Chapter VII

ENVIRONMENTAL ISSUES

Over the past two decades, the potentially adverse effects of commercial supersonic flight on the environment have been the subject of considerable controversy and, at times, heated debate. The principal issues are noise, the sonic boom, pollution from engine emissions, and, to a lesser extent, radiation effects on passengers and crew. During the debate, both fact and conjecture have been used to support opposing points of view, clouding the issues in the minds of most Americans.

In an effort to remove these clouds and to determine whether the environmental concerns are real or imagined, the U.S. Government initiated several research efforts following cancellation of the U.S. supersonic transport (SST) program in 1971. These research programs, although still not providing complete and final answers, have generated a greatly improved understanding of potential advanced supersonic transport (AST) environmental impacts. In the following sections, the results of U.S. Government studies are summarized briefly and the environmental impacts that are currently perceived for an AST design are discussed.

NOISE

Engine noise was a critical factor in the cancellation of the prior U.S. SST program and also the focus of controversy about the Concorde operating at Washington and New York airports. The noise issue will figure prominently in the consideration of any future U.S. aircraft program. Consequently, engine noise has been a major subject of the National Aeronautics and Space Administration's (NASA) research programs on both subsonic and supersonic technology.

Since the Concordes have been operating at Dunes and Kennedy and more recently at Dallas-Fort Worth airports, a doubt has surfaced as to whether these supersonic aircraft have actually increased the overall noise exposure of neighboring communities because the number of supersonic aircraft operations compared to the total number of aircraft operations is small. It is expected that supersonic aircraft will comprise only about 5 to 15 percent of future total aircraft operations and, hence, will always contribute relatively little to overall noise. In this regard, it is important to keep in mind that only one generation of supersonic transports is in operation today. This generation's design represents the technology available roughly between **1955** and 1965, a period before noise rules for any class of aircraft were promulgated. Thus, the supersonic transport has had no opportunity for the evolutionary progress in noise control that has benefited the subsonic fleet through several generations of aircraft and propulsion cycles.

Notwithstanding the fact that the noise impact of future ASTs would be relatively small, the NASA supersonic research program has aimed at achieving noise levels comparable to those of advanced long-range subsonic aircraft. The research centers on an advanced variable-cycle engine, which appears to have the capability of lessening noise by inherent design, and on advanced mechanical suppressors, which would substantially reduce noise with relatively small thrust loss. I The NASA program has made significant progress and, while verification through actual hardware is still necessary, it appears that an AST would be able to meet the Federal Aviation Administration (FAA) noise rule (FAR part **36** stage 2), issued in 1969. Thus,

'Cornelius Driver, "Advanced Supersonic Technology and Its Implications for the Future, " presented at the AIAA Atlantic Aeronautical Conference, Williamsburg, Va., May 26-28, 1979.

Photo credit: Environmental Protect/on Agency

Noise pollution

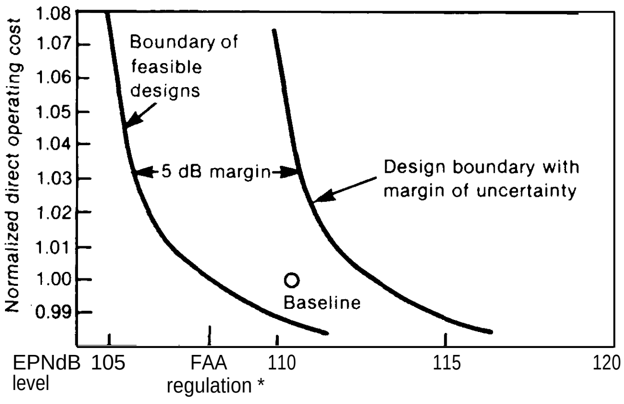
this research promises a considerable improvement over the-noise levels of currently operating Concordes and of models reached by the close of the prior U.S. SST program.

However, the viability of these improvements is thrown into doubt by the outstanding question of what additional noise standards both future subsonic and supersonic aircraft may have to satisfy by the time they are introduced into revenue operations. More stringent standards could affect the feasibility and acceptability of both kinds of aircraft and require further research and technology development.

Because of the greater interdependence of all design facets in the aircraft, an AST will probably be more sensitive to strict noise requirements than comparable subsonic aircraft. Given the current status of supersonic technology, achieving noise levels below FAR part 36, stage 2 will be very costly. Lockheed recently performed a study to provide data for FAA to use in working with the International Civil Aviation Organization (ICAO) Committee on Aircraft Noise, Working Group E. This committee is setting noise standards for possible future supersonic transports. Lockheed addressed the relationship between predicted noise levels at the FAR part 36 measurement points and predicted direct operating costs for a supersonic transport with a specified emission. The results are shown in figure 15.

