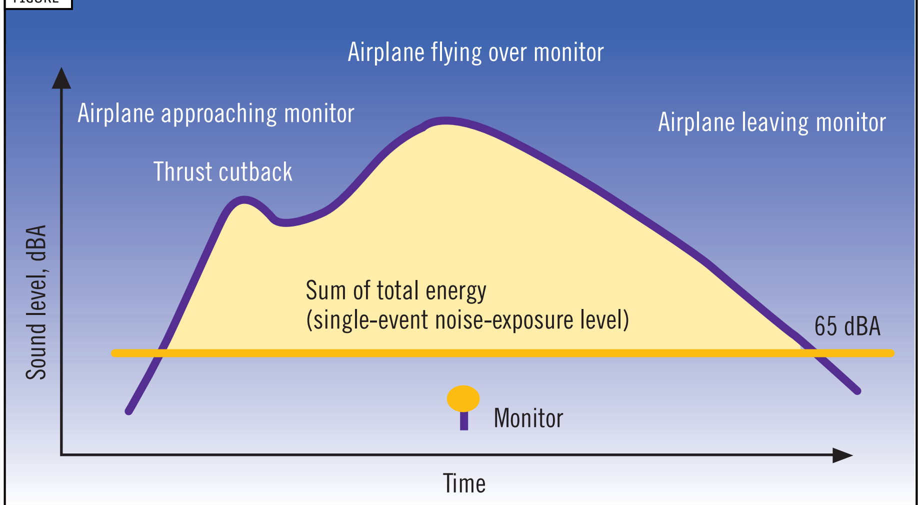


FIGURE 2 FLYOVER SOUND IN TIME-INTEGRATED MEASUREMENT



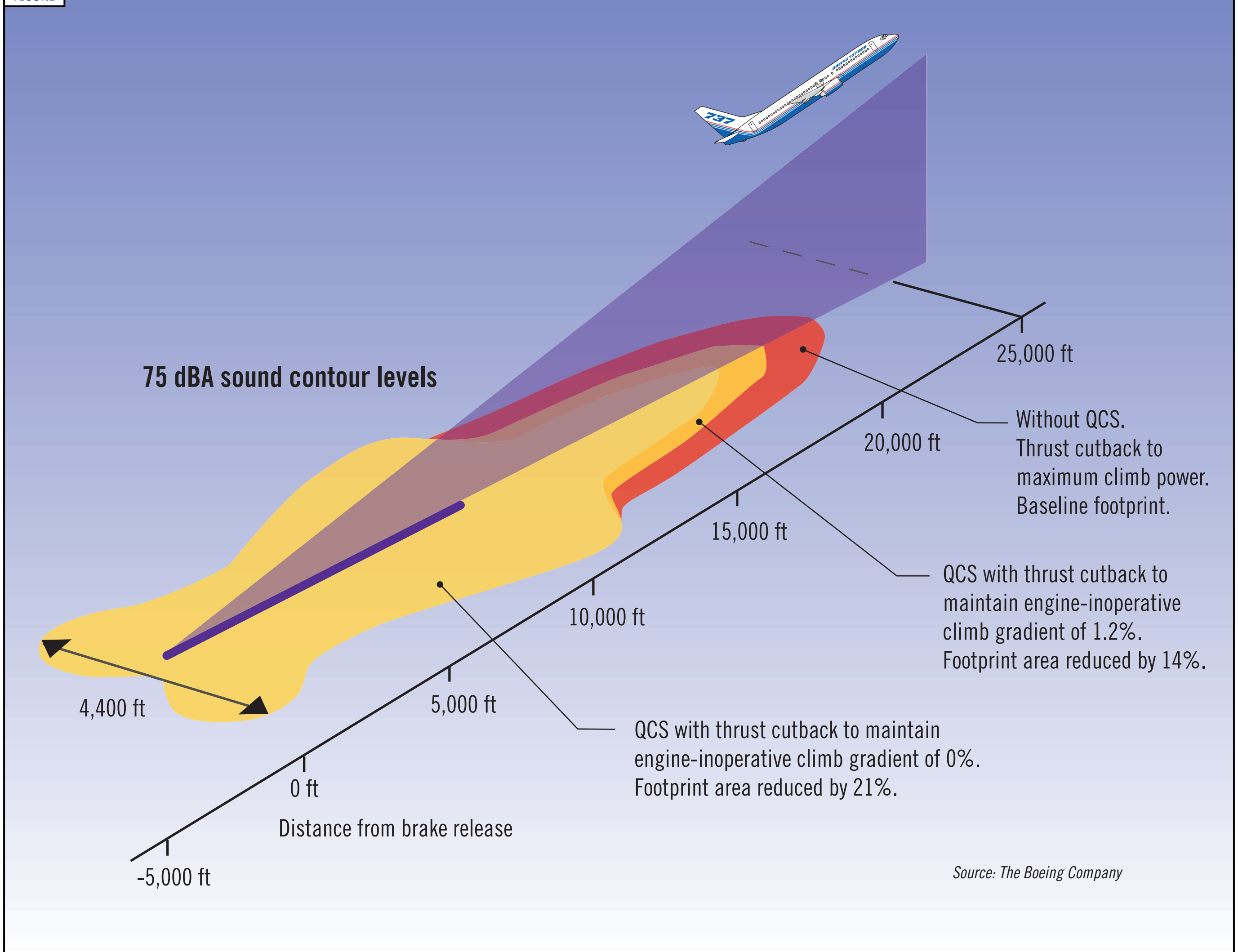
London Heathrow Airport.

