Possible design for a future supersonic airliner.

Sonic Impact

Lowering the boom of supersonic flight

By IVARS PETERSON

One design has the slim, sharply pointed profile of an arrow. Another looks like a flying wing, with no fuselage or tail. A third features a sleek, streamlined aircraft body with wide, triangular wings.

Though these designs represent dramatically different visions of future supersonic travel, they all share a common goal. Flying at 1,600 miles per hour (more than twice the speed of sound), any one of these proposed aircraft would carry as many as 300 passengers from Los Angeles to Tokyo in less than 5 hours, cutting the usual travel time by more than half.

But the supersonic speedway from the drawing board to commercial flight is studded with obstacles. To sell more planes, aircraft makers want a supersonic transport to fly as many routes as possible, over land and sea.

The trouble is that supersonic flight is inevitably accompanied by ear-splitting, window-shattering sonic booms. Even planes flying at 60,000 feet or more lay down a discernible sonic track across any landscape they traverse. This means that any future high-speed airliner would have to be considerably quieter than the Concorde, the only supersonic airplane now in commercial service.

In recent years, airplane manufacturers, NASA, and others throughout the world have been taking a fresh look at the prospects for commercial faster-than-sound flight. Since 1990, researchers have expended considerable effort on developing the knowledge needed to design a new generation of supersonic jets cleaner and greener than the Concorde (SN: 10/26/91, p.270).

One component of this effort has focused on ways to soften sonic booms—to reduce their impact by altering the plane's design or the way it's flown. But the right formula for achieving this goal has proved elusive.

Moreover, though researchers have made considerable progress in understanding and predicting the effects of sonic booms, recent studies and community surveys strongly suggest that people find even occasional sonic booms much more disturbing than loud, continuous noise such as that of an airport.

Such findings indicate that "any commercial, overland supersonic flight is highly unlikely within the near future," says Christine M. Darden of NASA's Langley Research Center in Hampton, Va.

Research continues to probe ways to reduce the peak intensity of sonic booms generated by aircraft and to make more accurate predictions of how these shock waves travel through the air and how disturbingly loud they sound at ground level.

Other studies likely to affect the development of supersonic transport involve ongoing assessments of the potential impact on marine life and wild birds of a projected 500 or more daily ocean crossings by supersonic airliners.

Researchers presented progress reports on various aspects of this work at a meeting of the Acoustical Society of America held in Washington, D.C., this May.

Like a ship plowing through water, an aircraft has to push air aside as it flies. When a plane travels faster than the speed of sound, the air cannot move quickly enough to get completely out of the way, so a tremendous pressure wave builds up, trailing behind the plane like a ship's wake.

This shock wave reaches to the ground and lays down a broad track that marks the plane's flight path. A stationary observer on the ground hears a sharply defined noise like a thunderclap and feels the vibration as the pressure wave roars by.

Supersonic transports have distinctive sonic signatures that depend on the airplane's shape, speed, and motion. The needle nose of the Concorde, for example, cuts drag and allows the jetliner to slice through the air efficiently. But this configuration also generates a particularly strong shock wave.

The shape of the resulting pressure waves can also be quite complex. A supersonic aircraft typically sheds at least two shock waves, including one from the plane's nose and another from its tail.

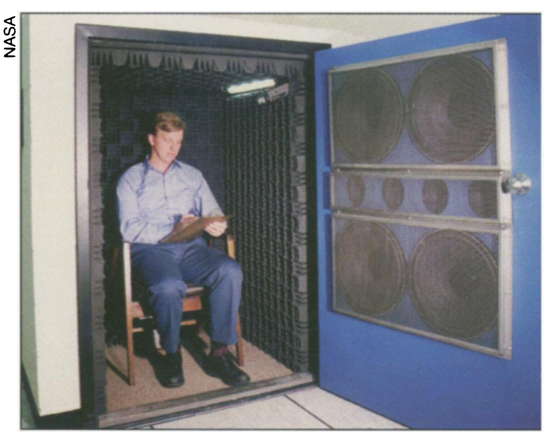
Although it's impossible to eliminate these pressure waves, aircraft designers have sought to reduce the boom's intensity by altering the plane's shape, thereby changing its signature. For example, a plane that gradually widens from front to back produces a sonic boom more like distant, rolling thunder than a sharp, intense crash.

Aeronautical engineers have also found that a thunderclap boom can be broken up into smaller bangs by spreading the lift-generating surfaces more evenly around the aircraft. But such modifications hurt the airliner's performance and decrease its fuel efficiency.

How a plane is flown also affects the sonic boom it generates. For example, accelerating an aircraft already moving in a straight line at supersonic speeds can intensify and focus the resulting boom.

Such maneuvers interest the U.S. Air Force, which would like to develop techniques for directing sonic booms, either to inflict psychological harm or structural damage at specific sites or to avoid causing such disturbances.

In April 1994, researchers from the Armstrong Laboratory at Wright-Patterson Air Force Base in Ohio conducted a series of flight tests at Edwards Air Force Base in California to collect data on the



A researcher sits inside a specially constructed simulator booth to listen and record his reactions to various types of sonic booms.

ability of air crews to focus sonic booms and control the placement of them.

Two crews flying jet fighters made 49 flights, and a large array of detectors recorded air pressure changes in the test area. More than half the time, the pilots managed to place booms within 500 feet of the target on a calm day and within 1,500 feet under turbulent atmospheric conditions.

Thermal turbulence greatly distorts the focus region, says Micah Downing of the Armstrong lab. Under such conditions, "you hear rolling thunder with a bang," he observes.