This figure plots achievable noise versus operating cost penalties. The curve on the left reflects the results of Lockheed's calculations. Optimistically it shows that such an airplane would readily meet FAR part 36, stage 2 (108

Figure 15.—The Cost and Uncertainty of Noise Reduction



"FAR part 36 stage 2.

SOURCE OTA Working Paper, Lockheed California Co , January 1979

EPNdB) without economic penalty and that it may meet stage 3 (about 105 EPNdB) with a 5- to 6-percent direct operating cost penalty. However, when the second curve is added, reflecting the margin of uncertainty, the cost of meeting the various noise regulations greatly increases. Part of the reason for the 5 db margin of uncertainty, is the lack of solid experimental data to support the theoretical predictions. Thus, the results indicate that going much beyond the **1969** FAR part 36, stage 2 standards is likely to involve substantial direct operating cost penalties. Unless much of this uncertainty in noise calculations for supersonic aircraft is removed or reduced significantly, no manufacturer is likely to commit to a new supersonic aircraft program because the investment is too large to risk failure in meeting the standard. Substantial research and engine hardware testing will be needed to develop the data with which to reduce the margin of uncertainty to acceptable proportions.

SONIC BOOM EFFECTS

The general issue of noise dovetails with the specific problem of the sonic boom. Designed without regard to limiting the sonic boom, the typical supersonic transport would produce overpressure levels ranging from 1.5 to 4.0 pounds per square foot (lb/ft^2). These shock waves generated during acceleration and cruise flight remain an environmental concern which U.S. regulations have responded to in prohibiting civil flights at speeds which generate a boom that reaches the ground.

Sonic boom effects on humans are difficult to pinpoint because of the subjectivity of the people's responses and because of the diversity of variables affecting their behavior. Responses depend on previous exposure, age, geographic location, time of day, socioeconomic status, and other variables.

Research and experimentation by FAA, NASA, and ICAO have turned up several findings about sonic boom phenomena related to humans, structures, and animals:[2 3]

- Sonic booms do not affect adversely human hearing and vision or the circulatory system. The human psychological response is more complex, involving attitudes and habituation to sonic booms and their sources. In addition to the general observation that unexpected and unfamiliar noise startled people, the research indicated that intense booms tend to disorient people.
- Damage to structures appears the most serious potential impact of sonic boom, although even here the projected damage caused by supersonic transports may be minimal. Sonic booms with an intensity of 1.0 to 3.0 lb/ft^2, that is the intensity associated with a large supersonic transport, can cause glass to break and plaster to crack. In the range of 2.0 to 3.0 lb/ft^2, overpressure will damage about 1 window pane per 8 million boom pane exposures. Booms with overpressure from **3.0** to **5.0** lb/ft^2 can cause minor damage to plaster on wood lath, old gypsum board and bathroom tile,

[2]Anon., *Concorde Supersonic Transport Aircraft, Draft Environmental Impact Statement (Washington,* D. C.: U, S, Department of Transportation, Federal Aviation Administration, March 1975).

[3]L. J. Runyan and E, J. Kane, *Sonic Boom Literature Survey. Volume I: State of the Art,* Federal Aviation Administration report No. RD-73-129-1, September 1973.

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and to new stucco. Sonic boom impact will vary according to the condition of the structure.

- Boom overpressure dissipates with depth of water (e.g., to a tenth of initial value at a depth of about 122 feet) and so appears to pose no threat to aquatic life, including the capacity of fish eggs to hatch.
- Research on chickens, embryo chicken and pheasant eggs, pregnant cows, race horses, sheep, wild birds, and mink indicates that sonic boom effects on fowl, farm, and wild animals are negligible. Like humans, animals are startled by loud noises, but this reaction was found to diminish during testing.

Although research indicates that overpressure of 4.0 lb/ft^2 or less produces little damage and few lasting psychological effects, sonic booms of such intensity would constitute a public nuisance. As ‘present regulations prescribe, current and, at least, any second-generation supersonic transport cannot fly supersonically over populated land masses. Thus, market studies for future ASTs are restricted to flight patterns involving city pairs with over water supersonic legs.

NASA has expended considerable effort on sonic boom minimization studies,[4 5] which point to the possibility of supersonic aircraft designs with a boom of lower intensity. Such low-boom airplanes will require a degree of technological refinement beyond current capabilities and are not a likelihood for the period considered in this report. Additional research could alter the picture, perhaps allowing an AST to be developed for introduction beyond the year 2010 that could operate over land.