London Heathrow Airport, in the United Kingdom, is one of the world's most heavily regulated airports. It has four departure runways for commercial airplanes and 10 sound monitors. To regulate airplane noise and its impact on local communities, the airport has established peak dBA noise limits for daytime, shoulder period, and nighttime operations. The daytime (7 a.m. to 11 p.m.) limit is 94 dBA; the shoulder period (11 p.m. to 11:30 p.m. and 6 a.m. to 7 a.m.) limit is 89 dBA; the nighttime (11:30 p.m. to 7 a.m.) limit is 87 dBA. For long-haul carriers with heavy fuel and passenger payloads, the lower two limits are difficult to meet.

John Wayne Airport.

John Wayne Airport, in Orange County, California, is another of the most heavily regulated airports. The airport has one departure runway for commercial airplanes and seven monitors. Airplane sound is measured using a single-event noise-exposure level (SENEL), which is a type of time-integrated measurement. The SENEL also uses dBA time history, but rather than reporting only the peak dBA, the energy of all sound levels >65 dBA is added to produce a single value.

FIGURE 3 THE BOEING QCS



Source: The Boeing Company

4 EFFECT OF THE BOEING QCS ON SOUND IN COMMUNITIES

The QCS reduces takeoff sound by reducing thrust, which helps airlines comply with noise restrictions that carry increasingly severe economic penalties for violations. At John Wayne Airport, for instance, fines can be as much as $500,000. To avoid such penalties, airlines that use a manual procedure to cut back and restore thrust during takeoff often reduce takeoff weight to ensure that sound levels stay within designated limits. Because the QCS standardizes the noise-abatement maneuver, the system minimizes the need to reduce takeoff weight. This, in turn, provides airlines with the added economic benefit of allowing airplanes to carry more passengers, cargo, or fuel.

The Quiet 737-800.

On current-production 737-800s with CFM International CFM56-7B26 engines, the QCS reduces the acoustic footprint by 14 percent. On these airplanes, the zero percent climb gradient QCS is expected to reduce the acoustic footprint by 21 percent. At John Wayne Airport monitor three (the most critical monitor for the 737-800), a typical departure with the 1.2 percent climb gradient QCS would lower the SENEL by ~3.2 dB. This improvement would permit an ~5,500-lb increase in payload with the same sound level registered at takeoff as on similar airplanes without QCS. The zero percent climb gradient QCS would lower the SENEL by an additional 1 dB at the same payload.

A Quieter 747-400.

