SST Design Changes

Supersonic transport engineers are adding wings and subtracting hinges before a piece of metal is cut.

The U.S. supersonic transport will have a problem keeping down to its planned gross weight of 675,000 pounds, but even though the Boeing Co. has yet to touch a piece of metal, the weight of paper accumulated by the SST's designers is growing fast.

Boeing has now reported to a huge review team representing the Federal Aviation Agency, the Air Force and the National Aeronautics and Space Administration ("everyone with a salary of more than five dollars a year," says a company man) that it is considering a raft of design changes affecting everything from instrument dials to the addition of a secondary "baby wing."

Originally, Boeing's design called for the plane's variable-sweep wing to be at an angle of 30 degrees while in the forward position for subsonic flight. Late last year, the wing plan was straightened out to 20 degrees to give more lift for landings and takeoffs (SN: 1/14). Now the figure is back to 30 degrees, largely because of the bigger, heavier pivot mechanism that would have been required.

Another feature of the plane that has recently been dechanged is the double-droop snoot. In order to let the pilot see over the SST's long nose while on the runway, the cockpit had originally been hinged to point sharply down. Then, shortly after Boeing beat Lockheed in the airframe competition, the objection was raised that the pivoted proboscis stuck down so far that it might bump into snowdrifts or dirt piles on the runway, and a second hinge was added further out the nose, bending the tip up again. Now this heavy, complicated system has been thrown out in favor of a single hinge, but placed further aft. The new design should give about six feet of ground clearance, versus three in the original design and four in the double-droop proposal.

The biggest change being considered is the addition of a canard, or baby wing, mounted on the fuselage ahead of the main wing. Boeing has been experimenting with many different combinations of control surfaces in order to compensate for pitch control problems in the 306-foot aircraft. Engineers from Boeing and NASA found that the plane might take as long as three seconds to respond to a nose-up command from the pilot.

The advantage of a canard, says the FAA's chief SST engineer, Charles Blake, is that angling the plane upward could be accomplished with upward air pressure on the canard, instead of by having to cancel out some of the plane's lift by down-loading the trailing edge of the main wing.

The canard will probably have a span of about 30 feet and a sweep angle of 45 degrees. The plane's main wing will be 174 feet across at a 30-degree angle for subsonic flight, and 106 feet across when swept back to 74 degrees in its supersonic configuration.

The canard may also have other advantages. The additional control it offers may enable the horizontal tail to be simplified through removal of movable elevators that were to be mounted over the plane's tail-mounted engine nacelles. The canard may also do a small bit to reduce the strength of the aircraft's sonic boom by redistributing lift along the fuselage (see following story).

Another change that seems likely to reduce the boom is the widening of the forwad part of the SST's fuselage. Boeing made the change recently so that the plane could seat seven passengers abreast, with two aisles, instead of six passengers divided by one central aisle. It came as a surprise both to the company and to the review team that the wider fuselage would affect the boom; apparently, the FAA says, it is due to the redistribution of the fuselage's area.

Dozens of smaller changes are being made or contemplated as the SST paperwork mounts. One group of engineers is studying the effect on the plane's weight distribution and center of gravity of moving the engine nacelles forward or back in their position under the tail, where they were shifted from the wing last year. Another is studying exotic materials such as boron fibers and beryllium as ways of saving weight; unfortunately, the technology of such materials is primitive, and the FAA estimates that even by 1985 there is likely to be little more than a 2,000-pound saving from this source. Structures are constantly being simplified, joints removed and spars rerouted. The vertical spars in the vertical tail assembly, for example, have been relocated to coincide with bulkheads in the fuselage, adding strength, reducing stress and simplifying layout.

With such a large airplane, it is essential, especially during takeoff and landing, for the pilot to know the location of the center of gravity. Late last year, Boeing added a strain gauge to the SST's nose wheel to indicate when unequally full fuel tanks were affecting the balance of the plane. Now similar gauges have been added on all the landing gear, to provide an even more detailed picture of the plane's weight distribution.

Obviously, judging from the strain gauges, droop snoots and the like, landing the SST will not be simple. As a result, Boeing, NASA, the FAA and the Air Force are all studying a technique called Direct Lift Control. In essence, DLC allows the pilot to change the angle at which the plane is landing without having to tilt the plane up or down. This gives the pilot a much more rapidly responding aircraft, since he doesn't have to wait for the huge SST to reorient itself before he can change his descent path. In addition, when the nose is moving up or down in a conventional plane, the rotational speed makes it seem to the pilot that the plane is descending faster or slower than it actually is, depending on whether the nose is rising or falling; there is no such effect with DLC, since the aircraft is always at the same angle with the ground.

DLC is not the only exotic innovation being planned for the SST. All the altimeters and airspeed indicators will probably operate from electrical sensors instead of mechanical ones. Going electrical hardly seems worthy of notice in such an advanced craft, but, says Blake, "it's a matter of forcing progress on the airlines."