Recently, the term “secondary sonic boom” has been used in connection with some Concorde operations. Secondary sonic boom is caused occasionally by certain meteorological phenomena. For example, the structure of the atmosphere is such that its temperature decreases from sea level up to an altitude of about 5 miles. From this altitude the temperature continually increases and decreases up to a region called the thermosphere.[6] This temperature structure is the primary factor that determines the noise profile in the atmosphere. With the wind profile it determines how sound propagates through the atmosphere and can result, under special circumstances, in sound radiated into the atmosphere being returned back to Earth.

In the case of aircraft-produced sonic boom, the source of the noise could be waves from the airplane that propagate upward and are then returned or could be waves that reflect off the surface of the ocean, travel upwards, and then are returned. Measurements of these shock waves have been taken showing overpressures on the order of 0.02 lb/ft^2.[7]

Sources of these secondary sonic booms have been identified as Concorde flights, distant gunnery practice, quarry blasting, and similar activities. They have also been associated with the overflight of space vehicles, including the Apollo 12 and 13 moon flights.[8]

A Naval Research Laboratory study has concluded that secondary sonic booms from Concorde are of sufficiently low amplitude and frequency that it is unlikely that they are either responsible for some mysterious sounds observed off the east coast in 1979 or likely to disturb the public.[9]

[4]F. E. Mclean and H. W. Carlson, “Sonic-Boom Characteristics of Proposed Supersonic and Hypersonic Airplanes, ” NASA TN D-3587, September 1966.

‘E. J. Kane, *A Study to Determine the Feasibility of a Low Sonic Boom Supersonic Transport,* NASA CR-2332, December 1973.

[6]M. Lessen and A. W. Pryce, “ Now Don’t Get Rattled,” *Journal of Acoustical Society* of America, 64(6), December 1978.

‘Ibid.

[8]D. Cotten and W. L. Dorm, “Sound From Apollo Rockets in Space,” *Science, vol.* 171, February 1971.

‘J. H. Gardner and P. H. Rogers, “Thermospheric Propagation of Sonic Booms From the Concorde Supersonic Transport, ” Naval Research Laboratory, NRL memorandum report 3904, Feb. 14, 1979.

EMISSIONS

In the early 1970's, concern was aroused that the engine emissions from a fleet of supersonic transports would deplete the ozone in the upper atmosphere, reduce the shielding from the Sun's ultraviolet rays, and, thus, cause an increase in the incidence of skin cancer. This concern, originally directed only at anticipated supersonic aircraft, spread to the potential impact of the growing fleet of subsonic aircraft. At the time the issue was raised, there was simply not enough knowledge from which to draw the needed scientific conclusions.[10]

During the congressional debate over the future of the SST program in 1970, the Department of Transportation (DOT) was directed to mount a Federal scientific program to obtain the knowledge needed to judge how serious the conjectured ozone-depletion effects might be and report the results to Congress by the end of calendar year 1974. This directive led to the establishment of DOT's climatic impact assessment program (CIAP), which drew on 9 other Federal departments and agencies, 7 foreign agencies, and the individual talents of 1,000 investigators in numerous universities and other organizations in the United States and abroad. At the same time, a special committee of the National Academy of Sciences (NAS) was organized to review the work of CIAP and to form an independent judgment of the results.

The principal findings of the CIAP study[11] were:

- Operations of present-day supersonic aircraft and those currently scheduled to enter service (about 30 Concordes and TU-144s) cause climatic effects which are much smaller than minimally detectable.
- Future harmful effects to the environment can be avoided if proper measures are taken in a timely manner to develop low-emission engines and fuels.
- If stratospheric vehicles (including subsonic aircraft) beyond the year 1980 increase greatly in number, improvements over 1974 propulsion technology will be necessary to assure that emissions do not significantly disturb the stratospheric environment.
- The cost of developing low-emission engines and fuels would be small compared to the potential economic and social costs of not doing so.
- Many uncertainties remain in our knowledge of the dynamics and chemistry of the upper atmosphere. A continuous atmospheric monitoring and research program can further reduce remaining uncertainties, can ascertain whether the atmospheric quality is being maintained, and can minimize the cost of doing so.