Approximately 90 percent of the 747-400s operating out of London Heathrow Airport could be quieter by slightly more than 1 dBA if they were equipped with the 1.7 percent QCS. The reduction would be even more significant for airplanes with lower takeoff weights. Alternatively, with the QCS, 75 percent of the 747-400s departing from Heathrow could increase their takeoff weight by an additional 25,000 lb and be as quiet at the monitors as similar airplanes without QCS.

About the Authors

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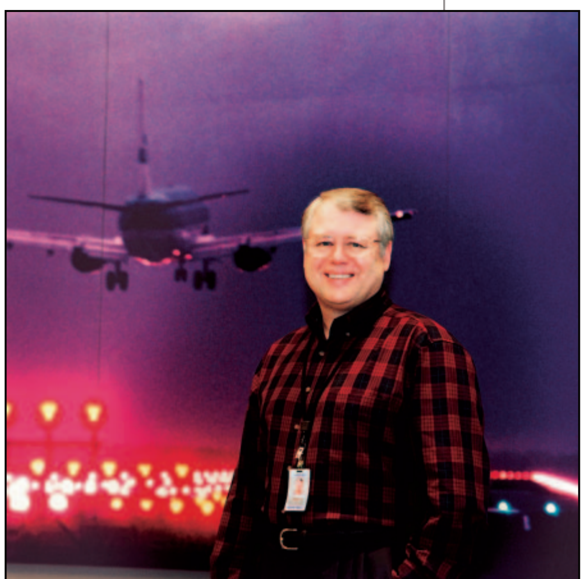
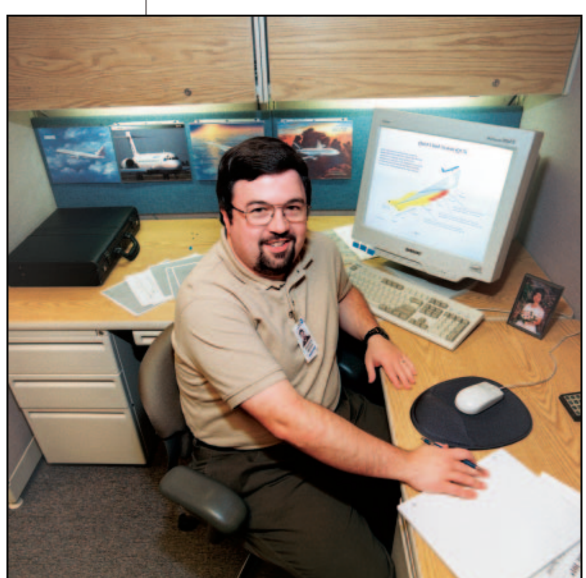


Daniel McGregor
has been with Boeing since 1985 and has extensive experience developing prediction applications that support airplane certification, community noise research, and interior noise. He is a lead engineer in Noise and Emissions and develops operational procedures to reduce the impact of airplanes in communities. He also is leader of the Boeing John Wayne Airport Air Carrier support team, which has streamlined airport review and qualification requirements resulting in cost savings for airlines and John Wayne Airport.



Douglas Weigold
is a 14-year veteran of the aerospace industry and has worked on airplane programs that include Longer Range 777, 717, MD-11, and High Speed Civil Transport. As part of the Production and Fleet Support Aerodynamics group, he currently works on narrow-body performance issues and is group noise focal for all airplane models.

SUMMARY

In response to increasingly stringent noise regulations and customer need, Boeing has developed the QCS, an advanced avionics systems feature that reduces pilot workload during the labor-intensive period of takeoff while helping airlines meet requirements without incurring penalties. The QCS automatically moves the throttle controls and retards engine thrust to maintain an optimal climb angle and airspeed, thereby reducing sound in the community and minimizing the impact on communities near an airport. An airplane equipped with the QCS may be able to carry more cargo, fuel, or passengers and still be quiet. The QCS currently is available on 737-600/-700/-800/-900 airplanes and is being considered for use on 747-400s. Some other Boeing models have systems similar to QCS.