"They have their stockpiles," he says, "and they want to use the same instruments on the 727 as they did on the 707. It's the same with the SST."

The designer of the SST's huge engines, General Electric Co., has made far fewer changes in its design, and is concentrating on uprating the engines from the thrust of the experimental version, about 47,000 pounds, to that called for in the final design, more than 60,000 pounds per unit. Early development problems included sheet metal cracks, turbine shroud rubbing and unwanted resonance in the compressor blades, but the FAA seems satisfied that these difficulties have been ironed out. The only major modification has been the change from an eight-stage to a nine-stage compressor. This was included in the original plan, and should enable enough more air to be pulled through the engines to reach their intended thrust without increasing their size.

Financially, the SST seems set to go, despite Vietnam and the plane's principal opponent, Senator William Proxmire (D-Wis.). Last week the House approved $142 million for the plane in fiscal 1968, and directed the FAA to add into the working kitty the $35 million "payback reserve" fund previously accumulated to reimburse the airlines if the project were shelved. Most of the discrepancy between the resulting total and the $198 million requested by the administration came from trimming off the $19 million additional payback reserve requested for fiscal 1968.

SONIC BOOM

Ground Effects May Slow SST

People who treasure quiet don't live around airports. Today it is relatively easy to escape the throbs, screeches and drones of incoming and departing aircraft—one simply moves away from the flight pattern.

In the mid 1970s, there could be no place to hide—if supersonic transports are allowed to fly over land.

If they are, sonic booms like thunderclaps five or six times a day will be a permanent fact of life for a good part of the population. The question is: What price in noise and annoyance are citizens willing to pay for the option of jetting across country in 1.5 hours; at 2.7 times the speed of sound?

So far there is no definitive answer on human tolerance—the Air Force and the Federal Aviation Agency are both studying the problem. But one thing is clear.

The SST booms offer no physiological danger. "Threshold levels for damage to hearing are 100 to 300 times the energy the sonic boom will generate," says Dr. Milton Whitcomb, executive secretary of the National Academy of Sciences committee on hearing, bioacoustics and biomechanics.

Whereas the SST is expected to create booms with an overpressure of two pounds per square foot, hearing damage requires pressures of around 300 pounds. And if ears are safe from damage, other functions, such as heart rate and circulation, should be unaffected.

So concludes the Academy's committee under chairman Dr. John Dunning of Columbia University, in its forthcoming report. The Dunning committee was set up three years ago to advise the Government on the SST in terms of its anticipated effects on people, structures and animals. It conducts no research of its own, but reviews the available information.

Beyond the problem of safety, however, lies the question of psychological tolerance. The most widely known study on human reactions, an Oklahoma survey done in 1964, found some 20 to 25 percent of the people subjected to sonic booms saying they could not tolerate five to six booms a day on a continuous basis.

In another analysis, Dr. K. D. Kryter of the Stanford Research Institute reviewed laboratory experiments with sonic booms at SST levels and concluded: the noise seems to be as "acceptable as the sound presently heard indoors directly under the flightpath of subsonic jet aircraft at an altitude of 1,500 feet following takeoff."

Dr. Whitcomb, a member of the Dunning committee, believes the tolerance limit will likely lie somewhere below two pounds per square foot. "Over two there is a growing body of evidence that the booms are going to be intolerable to enough people to make trouble." The SST, coming in at about 2.1 pounds, is "on the border," says Dr. Whitcomb.

Actually the problem is worse than that. As the SST skims through the air, it drags behind a cone of shock waves that interact with atmospheric conditions to create very minor booms or unusually big ones. Some booms have been magnified two or three times by atmospheric conditions.

If the SST were to hit six pounds per square foot very often, it would probably become totally unacceptable for overland flights because of public protest.

But until the SST actually flies, no one can judge precisely how it will interact with "burbles" or eddies in the air. In one instance, says Dr. Whitcomb, a burble might act like a lens, bending the shock wave into sharper focus; in another, it might dissipate the impact.

A St. Louis study in 1961 calculated that for every flight with overpressures ranging from 0.4 to 2.3, there was less than one (0.83) actual incident of property damage per million people.

"We don't know whether people adapt or get more irritated," says Dr. Whitcomb.

There is some evidence that people do adapt to sonic booms just as they adapt to airport noise. The trouble is that these studies, by necessity, were done on people who opt to live near

Sound Overpressure (lb/ft^2)	(dyn/cm^2)	Predicted Effects
0-1	0-478	No damage to ground structures; no significant public reaction, day or night.
1.0-1.5	478-717	No damage to ground structures; probable public reaction.
1.5-1.75	717-837	No damage to ground structures; significant public reaction particularly at night.
1.75-2.0	837-957	No damage to ground structures; significant public reaction.
2.0-3.0	957-1435	Incipient damage.

C. W. Nixon/Acoustical Society