On the recommendations of the CIAP studies, Congress has supported a NASA program to develop the technology for low-emission jet engines. This program has been successful in defining and testing a conceptual design for a burner which might solve potential future high-altitude emission problems as well as reduce low-altitude emissions.[12]

Also, on the CIAP recommendations, FAA initiated a high-altitude pollution program (HAPP) to monitor continuously the upper atmosphere and conduct systematic research to address the uncertainties regarding ozone depletion attributable to future subsonic and supersonic aircraft. The ongoing HAPP studies have already indicated that the earlier CIAP and NAS studies substantially exaggerated the extent to which future aircraft will reduce the ozone layer. Present understanding of the phenomena indicates much smaller impacts and perhaps no net impact at all.[13 14 15] The current predictions are compared with earlier CIAP and NAS predictions in figure 16.

[10] A. J. Grobecker, S. C. Coroniti, and R. H. Cannon, Jr., *The Effects of Stratospheric Pollution by Aircraft* (Washington, D. C.: U.S. Department of Transportation, report DOT-TST-75-50, December 1974).

[11] A. J. Grobecker, et a]., op. cit.

[12] Cornelius Driver, op. cit.

[13] A. Broderick, "Stratospheric Effects from Aviation, " presented at the AIAA/SAE 13th Propulsion Conference, AIAA paper 77-799, July 1977.

[14] See p. 90.

[15] See p. 90.

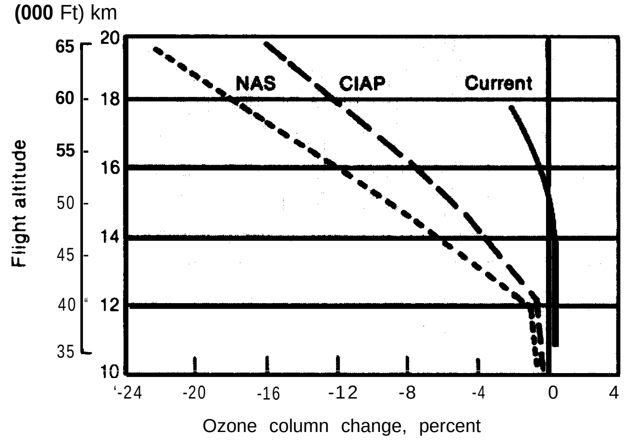
This is a significant finding, but it should be accepted only tentatively. Knowledge about atmospheric chemistry is growing and continued assessments are necessary as new data and improved atmospheric models become available. Current findings, however, are on much firmer ground than prior estimates and give some reason for optimism on the emission problems of advanced aircraft.

(Footnote continued from p. 89.)

14P. J. Crutzen, "A Two-Dimensional Photochemical Model of the Atmosphere Below 55 km: Estimates of Natural and Man Caused Ozone Perturbations Due to NO_x," *Proceedings of the Fourth Conference on the Climatic impact Assessment Program* (Washington, D. C.: U.S. Department of Transportation, report DOT-TSC-OST-75-38, 1976).

15I. G. Poppoff, R. C. Whiteen, R. P. Turco, and L. A. Capone, *An Assessment of the Effect of Supersonic Aircraft Operations on the Stratospheric Ozone Content,* NASA reference publication 1026, August 1978.

Figure 16.—Predicted Effect of Improved Aircraft Technology on the Ozone Layer



SOURCE: "High Altitude Pollution Program," Federal Aviation Administration, December 1977.

COSMIC RAY EXPOSURE

At the higher cruise altitudes expected of supersonic transports, cosmic rays are filtered by the atmosphere less than at subsonic cruise altitudes or on the ground. This factor has given rise to some concern that crew personnel will undergo excessive exposure to cosmic rays. However, the increased intensity of radiation will be somewhat compensated for by the decrease in exposure time resulting from the aircraft's supersonic speed. The best evidence to date is that such radiation exposure will not exceed permitted occupational levels.

SUMMARY

Based on the current state of knowledge and assuming all supersonic legs will be flown over water, noise is the most significant environmental problem of a new generation of supersonic aircraft. Although other concerns do not appear to be as critical at this time, it is likely that all of the environmental issues of a future supersonic transport will both intensify and subside in the future. They will intensify in the sense that regulation is likely to become more comprehensive and stringent, and measurement and evaluation techniques more sophisticated and accurate. At the same time, the regulations are more likely to be shaped by compromise between all relevant considerations and thus viewed as an equitable balance between diverse points of view and conflicting objectives. Debate concerning environmental standards will be a more familiar and established process. The regulations that will be derived from them will be more accepted, so that the equipment that conforms to these regulations will likewise be more accepted. While this process is evolving, it seems clear that the continued technical assessment and research on the environmental issues of future advanced aircraft are highly appropriate.