Indeed, weather and atmospheric conditions strongly influence how a pressure wave travels through the air, affecting its track and the loudness of the resulting sonic boom on the ground.

The Concorde, for instance, produces a double boom. One comes directly from the aircraft, whereas the other—a much fainter, delayed boom—represents a reflection of the plane's pressure wave from the upper atmosphere to the ground.

Using supercomputers and wind tunnels, researchers can predict with remarkable accuracy the kinds of shock waves a particular aircraft design will produce (SN: 3/18/95, p.168). But these test and simulation results apply only within a few lengths of the aircraft.

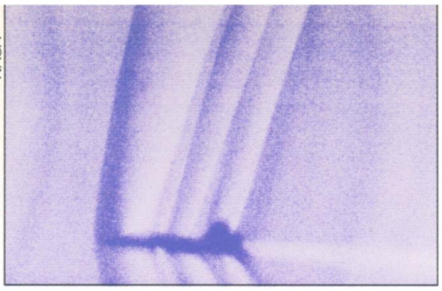
Researchers are now trying to develop computer models, incorporating absorption and turbulence effects, that can predict what happens to these shock waves as they pass through the atmosphere under various weather conditions and finally reach the ground. The resulting sonic signatures could then be correlated with measured or perceived levels of loudness.

Competing sound propagation models can be compared to measurements made in August 1992 during flight tests at the White Sands Missile Range in New Mexico. In these experiments, researchers recorded temperatures and wind speeds at various altitudes to go with sonic boom measurements on the ground.

"Flights were made in the early morning to have data in which low turbulence levels were expected and in midafternoon, when the desertlike conditions often generate high turbulence levels," Darden notes.

Leonard M. Weinstein and his coworkers at Langley have also developed a system for photographing the shock patterns generated by planes in flight. As an aircraft flies in front of the sun, individual shock waves can be seen emanating from the nose, canopy, and wing of the plane (see photograph).

With improvements in this imaging technique, engineers hope to observe the propagating shock pattern over distances of several thousand feet. Such data could be used to help assess computer models of pressure-wave motion and coalescence in the atmosphere under varying conditions.



NASA

Using a technique known as schlieren imaging, researchers at NASA's Langley Research Center and Wallops Flight Facility obtained photographs of the shock waves produced by a T-38 aircraft travelling at 1.1 times the speed of sound. Six strong shock waves emanate from the aircraft, but two pairs quickly merge, reducing the number to four. The engine exhaust shows up as a light streak behind the airplane.

Ultimately, the fate of commercial supersonic transport may hinge on which routes the planes will be allowed to fly. And that will depend on how much noise people are willing to put up with.

To determine that loudness level, researchers at Langley set up a simulator booth in which study participants could listen and react to various types of sonic booms. The investigators also developed a computer-driven compact disc system that could be used in private homes to study the effects indoors. This unit played recordings of sonic booms at random times throughout the day and collected the reactions of anyone within the house to those repeated blasts.

These studies suggest that tinkering with sonic boom signatures does little to increase the acceptability of such noise.

Researchers also gathered data from residents of the area around the Nellis Air Force Base in Nevada, where military aircraft frequently produce sonic booms. The Nellis survey, in particular, demonstrated that sonic booms upset people much more than other loud noises in the community do. What's more, studies of responses to airport noise do not accurately predict reactions to sonic booms, Darden says.

Overall, the results indicate that commercial airliners flying at supersonic speeds will have to stay away from populated areas and stick to ocean routes.

This raises the question of what impact overseas flights may have on the marine environment and on such animals as whales, seals, sea lions, and sea otters. Preliminary findings indicate that these animals face little chance of harm while in the water. The sound waves of a sonic boom simply die out too quickly underwater to pose a real threat.

This still leaves the possibility of harm to marine animals on the surface or hauled up on rocks or island beaches—not to mention passengers on cruise ships and residents of islands near ocean flight paths.

"Though preliminary assessments indicate no issue in any of the above areas, studies are continuing," Darden says.

In particular, new studies funded by NASA but conducted by various university and other research groups will look at the potential impact of sonic booms on the mating habits, migratory patterns, and other behaviors of marine mammals.

Though researchers have made considerable progress in elucidating the mechanics and impact of sonic booms, many obstacles still stand in the way of putting a new supersonic transport into the skies. □

Detecting Airquakes

Like earthquakes, sonic booms rattle buildings and shake the ground. In fact, the same instruments used to monitor earthquakes can be used to detect sonic booms. It's even possible to distinguish the shaking caused by sonic booms from other types of seismic disturbances.

Over the last few years, Bradford Sturtevant, Joseph E. Cates, and Hiroo Kanamori of the California Institute of Technology in Pasadena have been investigating the possibility of using networks of sensitive seismographs to track sonic booms over large areas of the United States. These networks "are especially well-suited for the analysis of long-range sonic boom propagation," the researchers say. Ground motion data from groups of stations provide accurate arrival times of sonic booms and useful estimates of their wave amplitude and waveform.

For example, the Southern California Seismic Network, consisting of 250 stations covering 50,000 square kilometers, routinely picks up booms from supersonic aircraft operating out of Edwards Air Force Base. The network has also detected indirect booms transmitted through the ground from space shuttle landings, even at stations hundreds of kilometers from the flight path. Other, more northerly seismic networks have detected sonic booms associated with meteorite entries into the atmosphere.

"There are sonic booms everywhere," the researchers note. "We've been quite surprised." —*I. Peterson*